U.S. AIR FORCE SCHOOL OF AEROSPACE MEDICINE

POLLUTION PREVENTION TOOLS, TECHNIQUES, AND TECHNOLOGIES

COURSE NUMBER B3OZY0000E-005

ENVIRONMENT
AWARENESS

STUDENT GUIDE

FOREWORD

To meet the scientific and technical challenges of the Air Force's Pollution Prevention Program, the U.S. Air Force School of Aerospace Medicine (USAFSAM) was directed to develop a technology-based course to further educate Air Force personnel whose daily duties involve pollution prevention. In response, USAFSAM developed the Pollution Prevention Tools, Techniques, and Technologies Course. The USAFSAM Pollution Prevention Tools, Techniques, and Technologies Course was designed for personnel whose occupational fields include environmental management, planning, and engineering. The course material was tailored to the technical aspects of pollution prevention and it is primarily designed to enable the students to determine the need for additional information and training. By the end of the course, students will be conversant on each topic, not as experts, but as knowledgeable people.

We hope that the students attending this Course will place a high value on the relationship of course materials to job function, and will recognize that this Course is of long-term value if they intend to remain in the environmental profession. This Student Guide has, therefore, been published to help the students retain information from the USAFSAM Pollution Prevention Tools, Techniques, and Technologies Course. The students can use this student guide as a desktop reference book.

Each section of the Student Guide is divided into the following subsections:

- Introduction
- Objectives
- Key Concepts

Students are encouraged to become familiar with the use and application of available training materials, related information resources, and technical assistance programs. Continuing education of Air Force personnel, whose day-to-day duties include various pollution prevention aspects, is necessary to ensure a workforce that is fully responsive and sensitive to Air Force pollution prevention mandates and goals. The Pollution Prevention Tools, Techniques, and Technologies Course will be the foundation for that continuing education.

TABLE OF CONTENTS

BLOCK 1: INTRODUCTION TO POLLUTION PREVENTION - FUNDAMENTAL CONCEPTS

1.0 Introduction

Block 1 outlines fundamental concepts and essential acronyms/abbreviations, terms, and definitions used in the Pollution Prevention Tools, Techniques, and Technologies Course. The science and technology of pollution prevention has many terms. Students may be familiar with many of the scientific and regulatory terms used in pollution prevention, however, many of the technologies introduced during the Course may be new or only generally understood by the student. Block 1 also includes a review of environmental words, phrases, and acronyms common to pollution prevention in a computer-based instruction (CBI) format.

2.0 Objective

To introduce the fundamental concepts of Pollution Prevention by: reviewing the Pollution Prevention Act of 1990, the Environmental Management Hierarchy Options, the Air Force Pollution Prevention Program, and the Benefits of a Pollution Prevention program.

1. Students will understand the Pollution Prevention Act of 1990 including:
   - Findings
   - National Policy
   - Definition of Source Reduction

2. Students will understand the priority of the Environmental Management Hierarchy Options:
   - Source reduction
   - Recycling
   - Treatment
   - Disposal or release

3. Students will understand the Air Force Pollution Prevention Program including:
   - Program goals
   - Program implementation practices
   - Program elements and approaches
   - Factors to consider when selecting options
   - Priority of pollution prevention projects

4. Students will understand the benefits of a Pollution Prevention Program.

3.0 Key Concepts

I. POLLUTION PREVENTION ACT OF 1990

The Findings of the Pollution Prevention Act of 1990 are:

- The U.S. annually produces millions of tons of pollution and spends tens of billions of dollars per year controlling this pollution.
- There are significant opportunities to reduce or prevent pollution at the source.
- Existing regulations focus upon treatment and disposal rather than source reduction and do not emphasize multi-media management of pollution (Air-groundwater).
- Source reduction is fundamentally different and more desirable than waste management and pollution control.
- The EPA must establish a source reduction program which collects and disseminates information.

Under section 6602 (b) of the Pollution Prevention Act of 1990, Congress established a national policy that:

- Pollution should be prevented or reduced at the source whenever feasible.
- Pollution that cannot be prevented should be recycled in an environmentally safe manner, whenever feasible.
- Pollution that cannot be prevented or recycled should be treated in an environmentally safe manner whenever feasible.
- Disposal or other release into the environment should be employed only as a last resort and should be conducted in an environmentally save manner.

Pollution Prevention means Source Reduction and other practices that reduce or eliminate the creation of pollution through:

- increased efficiency in the use of raw materials, energy, water, or other resources.
- protection of natural resources by conservation.

Source reduction is fundamentally different and more desirable than waste management and pollution control. Pollution prevention requires a cultural change - one which encourages more anticipation and internalizing of real environmental costs of pollution generation.

Definition of Source Reduction:

- Any practice which reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment, or disposal; and
- reduces the hazards to the public health and the environment associated with release of such substances, pollutants, or contaminants.

Source Reduction includes: equipment or technology modifications, process, or procedure modification, reformulation or redesign of products, substitution of raw materials, and improvements in housekeeping, maintenance, training, or inventory control.

Source Reduction does not include: any practice which alters the physical, chemical, or biological characteristics or the volume of substances through a process or activity which itself is not integral to and necessary for the production of a product or the providing of a service.

Pollution prevention approaches can be applied to all pollution-generating activities, including those found in the energy, agriculture, federal, consumer, as well as industrial sectors. The impairment of wetlands, groundwater sources, and other critical resources constitutes pollution, and prevention practices may include conservation techniques and changes in management practices to prevent harm to sensitive ecosystems. Pollution prevention does not include practices that create new risk or concerns.

II. ENVIRONMENTAL MANAGEMENT HIERARCHY OPTIONS

The environmental management hierarchy options in order of priority are:

- pollution prevention (source reduction)
- recycling
- treatment
- disposal or release.

The hierarchy should be viewed as establishing a set of preferences rather than an absolute judgment that pollution prevention is always the most desirable option. The selection of the best option for each case will depend on the requirements and applicable laws, the level of risk reduction that can be achieved, and the cost effectiveness of that option.

Environmental Management Hierarchy Options techniques:

- Pollution Prevention (Source Reduction). Source reduction techniques avoid the generation of hazardous wastes, thereby eliminating the problems associated with handling these wastes. Techniques for source reduction include:

- Good operating practices (Efficiency improvements):

  - Material handling and inventory improvements - reduce loss due to damage from mishandling or improper storage.
  - Loss prevention - minimize waste due to leaks, spills, and accidents. Reduce the frequency of tank/pipe cleanouts.
  - Waste stream segregation - prevent hazardous waste from contacting and contaminating nonhazardous waste.
  - Cost accounting practices - include the cost of handling and disposal of hazardous material in the total cost.

- Technology Changes

  - Changes in the production process - using a lower waste generating alternative.
  - Equipment, layout, or piping changes - modify/install equipment to provide material recovery/reuse.
  - Use of automation
  - Changes in process operating conditions - modify temperature or pressure.

- Input Material Changes

  - Material purification - reduce or eliminate the amount of hazardous materials used and or the amount of hazardous waste generated.
  - Material substitution - use nonhazardous materials to replace hazardous materials.

- Product Changes (reduce waste due to a products use)

  - Product substitution - use a nonhazardous product if available to replace a hazardous product.
  - Product conservation - use the minimum amount of a hazardous product required.
  - Change in product composition - change the product so that hazardous waste is not produced during use of the product.

- Recycling techniques - allow hazardous materials to be put to a beneficial use.

  - Use and Reuse - the return of a waste material either to the originating process as a substitute for an input material, or to another process as an input material.
  - Reclamation - the recovery of a valuable material from a hazardous waste that can be sold.

- Integrated waste management which includes treatment and disposal or release.

- Treatments include:

  - Stabilization
  - Neutralization
  - Precipitation
  - Evaporation
  - Incineration
  - Scrubbing

- Disposal includes:

- Disposal at a Permitted Facility

III. AIR FORCE POLLUTION PREVENTION PROGRAM

Air Force Pollution Prevention Program (PPP) was developed to implement the federal regulatory mandate of the Pollution Prevention Act of 1990.

The Pollution Prevention Program involves efforts to reduce hazardous and toxic materials and wastes by means of source reduction and environmentally sound recycling.

The goals of the AF Pollution Prevention Policy are:

- Reduce the use of hazardous materials in all phases of new weapons systems from concept through production, deployment, and ultimate disposal. Find alternate materials and processes, and measure their life cycle costs.
- Reduce the use of hazardous materials in existing weapons systems by finding less hazardous materials and processes and integrating them into TOs, MILSPECS, and MILDSTDS.
- Reduce hazardous materials use and waste generation at installations.
- Acquire world class Pollution Prevention technologies, and distribute them throughout the Air Force.
- Apply new technology to Pollution Prevention.
- Establish an investment strategy to fund the Pollution Prevention Program.

To implement the program, Air Force Pollution Prevention Practices include:

- Reducing the use of hazardous materials and the subsequent generation of pollutants, hazardous waste, medical waste, air emissions, water discharges, and sludges, and decreasing the volume of municipal solid waste and pesticide use through source reduction;
- Recycling unavoidable waste generated in an environmentally sound manner and treating those wastes that cannot be recycled. Disposal or other releases to the environment will be employed only as a last resort.
- Conserving energy and using clean efficient energy sources and transportation.
- Controlling nonpoint source pollution.
- Procuring products made with recovered and recycled materials.
- Environmental education and training for all personnel.

Each installation is expected to develop and execute a Pollution prevention program that addresses source reduction, recycling, and treatment opportunities for major pollutant sources.

The program should also include potential impacts of all activities, including volume of base traffic, water use, and resource management, to determine how to reduce risks to human health and the environment.

The Pollution Concept is designed to promote actions and incorporate existing activities at AF installations that will reduce and prevent harmful releases of hazardous and toxic materials to the air, land, groundwater, and surface water to determine how to reduce risks to human health and the environment.

By considering how any and all operations (not just those that produce hazardous wastes) contribute to the pollution of air, land, and water resources, the Air Force will be better prepared to identify and control more pollution sources.

The following elements will be incorporated in the Air Force Pollution Prevention program:

- Designing systems that do not use or produce hazardous substances or create pollution.
- Reducing solid waste generation.
- Increasing the amount of recycled municipal wastes.
- Improving onsite cleanup and maintenance processes.
- Selective procurement of hazardous materials and a proactive procurement of recycled materials.
- Selecting clean and efficient power/energy sources and supplies.
- Improved conservation of natural resources.

Factors to be considered when determining source reduction measures:

- Expected change in the amount of hazardous waste generated.
- Technical feasibility.
- Economic evaluation.
  - Capital costs
  - Operating costs
  - Waste management costs
  - Return on investment
  - Any other economic comparison method
- Effects on product quality.
- Employee health and safety implications.
- Permits, variances, compliance schedules of applicable state, local, and federal agencies.
- Releases and discharges.

The priority of pollution prevention projects in order are:

- Projects which reduce Air Force demand for ozone depleting chemicals, hazardous toxics listed on the EPA's 17 industrial toxic list, or other extremely hazardous toxics.
- Projects that reduce the volume of toxicity of hazardous waste being disposed. (ranked by percent volume or toxicity removed)
- Projects that reduce the volume of nonhazardous solid waste disposed, volatile or other hazardous air emissions, or contaminated water emissions.
- Education, training, and awareness programs.
- Projects which are interim fixes (new process that cannot be maintained indefinitely or that depend on a permanent solution being developed and acquired at a later date).

IV. Incentives for Pollution Prevention:

- Economics

  - Landfill disposal cost increasing.
  - Costly alternative treatment technologies.
  - Savings in raw material and manufacturing costs.

- Regulations

  - Land disposal restrictions and bans.
  - Increasing permitting requirements for waste handling and treatment.

- Liability

  - Potential reduction in generator liability for environmental problems at both on-site and off-site treatment, storage , and disposal facilities.
  - Potential reduction in liability for worker safety.

- Public Image

  - Improved image in the community

V. SUMMARY

This lesson presented an introduction to the Fundamental Concepts of Pollution Prevention. Pollution Prevention is driven by the Pollution Prevention Act of 1990 and RCRA which say that Source Reduction is the best option to reduce pollution. The Air Force Pollution Prevention Program is based on reducing the amount of materials and wastes by using source reduction. **Pollution Prevention will require a cultural change**. There are many benefits from a Pollution Prevention program. In the common-sense words of Benjamin Franklin, "An ounce of prevention is worth a pound of cure." Now that the students have a basic understanding of the Fundamental Concepts of Pollution Prevention they are ready for a more detailed study of source reduction procedures. Pollution Prevention is the most desirable option.

TERMS and DEFINITIONS

Air Force Center for Environmental Excellence (AFCEE)
The AFCEE provides the Air Force with the in-house capability to handle all aspects of environmental cleanup, planning, and compliance. One of AFCEE's principal roles is to assist major commands and installations execute their responsibilities related to pollution prevention.

Affirmative Procurement
Affirmative Procurement is the purchase of supplies and services utilizing post-consumer recycled products and minimizing the amount of waste generated or supplies listed. It is an integral part of a Pollution Prevention Program. The procurement levels, in order of ease of implementation, are:

- Supplies/services at base or installation
- Support systems at command level
- Weapons systems at service level

CE A-106 Module
The A-106 is the local base input module of WIMS-ES for pollution abatement requirements to enter the POM Process and Planning, Programming, Budgeting System. The A-106 module allows the Air Force to electronically meet the requirements of EPA's A-106 process. It replaces the by-hand method of passing paper back and forth between Air Staff, MAJCOM, and the bases. The A-106 module only makes reporting by paper obsolete -- not the reporting requirements. All environmental funding will be programmed through this automated system. The document that is produced from the A-106 module is unique in the sense that it contains a direct review by EPA of adequacy of all federal agencies' environmental budgets.

Specifically, each federal agency provides seven years of specific environmental project data to EPA which forms their Environmental Needs Plan. This information includes all activities the agency feels are necessary to ensure compliance, prevent pollution, and to plan for future environmental requirements.

The way it works is that all federal agencies provide a brief technical description of each activity as well as an estimate of the funds and the anticipated time frame needed to complete the activity. Each year, the EPA takes a one-year "slice" out of the agency seven-year plan. This "slice" covers the next budget year that will be submitted to congress by the President the following February. This data is reviewed and evaluated by the EPA and submitted on September 1 as a formal report from the EPA Administrator to the Director of the Office of Management and Budget (OMB). The report is a budget support document and is used by OMB and Congress in assessing each federal agency's environmental budget request. Congress then determines the size of the final budget.

The CE A-106 Module accomplishes the following things:

- Influences and tracks federal environmental dollars
- Plans, programs, and budgets environmental dollars
- Identifies projects to meet full compliance
- Allows OMB to determine funding adequacy
- Creates a comprehensive environmental database

Drag-Out
Drag-out is the term applied to the liquid that comes along on a part as it is removed from a tank. Excessive drag-out results in increased costs because it involves the removal of process liquid (plating solution cleaning media, etc.), thereby incurring replenishment costs, as well as cleanup costs. Methods for reducing drag-out include proper rack alignment, increased drainage, and installation of drain boards.

Environmental Compliance Assessment and Management Program (ECAMP)
ECAMP involves internal audits conducted annually by installation personnel and external audits conducted every 3 years by the MAJCOMs. Pollution prevention is being added as a protocol to ECAMP.

Good Operating Practices

The procedural, administrative, or institutional measures that can be used to prevent pollution are always considered good operating practices.

Hazardous Substance
A hazardous substance, under CERCLA, is defined as any substance EPA has designated for special consideration under the CAA, CWA, or TSCA, or any "hazardous waste" under RCRA. EPA may designate additional substances as hazardous which may present substantial danger to health and the environment. There are over 700 chemicals and 1500 radionuclides on EPA's list of hazardous substances. Petroleum and natural gas are excluded from the definition.

Hazardous Waste
A hazardous waste is a solid waste which because of its quantity, concentration, or characteristics may cause an increase in mortality or serious irreversible illness or pose a substantial hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed. Under the Resource Conservation and Recovery Act, hazardous wastes are identified and managed as a result of their being specifically placed on lists, or because they exhibit at least one of four particular characteristics (ignitability, corrosivity, reactivity, or toxicity). In addition, hazardous wastes may be specified pursuant to provisions of the Comprehensive Environmental Response, Compensation, and Liability Act, the Clean Water Act, the Clean Air Act, or the Toxic Substances Control Act.

Input Material Changes/Product Substitution
Input material changes or product substitutions reduce or eliminate the hazardous materials that enter the production process. Changes in input materials can be made to avoid the generation of wastes within the production processes. Input material changes include:

- Recycle
- Reuse
- Material purification
- Material substitution

Life Cycle Cost Accounting
A method of accounting which provides incentive by accounting for cost savings in reductions of material use and waste disposal.

Materials Recovery Facility (MRF)
MRF is an intermediate processing site which accepts, separates, and performs intermediate processing of base mixed waste, usually bottles and cans.

Multi-media
Multi-media refers to water, air, and land.

Nonpoint Sources
Nonpoint sources typically consist of stormwater runoff from parking lots and roads (asphalt, gravel, or dirt), rooftops, lawns, and disturbed areas such as construction sites and also vapor emissions from automobiles.

Opportunity Assessment (OA)
An OA represents a set of procedures that can be followed to identify opportunities for Pollution Prevention and for developing a comprehensive set of recommendations for implementation.

Ozone Depleting Chemicals (ODCs)
ODCs are chlorofluorocarbons, halons, and other substances that deplete the stratospheric ozone layer as classified by the Clean Air Act Amendments of 1990

Point Source
Point source discharges to water are those that originate from a specific location, such as a pipe or open channel which carries wastewater from sewage treatment or industrial process plants.

Pollutant or Contaminant
A pollutant or contaminant includes any element, substance, compound, or mixture, including disease-causing agents, which after release into the environment and upon exposure, ingestion, inhalation, or assimilation into any organism, either directly from the environment or indirectly by ingestion through food chains, will or may reasonably be anticipated to cause death, disease, behavioral abnormalities, cancer, genetic mutation, physiological malfunctions (including malfunctions in reproduction) or physical deformations, in such organisms or their offspring. In reference to the Comprehensive Environmental Response, Compensation, and Liability Act, the term "pollutant or contaminant" does not include petroleum, crude oil or any fraction thereof, or natural gas.

Pollution Prevention
Pollution prevention means "source reduction," as defined under the Pollution Prevention Act; and other practices that reduce or eliminate the creation of pollutants through:

- Increased efficiency in the use of raw materials, energy, water, or other resources
- Protection of natural resources by conservation
- Recycling
- Affirmative procurement

Under the Pollution Prevention Act, the term "source reduction" is defined as "any practice which (i) reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment, or disposal; and (ii) reduces the hazards to public health and the environment associated with the release of such substances, pollutants, or contaminants."

PRO-ACT
PRO-ACT is an environmental information clearinghouse and hotline provided by the Air Force Center for Environmental Excellence (AFCEE). It is designed to be the first point of contact for environmental support services with AFCEE.

PRO-ACT services are provided free of charge to all Air Force personnel. These services include an 800 number for prompt access to technical and regulatory information and technical databases; up to 40 hours of free research on environmental issues; regulatory alerts and updates; bibliographic and literature searches; and an electronic bulletin board system (EBBS) for the dissemination of a broad range of environmental information.

Currently, PRO-ACT is manned from 7am to 7pm Central Standard Time, and may be reached at:
Commercial 210-536-4214
DSN 240-4214
Facsimile 240-2461 or (210) 536-2461, or
E-mail via Wang to PRO-ACT.

Product Changes
Product changes are performed by the manufacturer of a product with the intent of reducing waste resulting from a product's use. Product changes include:

- Product substitution
- Product conservation
- Changes in product composition

Reclamation
Reclamation is the recovery of a material from a waste. Reclamation techniques differ from use and reuse techniques in that the recovered material is typically sold to another company.

Recycled Products
Recycled products are items manufactured with recycled materials used in place of a raw or new material. These materials are derived from post production and post consumer waste that served its intended use and has been discarded. For example, industrial scrap, material derived from agricultural wastes, and other items, all of which can be used in the manufacture of new products.

Recycling

Recycling refers to the use or reuse of a waste as an effective substitute for a commercial product, or as an ingredient or feedstock in an industrial process. It also refers to the reclamation of useful constituent factions within a waste material or removal of contaminants from a waste to allow it to be reused. A material is 'recycled' if it is used, reused, or reclaimed(40 CFR 261.1(b)(7).

Solid Waste
Solid waste is any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous materials resulting from industrial, commercial, mining, and agricultural activities and from community activities (does not include solid or dissolved materials in domestic sewage or in industrial sources subject to permits under the CWA).

Source Reduction
Source reduction means any practice which:

- Reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment, or disposal; and

- Reduces the hazards to public health and the environment associated with the release of such substances, pollutants, or contaminants.

The term includes equipment or technology modifications, process or procedure modifications, reformulation or redesign of products, substitution of raw materials, and improvements in housekeeping, maintenance, training, or inventory control.

The term "source reduction" does not include any practice which alters the physical, chemical, or biological characteristics or the volume of a hazardous substance, pollutant, or contaminant through a process or activity which itself is not integral to and necessary for the production of a product or the providing of a service.

Standard Industrial Classification (SIC)
SIC codes refers to the 2-digit code numbers used for classification of economic activity in the Standard Industrial Classification Manual. An example of a SIC code is the *Major Group* 07 which corresponds to Agricultural Services. An example of other 2-digit codes in the SIC Manual include: Forestry (Major Group 08), Oil and gas extraction (Major Group 13), and Rubber and miscellaneous plastics products (Major Group 30).

All the economic activities listed in the SIC manual are further classified by specific sub-activities. For the Agricultural Services economic activity (Major Group 07), the sub-activity of Crop Services is listed with an *Industry Group Number* of 072 and an *Industry Number* of 0721.

A definition of the Crop Services sub-activity is illustrated in the following excerpt from the SIC manual:

> Establishments primarily engaged in performing crop planting, cultivating, and protecting services.
>
> Entomological service, agricultural
> Insect control for crops
> Irrigation system operation
> Surgery on orchard trees and vines
> Dusting crops, with or without fertilizer
> Weed control measures after planting

Strategic Environmental Research and Development Program (SERDP)
SERDP serves to address environmental matters of concern to the Department of Defense and the Department of Energy through support for basic and applied research and development of technologies that can enhance the capabilities of the departments to meet their environmental obligations. SERDP also serves to identify research, technologies, and other information developed by the Department of Defense and the Department of Energy for national defense purposes that would be useful to governmental and private organizations involved in the development of energy technologies and of technologies to address environmental restoration, waste minimization, hazardous waste substitution, and other environmental concerns, and to share such research, technologies, and other information with such governmental and private organizations. The

program furnishes other governmental organizations and private organizations with data, enhanced data collection capabilities, and enhanced analytical capabilities for use by such organizations in the conduct of environmental research, including research concerning global environmental change. Finally, SERDP exists to identify technologies developed by the private sector that are useful for Department of Defense and Department of Energy defense activities concerning environmental restoration, hazardous and solid waste minimization and prevention, hazardous material substitution, and provide for the use of such technologies in the conduct of such activities.

Technology Changes
Technology changes are oriented toward process and equipment modifications to reduce waste, primarily in a production setting. Technology changes can range from minor changes that can be implemented in a matter of days at low cost, to the replacement of processes involving large capital costs. These changes include the following:

- Changes in the production process
- Equipment, layout, or piping changes
- Use of automation
- Changes in process operating conditions, such as: Flow rates, Temperatures, Pressures, and Residence times.

Toxic Chemicals
Toxic chemicals are substances listed in Section 313 of the Superfund Amendments and Reauthorization Act of 1986.

Use and Reuse
The use and reuse of a material involves the return of a waste material either to the originating process as a substitute for an input material, or to another process as an input material.

Waste minimization
Waste minimization means the reduction, to the extent feasible, of hazardous waste that is generated or subsequently treated, stored, or disposed of. It includes any source reduction or recycling activity undertaken by a generator that results in either: 1) the reduction of total volume or quantity of hazardous waste; or 2) the reduction of toxicity of hazardous waste, or both, so long as such reduction is consistent with the goal of reducing present and future threats to human health and the environment.

Waste Minimization Assessment (WMA)
A waste minimization assessment is:

- A subpart of Opportunity Assessment
- Less inclusive than Opportunity Assessment
- A systematic planned procedure with the objective of identifying ways to reduce or eliminate waste. First, a careful review is made of a plant's operations and waste streams to select specific areas to assess. Second, a number of options with the potential to minimize waste are developed and screened. Third, the technical and economic feasibility of the selected options are evaluated. And finally, the most promising options are selected for implementation.

Work Information Management System - Environmental Subsystem (WIMS-ES)
WIMS-ES provides an automated management tool for program areas within the environmental arena. These program areas are identified as "modules" of WIMS-ES. As the name indicates, WIMS-ES is a subsystem to Civil Engineering's Wang-based WIMS.

BLOCK 2: REGULATORY COMPLIANCE

1) *Mixed waste* - A radioactive waste (regulated under the Atomic Energy Act) and hazardous waste (regulated under RCRA)

2) *Generator* - A generator includes any facility owner or operator or person who first creates a hazardous waste or person who first makes the waste subject to RCRA (e.g., imports a hazardous waste from a TSD facility, or mixes hazardous wastes). The generator has the responsibility for

preparing the Uniform Hazardous Waste Manifest, a control and transport document which accompanies the hazardous waste at all times.

3) *Transporter* - A transporter is a person engaged in the off-site transportation of hazardous waste by air, rail, highway, or water. Anyone who moves hazardous waste off the site where it is generated or the site where it is being treated, stored, or disposed of, will be subject to transporter standards.

4) *Treatment, Storage, and Disposal* - TSD facilities are subject to permit requirements and to a comprehensive facilities set of EPA regulations governing location, design, facility operation, and closure of TSD facilities.

5) *Corrective Actions* - Enforcement actions which are imposed through permits or enforcement orders issued by EPA to address releases of any media from any unit at a TSD facility.

6) *Pollutant or Contaminant* - Under CERCLA, can be any other substance not on the hazardous substances list which will or may reasonably be expected to cause any type of adverse effects in organisms and/or their offspring. Petroleum and natural gas are excluded from the definition.

7) *Removal Action* - A removal action is a short-term, limited response to a more manageable problem pursuant to CERCLA.

8) *Remedial Action* - A remedial action is a longer-term, more permanent and expensive solution to a more complex problem pursuant to CERCLA.

9) *Source Reduction* - Under the Pollution Prevention Act, the term "source reduction" is defined as "any practice which (i) reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment, or disposal; and (ii) reduces the hazards to public health and the environment associated with the release of such substances, pollutants, or contaminants."

BLOCK 3: DOD AND AIR FORCE POLICY

1) *Alternatives* - Ways of reducing the adverse effects of hazardous material.

2) *Cost factors* - The expenses and cost avoidances associated with hazardous material that may be reduced to monetary terms, which includes future liability.

3) *Economic Analysis* - An evaluation of the costs associated with the use of hazardous material and potential alternatives, which is conducted in accordance with DoD Instruction 7041.3 (Economic Analysis and Program Evaluation for Resource Management [October 18, 1972])

4) *Functional Areas* - The operations or areas of responsibility that affect or are affected by the use of hazardous material.

5) *Hazardous Material* - Anything that due to its chemical, physical, or biological nature causes safety, public health, or environmental concerns that result in an elevated level of effort to manage it.

6) *Intangible Factors* - Influences bearing on the use or effects of hazardous material, which may not be reduced to monetary terms.

7) *Life Cycle of a Hazardous Material* - The period starting when the use or potential use of hazardous material is first encountered and extending as long as the actual material or its after effects, such as a discarded residual in a landfill, have a bearing on cost.

8) *Hazardous Material Pollution Prevention Plan* - Typically a plan including action and milestone, responsibilities, regulations, and other variations under an appropriate formal, issued implementing document.

BLOCK 4: OPPORTUNITY ASSESSMENTS

1) *Input materials* - Materials that are introduced into the daily product line or waste stream are deemed input materials.

2) *Waste Stream* - The byproduct or product produced during the life cycle of any given product or material is considered to make up the waste steam of pollution. This material may be a contaminant which may or may not exceed maximum acceptable contaminant levels.

3) *Waste Minimization* - As defined by EPA, waste minimization is a policy specifically mandated by the 1984 Hazardous and Solid Waste Amendments to RCTA. Source Reduction is the first phase of Waste Minimization.

BLOCK 5: RECYCLING AND AFFIRMATIVE PROCUREMENT

1) *Affirmative Procurement* The purchase of supplies and services utilizing recycled products and minimizing the amount of waste generated or supplies listed. It is an integral part of a Pollution Prevention Program. The procurement levels in order of ease of implementation are:

- Supplies/services at base or installation
- Support systems at command level
- Weapons systems at service level

2) *Closed-Loop Recycling* - Use or reuse of a waste as an ingredient or feedstock in the production process on-site. Recycling in which a waste is recovered and reused in the same production process onsite as an input is a form of pollution prevention

3) *Commingled Materials* - The mix of several recyclables collected in one container.

4) *Composting* - The controlled biological decomposition of organic solid waste under aerobic conditions.

5) *Curbside Collection* - Programs where recyclable materials are collected at curb, often from special containers, to be brought to various processing facilities.

6) *Ferrous Metals* - Pertaining to, or derived from, iron; often used to refer to materials that can be removed from the waste stream by magnetic separation.

7) *Materials Recovery Facility (MRF)* - Is an intermediate processing site which accepts, separates, and performs intermediate processing of base mixed waste, usually bottles and cans.

8) *Post-Consumer Recycling* - The reuse of materials generated from residential and commercial waste, excluding recycling of material from industrial processes that has not reached the consumer, such as glass broken in the manufacturing process.

9) *Procuring Agency* - Any Federal agency, or any State agency or agency of a political subdivision of a State which is using appropriated Federal funds for such procurement, or any person contracting with any such agency with respect to work performed under such contract.

10) *Recovered Material* - Waste material and byproducts which have been recovered or diverted from solid waste, but such term does not include those materials and byproducts generated from, and commonly reused within, an original manufacturing process.

11) *Recyclables* - Materials that still have useful physical or chemical properties after serving their original purpose and can, therefore, be reused or recycled for the same or other purposes.

12) *Recycling* - The process by which materials otherwise destined for disposal are collected, recovered and reused.

13) *Recycling of hazardous waste* - The process of removing a substance from a waste and returning it to productive use. Generators of hazardous waste commonly recycle solvents, acids, and metals.

14) *Source Separation* - The segregation of specific waste materials at the point of discard for separate collection.

15) *Tipping Fee* - A fee for the unloading or dumping of waste at a landfill, transfer station, recycling center, or waste-to-energy facility, usually stated in dollars per ton; also called a disposal or service fee.

16) *Use and Reuse* - The return of a waste material either to the originating process as a substitute for an input material, or to another process as an input material.

17) *White Goods* - Large household appliances such as refrigerators, stoves, air conditioners, and washing machines.

BLOCK 6: SOURCE REDUCTION

1) *Hazardous Waste* - By-products of society that can pose a substantial or potential hazard to human health or the environment when improperly managed. Possess at least one of four characteristics (ignitability, corrosivity, reactivity, or toxicity) or appears on special EPA lists.

2) *Source* - Any building, structure, facility, or installation from which there is or may be a discharge of pollutants.

3) *Source reduction* - Any practice which - 1) reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment, or disposal; and 2) reduces the hazards to public health and the environment associated with the release of such substances, pollutants, or contaminants. The term includes equipment or technology modifications, process or procedure modifications, reformulation or redesign of products, substitution of raw materials, and improvements in housekeeping, maintenance, training, or inventory control.

BLOCK 7: POLLUTION PREVENTION AND ENERGY CONSERVATION

1) *Closed biomass* - The production of synthetic fuels, such as methane hydrogen, from terrestrial and sea plants and from animal wastes.

2) *Energy balance* - A concept based on a fundamental law of physical science (conservation of energy) known as the first law of thermodynamics which says that although energy may be transformed it may not be destroyed.

3) *Heat balance* - A loose term applied to a special form of energy balance frequently used in processes which are associated with gaseous pollutant control by combustion (heat balance/material balance).

4) *Energy recovery* - (1) The retrieval of energy from waste by converting heat from incineration or methane gas from landfills. (2) Conversion of waste energy, generally through the combustion of processed or raw refuse to produce steam.

5) *Energy recovery processes* - Processes that recover the energy content of combustible wastes directly by burning, or indirectly by being converted to another fuel form such as gas or oil.

BLOCK 8: TODAY'S HOT ISSUES - 93'S PROBLEM CHEMICALS

1) *Pollution prevention* - Defined as the use of substitute materials, processes or practices to reduce or eliminate the creation of pollutants. The next step in the hierarchy is responsible recycling of any wastes that cannot be reduced or eliminated at the source. Wastes that cannot be recycled should be treated in accordance with regulatory standards and Best Demonstrated Available Technology (BDAT).

BLOCK 10: CASE STUDIES: REVIEW OF PAINT REMOVAL TECHNOLOGIES

1) *Paint* - A combination of a pigment, extender and vehicle, and frequently other additives, in a liquid composition, which is converted to an opaque solid film after application.

2) *Paint manufacturing plant* - A plant that mixes, blends, or compounds enamels, lacquers, sealers, shellacs, stains, varnishes, or pigmented surface coatings.
3) *Paint stripping* - The process of removing an organic coating from a workpiece or painting fixture. The removal of such coatings using processes such as caustic, acid, solvent and molten salt stripping are included.

BLOCK 11: ECONOMIC EVALUATION

1) *Life Cycle Costing* - Sometimes referred to as Total Cost Accounting, this method analyzes the costs and benefits associated with a piece of equipment or a procedure over the entire time the equipment or procedure is to be used. In justifying pollution prevention costs, all benefits and costs must be spelled out in the most concrete terms possible over the life of each option.

2) *Present Worth* - The importance of present worth, or present value, lies in the fact that time is money. The preference between a dollar now or a dollar a year from now is driven by the fact that the dollar in-hand can earn interest. Mathematically, this relationship is as follows:

$$\text{Present value} = \frac{\text{Future Value}}{(1+\text{interest})^{\text{number of years}}} \qquad P = \frac{F}{(1+r)^n}$$

where P is the present worth or present value, F is the future value, r is the interest or discount rate, and n is the number of periods.

3) *Comparative Factors for Financial Analysis* - The more common methods for comparing investment options all utilize the present value equation. Generally, one of the following four factors is used:

A. Payback Period: This factor is often used in the research and development arena and is a measure of how long it takes to return the investment capital. Conceptually, the project with the quickest return is the best investment.

B. Internal Rate of Return: This factor is also called return on investment (ROI) or rate of return. It is the interest rate that would produce a return on the invested capital equivalent to the project's return. For example, a project with an internal rate of return of 23 percent would indicate that pursuing the pollution prevention project would be financially equivalent to investing the resources in a bank and receiving 23 percent interest.

C. Benefits Cost Ratio: This factor is a ratio determined by taking the total present value of all financial benefits of a pollution prevention project and dividing by the total present value of all costs of the project. If the ratio is greater than 1.0, the benefits outweigh the cost and the project is economically worthwhile to undertake.

D. Present Value of Net Benefits: This factor shows the worth of a pollution prevention project as a present value sum. It is determined by calculating the present values of all benefits, doing the same for all costs and subtracting the two totals. The net result would be an amount of money that would represent the tangible value of undertaking the project.

While any of these factors may be used, the importance of life cycle costing or total cost analysis makes the Present Value of Net Benefits the preferred method.

BLOCK 12: AFCEE'S HAZARDOUS MATERIAL PHARMACY CONCEPT

1) *Generator* - A generator includes any facility owner or operator or person who first creates a hazardous waste or person who first makes the waste subject to RCRA (e.g., imports a hazardous waste from a TSD facility, or mixes hazardous wastes). The generator has the responsibility for preparing the Uniform Hazardous Waste Manifest, a control and transport document which accompanies the hazardous waste at all times.

BLOCK 13: MANAGEMENT OF MUNICIPAL SOLID WASTES

1) *Solid Waste* - The RCRA definition of solid waste: "any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant or air pollution control facility and other discarded

material, including solid, liquid, semisolid, or contained gaseous materials resulting from industrial, commercial, mining and agriculture activities and from community activities but does not include solid or dissolved material in domestic sewage, or solid or dissolved materials in irrigation return flows or industrial discharges which are point sources subject to permits under section 402 of the Federal Water Pollution Control Act, as amended, or source, special nuclear, or byproduct material as defined by the Atomic Energy Act of 1954, as amended" (p. 409-410, Environmental Law Handbook).

BLOCK 14: BASICS OF SOLVENTS

1) *Solvent* - A liquid substance that is used to dissolve or dilute another substance.

2) *Solvent recovery* - The recovery of volatile solvents that are present in air or a gas stream.

3) *Solvent recovery system* - The equipment associated with capture, transportation, collection, concentration, and purification of organic solvents. It may include enclosures, hoods, ducting, piping, scrubbers, condensers, carbon absorbers, distillation equipment, and associated storage vessels.

BLOCK 15: CASE STUDIES: CLEANING AND DEGREASING

1) *Equipment cleaning* - A maintenance function typically performed for the following reasons:

- To restore or maintain the operating efficiency of equipment, e.g., to restore adequate heat transfer rate and low pressure drop in heat exchangers.
- To avoid or limit product contamination, e.g., when a paint mix tank needs to be cleaned between batches of varying paint formulations.
- To minimize corrosion and extend equipment lifetime.
- To allow for inspection and repair of equipment.
- To improve appearance (exterior surfaces only).
- To prepare the surface for further treatment.

2) *Degreasing* - Involves the removal of an oil-based coating from a metal part prior to further material processing, and in this way is a specific type of cleaning. Oil-based coatings are applied to metal parts to prevent corrosion and/or surface oxidation during such operations as transport or storage. If the part were to undergo some further surface operation (e.g., plating), then it must be cleaned (degreased) prior to this process.

3) *Cold cleaning* - Cleaning that employs unheated or slightly heated nonhalogenated solvents, and is the most common type of cleaning. The four categories of cold cleaning are (1) wipe cleaning; (2) soak cleaning; (3) ultrasonic cleaning; and (4) steam gun stripping. Wipe cleaning consists of soaking a rag in solvent and wiping the metal part clean. Soak cleaning involves the immersion of the parts in a solvent tank. Ultrasonic cleaning is identical to soak cleaning, except that an ultrasonic unit is added to the tank, which provides a vigorous cleaning action throughout the tank. The main application of steam gun stripping is for paint removal from metal objects. A stripper made up of nonhalogenated solvents is fed into a steam line, through an adjustable valve, mixed with the steam and ejected at high speed from a nozzle.

4) *Diphase cleaning systems* - So named because they use both water and solvent phases for cleaning. Parts to be cleaned first pass through a water bath, then a solvent spray. Vapor phase cleaning, also called vapor degreasing, consists of a tank of halogenated solvent heated to its boiling point. Parts to be cleaned are placed in the vapor zone above the liquid solvent. The vapor that condenses on the cooler part dissolves oil-based contamination and rinses the part clean. Since the potential exists for considerably greater air emissions from vapor phase cleaning than from cold cleaning tanks, special recovery equipment is installed, consisting of cooling jackets and/or finned coil condensers. By cooling the air above the vapor, a dense cool air blanket is formed which helps suppress vapor from

escaping. The second unit, a finned coil condenser, is installed inside the tank and condenses any vapor that reaches it.

BLOCK 16: BASICS OF SURFACE COATINGS

1) *Anode* - The electrode at which oxidation or corrosion occurs.

2) *Anodic Protection* - An appreciable reduction in corrosion by making a metal an anode and maintaining this highly polarized condition with very little current flow.

3) *Aqueous* - Pertaining to water; an aqueous solution is a water solution.

4) *Corrosion* - The destruction of a substance; usually a metal, or its properties because of a reaction with its surroundings (environment).

5) *Electrolysis* - Chemical changes in an electrolyte caused by an electrical current.

6) *Hazardous Waste* - A solid waste that exhibits the characteristics of ignitability, corrosivity, extraction procedure toxicity, and reactivity, or appears on any of EPA's lists of hazardous wastes.

7) *Material Substitution* - Replacing a material with another which may result in wastes that are less hazardous or nonhazardous.

8) *Source Reduction* - The reduction or elimination of waste at the source, usually through process changes.

9) *Waste Minimization* - The reduction, to the extent feasible, of hazardous waste that is generated prior to treatment, storage or disposal of the waste.

BLOCK 17: POLLUTION PREVENTION MODELS, DATABASES, AND GUIDELINES

1) *Bulletin Board System* - BBS computer software runs on a host machine that allows telecommunications access by "guest" computer users to services such as electronic mail, announcements, file transfers (uploading and downloading), and programs such as databases.

2) *File Compression* - Use of software to convert computer files into smaller "archive" files to facilitate transfer or storage. Example software: PKZIP.

3) *File Transfer Protocol* - Software that facilitates transfers of computer files from one computer to another. Usually includes error checking routines to assure accurate transfer. Examples: XMODEM, YMODEM, ZMODEM, KERMIT.

4) *Log On or Log In* - The access to a BBS or computer dial-in system. Logon or Login may also be your identifier by which the computer system knows you.

5) *Password* - Confidential alphanumeric combination associated with Login to eliminate unauthorized computer access.

6) *SYSOP* - System Operator of a BBS or computer dial-in system.

BLOCK 18: CASE STUDIES: PAINTING AND COATING

1) *Aqueous cleaning* - Cleaning parts with water to which may be added suitable detergents, saponifiers or other additives.

2) *Biodegradable* - Products in wastewater are classed as biodegradable if they can be easily broken down or digested by, for example, sewage treatment.

3) *CFC-113* - A common designation for the most popular CFC solvent, 1,1,2-trichloro-1,2,2-trifluoroethane, with an ODP of approximately 0.8.

4) *Chlorofluorocarbon* - An organic chemical composed of chlorine, fluorine and carbon atoms, usually characterized by high stability contributing to a high ODP.

5) *Detergent* - A product designed to render, for example, oils and greases soluble in water, usually made from synthetic surfactants.

6) *Electrostatic system* - Painting/coating system in which charged droplets or particles are attracted toward finish surface having opposite charge

7) *Metal cleaning* - General cleaning or degreasing of metallic components or assemblies, without specific quality requirements or with low ones.

8) *ODP* - An abbreviation for ozone depletion potential.

9) *Ozone* - A gas formed when oxygen is ionized by, for example, the action of ultraviolet light or a strong electric field. It has the property of blocking the passage of dangerous wavelengths of ultraviolet light. Whereas it is a desirable gas in the stratosphere, it is toxic to living organisms at ground level (see volatile organic compound).

10) *Ozone depletion* - Accelerated chemical destruction of the stratospheric ozone layer by the presence of substances produced, for the most part, by human activities. The most depleting species for the ozone layer are the chlorine and bromine free radicals generated from relatively stable chlorinated, fluorinated, and brominated products by ultraviolet radiation.

11) *Ozone depletion potential* - A relative index indicating the extent to which a chemical product may cause ozone depletion. The reference level of 1 is the potential of CFC-11 and CFC-12 to cause ozone depletion. If a product has an ozone depletion potential of 0.5, a given weight of the product in the atmosphere would, in time, deplete half the ozone that the same weight of CFC-11 would deplete. The ozone depletion potentials are calculated from mathematical models which take into account factors such as the stability of the product, the rate of diffusion, the quantity of depleting atoms per molecule, and the effect of ultraviolet light and other radiation on the molecules.

12) *Ozone layer* - A layer in the stratosphere, at an altitude of approximately 10-50 km, where a relatively strong concentration of ozone shields the earth from excessive ultraviolet radiation.

13) *Methyl chloroform* - 1,1,1-trichloroethane, a chlorinated solvent used as degreaser

14) *Surfactant* - A product designed to reduce the surface tension of water. Also referred to as tensio-active agents/tensides. Detergents are made up principally from surfactants.

15) *Terpene* - Any of many homocyclic hydrocarbons with the empirical formula $C_{10}H_{16}$, characteristic odor. Turpentine is mainly a mixture of terpenes. See hydrocarbon/surfactant blends.

16) *TBT* - Tributyltin

17) *TBTO* - Tributyltin oxide

18) *Volatile organic compound (VOC)* - These are constituents that will evaporate at their temperature of use and which, by a photochemical reaction, will cause atmospheric oxygen to be converted into potential smog-promoting tropospheric ozone under favorable climatic conditions.

BLOCK 20: PARTICIPATION IN THE POLLUTION PREVENTION FUNDING PROCESS

1) *Planning, Programming, and Budgeting System (PPBS)* - The PPBS is a system that the Resource Management Systems provide information to managers to allow them to effectively and efficiently establish objectives, translate those objectives into programs, and match resources (personnel, money, and material) to the program. The products of the PPBS provide the basis for making informed affordability assessments and resource allocation decisions on defense acquisition programs. The PPBS is based on affordability goals, affordability constraints, and firm unit costs.

2) *Program Objectives Memoranda (POM)* - This document describes the six-year program proposals from each military department and links these proposals to national policies, strategy, and objectives

from specific forces and major programs that are based on the Defense Planning Guidance and on out-year fiscal projections. POMs are submitted to the Secretary of Defense every other calendar year and must recommend programs to be carried out within the budget in the Defense Guidance. The POM is the most important document for the program manager who is attempting to obtain funding for programs.

BLOCK 21: AFFECTING CHANGES IN TECHNICAL ORDERS AND MIL SPECS

1) *Technical Order (TO)* - A publication which provides instructions for safe and effective operation and maintenance of military systems and equipment. Often a step-by-step "how to" manual, analogous to a Chilton's Manual for automobiles. In the military, a TO constitutes a military order, and is issued in the name of the Chief of Staff, and by order of the Secretary of the Service.

2) *Air Force Technical Order (AFTO)* - A technical order which has been formally included in the Air Force Technical Order System, as outlined in Air Force Regulation 8-2, Air Force Technical Order System.

3) *Technical Manual (TM)* - The term "Technical Manual" includes such items as military specification technical manuals and technical orders, checklists, work packages, job guides, workcards, Flight Manuals, Methods and Procedures TMs (MPTM), Time Compliance TOs (TCTO), and commercial manuals officially adopted by the Services. TM is also the name used by the U.S. Army and U.S. Navy for their versions of technical orders. The terms "Technical Manual" and "Technical Order" are interchangeable when referring to publications in the USAF Technical Order System.

4) *Initiator* - The individual who identifies a discrepancy or deficiency in the TO system and prepares the documentation and recommended change for submission to the final approving authority.

5) *MIL-SPEC or MIL-STD* - A written specification for an item or substance, developed and maintained by a Service specification preparing activity -- normally a System Program Manager's office. All MIL-SPECs and MIL-STDs are listed in the DoD Index of Specifications and Standards (DODIS), and are cross-referenced therein to responsible specification preparing activity. The DODIS is available on CD-ROM, Microfiche, or paper from the Defense Logistics Agency (DLA).

6) *FED-SPEC or FED-STD* - Same as a MIL-SPEC or MIL-STD, only developed and maintained by a General Services Administration (GSA) depot.

7) *Technical Documents* - The formal documentation of a MIL-SPEC, MIL-STD, FED-SPEC, or FED-STD. These Technical Documents are available to logistics agencies worldwide through GSA. Each Technical Document includes forms at the back of the Technical Document to submit suggested changes to the specification.

BLOCK 22: CASE STUDIES: MACHINING, METAL WORKING, AND METAL PLATING

1) *Fabricated Metal Processes* - Classified under Standard Industrial Classification (SIC) 34, and include processes such as machining, metalworking, and metal plating. These processes generate a variety of hazardous and non-hazardous wastes, including metal-bearing fluids, and organic contaminants. The principal chemicals of concern include:

- Cadmium
- Chromium
- Cyanide
- Nickel
- Mercury

Other waste such as oils, lubricants, contaminated rags and sludges may also be produced from the processes. Degreasing and cleaning procedures prior to the actual metal-working operations are also inherent to these procedures.

2) *Metal Fabrication Operations* - Metal fabrication operations can be broken down into four general categories: metal removal, displacement, addition, and joining. Metal removal involves shaping the raw piece to the desired shape by removing metal in selected areas. Traditionally, there have been two ways to accomplish this: mechanically (machining) and chemically (etching). Metal

displacement implies "pushing" or "pulling" the entire piece to the desired shape no metal is lost in the process. Examples include forging (which involves hammering or pressing the piece), rolling (plastically deforming the piece by passing it through rollers), drawing (pulling the metal through a die), extrusion (pushing the metal through a die), and bending or shearing. Metal addition involves adding different metals or elements to the piece to impart some desired characteristic to the metal. For example, plating is the addition of a metal different from the base metal to the surface of the piece, for corrosion resistance, wear resistance, or increased electrical contact. Surface hardening is the addition of elements such as carbon or nitrogen into the surface of the piece to form compounds which make the metal harder. Metal joining is the fastening of two fabricated pieces together. This is typically done by welding or brazing.

3) *Mechanical Removal of Metal (Machining)* - Removal of metal may be conducted by a variety of means. *Sawing* is a process to roughly shape the piece. *Grinding* is the use of abrasives to further shape the piece. *Deburring* involves using mechanical action to shape the piece. *Turning* processes and some *drilling* are done on lathes, which hold and rapidly spin the workpiece against the edge of the cutting tool. *Broaching* is a process whereby internal surfaces such as holes of circular, square or irregular shapes, or external surfaces like key ways are finished. *Drilling* machines are intended not only for making holes, but for *reaming* (enlarging or finishing) existing holes. This process is also carried out by reaming machines using multiple cutting edge tools. *Milling* machines also use multiple edge cutters, in contrast with the single point tools of a lathe. While drilling cuts a circular hole, milling can cut unusual or irregular shapes into the workpiece. *Finishing* and *polishing* use fine abrasives to produce smooth surfaces on the metal pieces.

4) *Plating Operations* - Plating operations can be categorized as electroplating and electroless plating processes. Surface treatment includes chemical and electrochemical conversion, case hardening, metallic coating, and chemical coating. Most metal surface plating processes include: the actual modification of the surface, involving some change in its properties (e.g., case hardening, or the application of a metal layer); and rinsing or other workpiece finishing operations.

5) *Chemical and Electrochemical Conversion Treatments* - Treatments that are designed to deposit a coating on a metal surface that performs a corrosion protection and/or decorative function. Processes include phosphating, chromating, anodizing, passivation, and metal coloring.

6) *Case Hardening* - Case hardening produces a hard surface (the case) over a metal core that remains relatively soft. The case is wear-resistant and durable, while the core is left strong and ductile. Case hardening methodologies include carburizing (diffusion of carbon into a steel surface at temperatures of 845 to 955 C), carbonitriding and cyaniding (diffusion of both carbon and nitrogen simultaneously into a steel surface), nitriding (diffusion of nascent nitrogen into a steel surface to produce case-hardening), microcasing, and hardening using localized heating and quenching operations.

BLOCK 23: CASE STUDIES: ACQUISITION MANAGEMENT OF HAZARDOUS MATERIALS

1) *Hazardous Material Pharmacy* - A program conducted by the Air Force Center for Environmental Excellence (AFCEE) which places central control on hazardous materials and waste management for an installation. The following are the characteristics of the Hazardous Material Pharmacy Program:

- Controls and manages hazardous material inventory replenishment.
- Regulates the distribution of hazardous materials.
- Facilitates material reuse, alternative use, and recycling of material.
- Centralizes the hazardous material and waste management tasks which were once placed on functional organizations.

2) *Life Cycle Management* - Consideration of all phases of the life of any product when making decisions concerning that product. These phases include acquisition, use, storage, transportation, and disposal of the product. This concept compels organizations to consider the full cost of using a material or product, thus reducing long-term storage, disposal, handling, and administrative costs.

3) *Proactive Planning* - Attempting as much "thinking ahead" as possible to prevent unforseen costs or problems from mounting. See "life cycle management".

4) *Hazmin* - Minimization of hazardous materials and wastes through improved management and planning practices.

ACRONYMS

AR	Administrative Record
ATTIC	Alternative Treatment Technology Information Center Database
BTEX	Benzene, Xylene, Ethyl Benzene, Toluene
CAA	Clean Air Act
CEAM	Center for Exposure Assessment Modeling
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFC	Chlorofluorocarbon
CWA	Clean Water Act
DoD	Department of Defense
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
EPC	Environmental Protection Committee
ESA	Endangered Species Act
Freon	Trichlorotrifluoroethane
FSA	Food Security Act
FWPCA	Federal Water Pollution Control Act
FWS	Fish and Wildlife Service
IAG	Interagency Agreement
IGWMC	International Groundwater Monitoring Center
LTM	Long-term Monitoring
MACT	Maximum available control technology
MCLG	Maximum Contaminant Level Goals
MEK	Methyl ethyl ketone
NAAQS	National Ambient Air Quality Standards
NAPL	Non-Aqueous Phase Liquids
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NPL	National Priorities List
NSPS	New Source Performance Standard
O&M	Operation and Maintenance
OHW	Other Hazardous Waste
PA/SI	Preliminary Assessment/Site Investigation
PCBs	Polychlorinated biphenyls
PCE	Perchloroethylene/Tetrachloroethylene
PMN	Premanufacture notification
POLs	Petroleum, Oils, Lubricants
POTW	Publicly-owned treatment works
PSD	Prevention of Significant Deterioration
RACT	Reasonably available control technology
RCRA	Resource Conservation and Recovery Act
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SERDP	Strategic Environmental Research and Development Program
SIP	State Implementation Plan
TCA	Trichloroethane
TCE	Trichloroethylene
TRC	Technical Review Committee
TRI	Toxic Chemical Release Inventory
TSCA	Toxic Substances Control Act
TSD	Treatment, Storage, and Disposal facilities
VOC	Volatile organic compounds

BLOCK 2: REGULATORY COMPLIANCE

1.0 Introduction

This block presents information on federal environmental laws relating to pollution prevention. Material on the manner in which these laws apply to federal facilities is also provided, along with information on civil and criminal penalties for violations. Finally, DOD and service pollution prevention policies are explained.

2.0 Objective

To provide a comprehensive review and update of federal environmental laws relevant to pollution prevention, including the Pollution Prevention Act, CWA, CAA, TSCA, RCRA, CERCLA, the Federal Facilities Compliance Act, and NEPA. To address applicable Executive Orders and DoD and EPA policies, and how they relate to DoD activities. To provide Information on civil and criminal penalties.

1. Students will obtain a working knowledge of environmental laws, regulations, and policies relevant to DoD pollution prevention efforts.

2. Students will understand potential causes of action and how to avoid them.

3. Students will learn potential civil and criminal penalties for violations of applicable laws and regulations.

3.0 Key Concepts

I. THE NATIONAL ENVIRONMENTAL POLICY ACT (NEPA)

NEPA can easily be described as the nation's first pollution prevention statute. Enacted on January 1, 1970 and one of the first environmental laws, NEPA remains a comprehensive and significant tool for promoting pollution prevention in the federal government.

A. **Background**. Recognizing that the federal government was both a major cause of environmental problems and an important instrument for change, Congress charged the federal government to "use all practicable means, consistent with other essential considerations of national policy, to improve and coordinate federal plans, functions, programs, and resources to the end that the Nation may ... attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences...."

B. **General**. To ensure that the goals and policies of NEPA were implemented by the federal agencies, Congress directs them to consider the environmental implications of their actions before making a decision on a proposed federal action. Through the preparation of an environmental impact statement (EIS), agencies are directed to consider:

- The environmental impact of the proposed action;
- Any adverse environmental effects which cannot be avoided should the proposal be implemented;
- Alternatives to the proposed action;
- The relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity; and
- Any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.

The Council on Environmental Quality (CEQ), which was created by NEPA, is charged with oversight of the federal government's compliance with the act. CEQ has issued binding regulations which set forth the requirements for the procedural implementation of NEPA by the federal agencies. The structure of NEPA compliance in the CEQ regulations is designed with the goal of preventing, eliminating, or minimizing environmental degradation.

II. INTRODUCTION TO MEDIA-SPECIFIC ENVIRONMENTAL LAWS

In order to understand the basis for current pollution prevention initiatives, it is important to understand the media-specific environmental laws which were enacted first.

A. CLEAN AIR ACT (CAA)

1. **Background.** The Clean Air Act was first enacted in 1970, amended in 1977, and greatly overhauled and expanded in 1990. The act makes health protection the basis for much of its air pollution control regulation and creates a pervasive regulatory system.

2. **General.**

a. National Ambient Air Quality Standards (NAAQS). EPA must set these standards for each pollutant which it determines may reasonably be anticipated to endanger public health or welfare.

b. State Implementation Plan (SIP) process. This is the mechanism through which emission controls are imposed by the states on stationary sources in order to meet NAAQSs. Where a state fails to devise a SIP adequate to meet NAAQSs, the act requires EPA to impose such emission limitations and take other necessary steps.

c. New Source Performance Standard (NSPS) system. States are required to develop a program for new or modified stationary sources of emissions to assure that the nationally applicable, technology-based emission limitations developed by EPA for new or modified sources are enforced.

d. Prevention of Significant Deterioration (PSD) program. This program requires that all new or modified sources larger than certain thresholds must use best available control technology (BACT) which is at least as stringent as NSPS requirements for the source category and that such new and modified sources undergo a rigorous air quality review designed to meet tightened air quality standards.

e. Nonattainment area program. The act provides that new or modified sources located in areas where air is worse than NAAQS require (nonattainment areas) must meet special technology-based and air quality based requirements in addition to NSPSs. In addition, existing sources in nonattainment areas must use reasonably available control technology (RACT).

f. National Emission Standards for Hazardous Air Pollutants (NESHAP). This section of the act establishes an elaborate program to regulate emissions of 189 hazardous air pollutants through technology-based standards (maximum available control technology (MACT)) and, if necessary, additional health-based standards.

g. Acid precipitation provisions. These provisions of the act are designed to reduce sulfur dioxide and nitrogen oxides emissions (primarily from coal-burning facilities) which are linked to the problem of acid precipitation and deposition. Acid precipitation is thought to have had adverse effects on fish and lakes in New York, New England, and Canada and to have caused damage to forest growth, buildings, paints, soil fertility, and crops.

h. Permit program. The 1990 amendments to the act imposed a federal permit program for major sources of air pollution. It is illegal for a source required to have a permit (generally a source emitting more than 100 tons per year of any air pollutant or 10 or more tons per year of any hazardous air pollutant) to operate without one or to operate in violation of the permit and its conditions.

i. Mobile source and fuels provisions. The act regulates motor vehicle emission and fuel and fuel additives through a certification and registration program.

j. CFC provisions. Ozone, while considered a pollutant at ground level, is essential in the stratosphere to screen out harmful ultraviolet radiation which can cause skin cancers and reduce crop yields if exposures become excessive. Chlorofluorocarbons (used as refrigerants, aerosol propellants, and cleaners) have been implicated in stratospheric ozone depletion and the 1990 amendments to the act establish a comprehensive schedule for the complete phase-out of ozone depleting chemicals over the next 40 years.

B. FEDERAL INSECTICIDE, FUNGICIDE, AND RODENTICIDE ACT (FIFRA)

1. **Background**. Public concern regarding pesticides was a principal cause of the rise of the environmental movement in the 1960s and 1970s, after the publication of Rachel Carson's Silent Spring. Although Congress first passed FIFRA in 1947, the early law was dealt primarily with labeling and product safety. The act was rewritten in 1972 (and amended again in 1975, 1978, 1980, and 1988).

2. **General**

a. Pesticide registration. All new pesticide products used in the U.S. must first be registered with EPA. Manufacturers must submit the complete formula, a proposed label, and a full description of the tests made and results of those tests upon which claims are made. EPA must approve the registration if, among other things, it will perform its intended function without unreasonable adverse effects on the environment.

b. Control over usage. Pesticides are classified into either general or restricted categories, with the latter being available only to certified applicators. Certification standards are prescribed by EPA. It is unlawful to use any registered pesticide classified for restricted use other than in accordance with the registration.

c. Removal of pesticides from the market

i. *Cancellation*. This is the process initiated by EPA to review a substance suspected of posing a substantial question of safety to man or the environment. During the pendency of the proceedings, the product may be freely manufactured and shipped. A recommended decision after a cancellation hearing is sent to the EPA administrator who makes the final agency determination.

ii. *Suspension*. A suspension order is an immediate ban on the production and distribution of a pesticide. It is mandated when a product constitutes an imminent hazard to man or the environment. A suspension order must be accompanied by a cancellation order if one is not then outstanding.

iii. *Compensation*. FIFRA provides for financial compensation to registrants and applicators owning quantities of pesticides who are unable to use them because of cancellation or suspension.

d. Exports and Imports. U.S. exports are not covered under the act, but imports are subject to the same requirements of testing and registration as domestic products.

C. CLEAN WATER ACT (CWA)

1. **Background**. Congress enacted the Federal Water Pollution Control Act in 1972, and renamed it the Clean Water Act when it was amended in 1977. The act was also amended in 1987, and in 1990 with the Oil Pollution Act.

2. **General**. The primary objective of the CWA is to "restore and maintain the chemical, physical, and biological integrity of the nation's waters". The act has five main elements which seek to meet this objective:

- A system of minimum national effluent standards for each industry;
- Water quality standards;
- A discharge permit program (the National Pollutant Discharge Elimination System (NPDES) permit) where water quality standards are translated into enforceable limitations;
- Provisions for special problems such as toxic chemicals and oil spills; and
- A revolving construction loan program for publicly-owned treatment works (POTWs)

a. NPDES Permits. Under the NPDES program, any person responsible for the discharge of a pollutant or pollutants into any waters of the U.S. from any point source must apply for and obtain a permit. The definition of "pollutant" is quite broad and has been interpreted to include virtually all waste material. A "point source" includes any discernible, confined, or discrete conveyance from which pollutants are or may be discharged. The permit program requires dischargers to disclose the volume and nature of their discharges, authorizes EPA to specify the limitations to be imposed on such discharges, imposes on dischargers the obligation to monitor and report as to their compliance or non-compliance with the limitations imposed, and authorizes EPA and citizen enforcement (i.e., citizen suits) in the event of noncompliance.

b. Dredge and Fill Permits. Section 404 of the Clean Water Act substantially affects development in areas adjacent to navigable waters (defined as all waters of the United States including wetlands). This section stringently controls dredging activity and the disposal of dredged or fill material into navigable water by granting to the Army Corps of Engineers the authority to designate disposal areas and issue permits to discharge dredged and fill material in those areas.

i. The Army Corps construes Section 404 to cover not only disposal of dredged or fill material but also the emplacement of dredge or fill material for development purposes and the construction of structures.

ii. Since Section 404 permits are issued by the Army Corps, issuance of those permits are subject to the requirements of NEPA.

iii. The Army Corps, through the Justice Department, has the power to bring enforcement actions to collect penalties and to compel restoration of areas which have been dredged or filled without the necessary permit, or dredged in violation of a permit.

D. SAFE DRINKING WATER ACT (SDWA)

1. **Background**. The SDWA was enacted in 1974 and substantially amended in 1986. The act was a response to information suggesting that chlorinated organic chemicals were contaminating major surface and underground drinking water supplies, that underground injection operations were threatening major aquifers, and that public water supply systems were becoming a threat to public health.

2. **General**. The 1974 act federalized regulation of drinking water systems, required EPA to set national standards for levels of contamination in drinking water, created a program for states to regulate underground injection wells, and sought to protect sole source aquifers. The 1986 amendments were intended to force EPA to quicken the pace of issuing drinking water standards. As now structured, the SDWA

a. Requires EPA to set minimum national standards to protect public health from contaminants found in drinking water (Maximum Contaminant Level Goals (MCLG) and National Primary Drinking Water Standards, usually maximum contaminant levels (MCL));

b. Regulates underground injection wells (subsurface emplacement of fluid through a well or dug-hole whose depth is greater than its width) and provides for state programs to regulate or ban such wells;

c. Establishes procedures to protect sole source aquifers and wellhead areas;

d. Bans lead in new water supply piping and solder;

e. Provides for federal funding (not always appropriated by Congress)

E. RESOURCE CONSERVATION AND RECOVERY ACT (RCRA)

1. **Background**. RCRA, enacted in 1974 as an amendment to the Solid Waste Disposal Act and itself amended in 1984, is frequently described as a "cradle-to-grave" program; its regulatory scheme provides for control of the treatment, storage, and disposal of hazardous wastes so as to minimize the

present and future threat to human health and the environment. Management requirements are imposed upon generators and transporters of hazardous wastes and upon owners and operators of treatment, storage, and disposal facilities. RCRA also covers nonhazardous waste, household hazardous waste, and hazardous waste generated by small quantity generators.

2. **General.**

a. Definitions

i. *Solid waste* -- defined as any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous materials resulting from industrial, commercial, mining, and agricultural activities and from community activities (does not include solid or dissolved materials in domestic sewage or in industrial sources subject to permits under the CWA).

ii. *Hazardous waste* -- defined as a solid waste which because of its quantity, concentration, or characteristics may cause an increase in mortality or serious irreversible illness or pose a substantial hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed.

"hazardous waste" must meet one of four criteria: ignitability, corrosivity, reactivity, or extraction procedure toxicity (likely to leach hazardous concentrations of particular toxic constituents into the ground if not properly managed)

EPA has three lists of hazardous wastes: nonspecific source waste (generic manufacturing and industrial waste), specific source waste (from particular industries), and commercial chemical products (e.g., chloroform, creosote, DDT, kepone)

Note that any nonhazardous waste **mixed with** hazardous waste becomes a hazardous waste.

Note also that any residue **derived from** a listed hazardous waste is itself a hazardous waste.

iii. *Mixed waste* -- is a radioactive waste (regulated under the Atomic Energy Act) and hazardous waste (regulated under RCRA); generators must comply with both statutes.

b. Hazardous waste management program

i. *Generators* -- A generator includes any facility owner or operator or person who first creates a hazardous waste or person who first makes the waste subject to RCRA. A generator is initially required to determine whether any of its solid wastes are hazardous wastes as defined by the statute and EPA. A generator must obtain an EPA identification number before any hazardous waste can be shipped, treated, stored, or disposed of, and only transporters and TSD facilities with EPA identification numbers may be used. The generator has the responsibility for preparing the Uniform Hazardous Waste Manifest, a control and transport document which accompanies the hazardous waste at all times.

ii. *Transporters* -- A transporter is any person engaged in the off-site transportation of hazardous waste by air, rail, highway, or water. Anyone who moves hazardous waste off the site where it is generated or the site where it is being treated, stored, or disposed of, will be subject to transporter standards.

iii. *Treatment, Storage, and Disposal (TSD) facilities* -- TSD facilities are subject to permit requirements and to a comprehensive set of EPA regulations governing location, design, operation, and closure of TSD facilities.

iv. *Land ban program* -- Amendments enacted in 1984 prohibited land disposal of hazardous wastes. This prohibition, carried out in a phased program, is intended to minimize reliance on land disposal of untreated hazardous wastes and to encourage or require advanced treatment and recycling of wastes.

v. *Corrective actions* -- are imposed through permits or enforcement orders issued by EPA to address releases of any media from any unit at a TSD facility.

c. State solid waste programs. Regulation of nonhazardous waste is the responsibility of the states; federal involvement is limited to establishing minimum criteria prescribing the best practicable controls and monitoring requirements for solid waste disposal facilities, e.g. landfills.

d. Underground storage tanks. The act also requires EPA to develop a comprehensive regulatory program for underground storage tank (UST) systems. EPA has promulgated regulations imposing technical standards for tank performance and management, including closure and site cleanup, and establishing financial responsibility standards for tank owners.

e. Medical waste. In 1988 Congress added provisions to the act to address the issue of medical wastes washing up on beaches. Congress directed EPA to set up a demonstration program for tracking the shipment and disposal of medical wastes in a selected number of states.

F. TOXIC SUBSTANCES CONTROL ACT (TSCA)

1. **Background**. Enacted in 1976, TSCA gives EPA authority to require testing of chemical substances entering the environment and to regulate them as necessary. An amendment to TSCA passed in 1986 establishes asbestos abatement programs in schools.

2. **General**. TSCA has two main regulatory features--the acquisition of information by EPA to evaluate potential hazards from chemical substances and the regulation of production, use, distribution, and disposal of such substances when warranted.

a. Premanufacture notification (PMN) provisions

i. a manufacturer must notify EPA 90 days before producing a new chemical substance (defined as any chemical not listed on a specially compiled inventory list). Notification is also required for older chemicals already on the list if EPA concludes that there is a significant new use which increases human or environmental exposure.

ii. if EPA determines that the data submitted in the notice is insufficient to permit a reasoned evaluation or that the chemical may pose a risk of man or the environment, the agency may restrict or prohibit any aspect of the chemical's production or distribution.

b. Reporting. EPA regulations promulgated in 1982 require chemical manufacturers to report production, release, and exposure data on 245 chemicals, chosen because of toxicity or exposure levels. Manufacturers must also provide copies of health and safety studies conducted, initiated by, or known to the manufacturer.

c. Testing. EPA may require testing of any chemicals, new or old, if an unreasonable risk to health or the environment is suspected. Testing may also be required if a chemical will be produced in such quantities that significant human or environmental exposure could result. TSCA provides for a priority list of chemicals for testing; the list may not exceed 50 at any one time.

d. Enforcement. borrowing from FIFRA, TSCA allows EPA to remove a chemical from the market ("cancellation") if the agency finds that the chemical presents or will present an unreasonable risk of injury to health or the environment. EPA may also limit the amount produced, prohibit or limit particular uses, require labels, mandate recordkeeping and monitoring, and control disposal.

G. COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (CERCLA or Superfund)

1. **Background**. Enacted in 1980, CERCLA's basic purpose is to provide funding and enforcement authority for cleaning up thousands of hazardous waste sites which have been created in the U.S. and for responding to hazardous waste spills. Significant revisions to CERCLA were enacted in 1986 through the Superfund Amendments and Reauthorization Act (SARA).

2. **General**. Events that may trigger CERCLA response or liability are the release or threatened release into the environment of a hazardous substance or pollutant or contaminant.

a. Definitions

i. *Hazardous substance* -- is any substance EPA has designated for special consideration under the CAA, CWA, or TSCA, or any "hazardous waste" under RCRA. EPA may designate additional substances as hazardous which may present substantial danger to health and the environment. There are over 700 chemicals and 1500 radionuclides on EPA's list of hazardous substances. Petroleum and natural gas are excluded from the definition.

ii. *Pollutant or contaminant* -- can be any other substance not on the hazardous substances list which will or may reasonably be expected to cause any type of adverse effects in organisms and/or their offspring. Petroleum and natural gas are excluded from the definition.

b. Cleanup process -- whenever there is a release or a substantial threat of a release into the environment of any hazardous substance or any pollutant or contaminant where the pollutant or contaminant may present an imminent and substantial danger, EPA is authorized to undertake removal and or remedial actions.

i. *Removal action* -- a removal action is a short-term, limited response to a more manageable problem.

ii. *Remedial action* -- a remedial action is a longer-term, more permanent and expensive solution to a more complex problem.

- EPA may not undertake its own remedial action at a site unless the agency has first entered into a cooperative agreement with the state in which the site is located.

- Only those sites listed on the National Priorities List (NPL) will be eligible for fund-financed remedial actions. As part of its National Contingency Plan (NCP) regulations, EPA has created a structured program for evaluating sites and placing some of them on the NPL.

- Before a remedial action can take place, a Remedial Investigation/Feasibility Study (RI/FS) must be prepared, followed by the preparation of a Work Plan for the RI/FS and EPA's selection of the remedy with a Record of Decision (ROD).

Note that some CERCLA sites have been segregated into "operable units" (OU); for each OU at a site there will be a separate RI/FS and ROD.

- The RI will attempt to characterize the conditions at the site (or the OU) and will present data on the source and extent of the contamination in sufficient detail to develop and evaluate remedial alternatives.

- The FS, based upon the RI information, will present a series of specific engineering or construction alternatives for cleaning up a site.

- After preparing its RI/FS and proposed ROD, EPA provides an opportunity for public comment on the proposed cleanup.

c. Liability of responsible parties. CERCLA authorizes EPA to draw upon two types of resources to pay for site remedies: from the Superfund (federal trust fund) and from "responsible parties" (present and past owners of the site, parties who transported waste to the site, and parties who arranged for wastes to be disposed of or treated at the site). The liability scheme for private parties applies to cleanup costs as well as to natural resource damages, i.e., damages inflicted upon the flora, fauna, groundwater, surface water, and other natural resources managed by federal and state governments.

3. **Judicial Review**: The 1986 SARA amendments make it clear that EPA's removal or remedial action decisions may be judicially reviewed only at particular times. In enacting this provision, Congress agreed with EPA's position that courts should not be allowed to review EPA's remedial decisions in separate litigation, but only in connection with cases initiated by EPA to force parties to perform a remedy or to recover costs for the amount it has expended.

H. EMERGENCY PLANNING AND COMMUNITY RIGHT-TO-KNOW ACT (EPCRA)

1. **Background**. The major stimulus behind the enactment of this statute was the December 1984 release of methyl isocyanate from the Union Carbide plant in Bhopal, India. Through EPCRA, Congress was endeavoring to forestall similar disasters by requiring state and local governments to develop emergency plans for responding to unanticipated environmental releases of a number of acutely toxic materials known as "extremely hazardous substances."

2. **General**. In general, businesses covered by EPCRA are required to notify state and local emergency planning entities of the presence and quantities in inventory of hazardous materials at their facilities and to notify federal, state, and local authorities of planned and unplanned releases of those substances. The authorities receiving the information are required to make it easily available to any interested person.

3. **Reporting**. Of particular relevance to pollution prevention is Section 313 of the act which mandates the Toxic Chemical Release Inventory (TRI) Report. These reports provide information on releases into each environmental medium of specified toxic chemicals that can reasonably be anticipated to cause adverse human health effects or significant adverse effects on the environment.

Note that federal agencies are not (yet) required to comply with the TRI reporting requirements.

I. ENFORCEMENT

Most environmental laws have similar provisions for enforcement. These provisions involve:

1. **Administrative penalties**. EPA is authorized to issue administrative orders for compliance and to assess penalties for noncompliance. There are various procedural safeguards, including the opportunity for hearings before administrative penalties are imposed.

2. **Civil penalties**. EPA is authorized to refer to the Department of Justice cases for civil enforcement through the courts. Many civil enforcement cases are settled rather than tried; settlements frequently include the payment of significant civil penalties and commitments to correction violations through the installation of additional control equipment.

3. **Criminal penalties**. Criminal enforcement actions, like civil enforcement actions, are referred to the Department of Justice for prosecution. Criminal liability arises from negligent actions or omissions, from knowing violations, and from knowing endangerment. Monetary penalties and imprisonment are authorized under many environmental laws.

a. U.S. Sentencing Guidelines. The Comprehensive Crime Control Act of 1984 established the U.S. Sentencing Commission to develop guidelines for sentences for criminal offenses. The most recent guidelines became effective on November 1, 1992. Seven categories of environmental offenses are included in the sentencing guidelines:

i. knowing endangerment resulting from mishandling hazardous or toxic substances, pesticides, or other pollutants

ii. mishandling of hazardous or toxic substances or pesticides; tampering or falsifying records relating to hazardous or toxic substances or pesticides

iii. mishandling of other environmental pollutants; tampering or falsifying records relating to other environmental pollutants

iv. tampering or attempted tampering with public water system

v. threatened tampering with public water system

vi. hazardous or injurious devices on federal lands

vii. smuggling or otherwise unlawfully dealing in specially protected fish, wildlife, or plants

Term of imprisonment required by sentencing guidelines will depend on type of violation, with adjustments for degree of actual or potential harm resulting from offense, nature and quality of the substance involved, duration of the offense, the risk associated with the offense, and culpability of the particular defendant. These sentencing rules make sentencing essentially a mathematical exercise, severely reducing judicial discretion. Sentences for environmental crimes are relatively harsh.

4. **Citizen suit provisions**. Many environmental laws allow private individuals and groups to initiate litigation seeking redress for alleged violations. These provisions generally grant citizens the right to participate in or initiate enforcement of most provisions of a statute and its regulations. Citizens usually cannot begin such litigation without giving notice to the federal government (EPA and the Department of Justice); attorneys fees can be paid to the prevailing party either under specific environmental laws or under the Equal Access to Justice Act. Citizen suits have been a major factor in environmental enforcement litigation.

III. APPLICATION OF ENVIRONMENTAL LAWS TO FEDERAL FACILITIES

The environmental laws outlined above are generally applicable only to private entities, not to the federal government. The American public and Congress are increasingly demanding that federal agencies be required to comply with the same laws as private parties.

A. CLEAN AIR ACT

Amendments to the CAA state that each agency of the federal government having jurisdiction over any property or facility or engaged in any activity resulting in the discharge of air pollutants shall be subject to and comply with all federal, state, interstate, and local requirements respecting the control and abatement of air pollution in the same manner and to the same extent as any nongovernmental entity. [42 USC § 7418]

B. CLEAN WATER ACT

The CWA states that each agency of the federal government having jurisdiction over any property or facility or engaged in any activity resulting in the discharge of pollutants shall be subject to and comply with all federal, state, interstate, and local requirements respecting the control and abatement of water pollution in the same manner and to the same extent as any nongovernmental entity. [33 USC § 1323]

C. SAFE DRINKING WATER ACT

The SDWA states that each agency of the federal government having jurisdiction over any source of contaminants identified by a state program to protect wellhead areas shall be subject to and comply with all requirements of the state program in the same manner and to the same extent as any other person is subject to such requirements, including payment of reasonable charges and fees. [42 USC § 300h-7(h)]

In addition, each federal agency having jurisdiction over any federally owned or maintained public water system or engaged in any activity resulting or which may result in underground injection which endangers drinking water shall be subject to and comply with all federal, state, and local requirements, both substantive and procedural, respecting the provision of safe drinking water and respecting any underground injection program in the same manner and to the same extent as any nongovernmental entity. [42 USC § 300j-6]

D. RESOURCE CONSERVATION AND RECOVERY ACT

RCRA states that each federal agency having jurisdiction over any solid waste management facility or disposal site or engaged in any activity resulting or which may result in the disposal or management of solid or hazardous waste shall be subject to and comply with all federal, state, and local requirements, both substantive and procedural, respecting control and abatement of solid waste or hazardous waste disposal in the same manner and to the same extent as any nongovernmental entity. [42 USC § 6961]

EPA is authorized to undertake annual inspection of TSD facilities owned or operated by the federal government to enforce compliance with the act. Federal facilities must undertake inventories of each site where hazardous waste is stored, treated or disposed. [42 USC §§ 6927 and 6937]

In addition, federal agencies must comply with provisions relating to underground storage tanks and medical wastes in the same manner and to the same extent as any nongovernmental entity. [42 USC §§ 6991f and 6992e]

E. COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT

In the SARA amendments in 1986, federal agencies are required to comply with CERCLA in the same manner and to the same extent, both procedurally and substantively, as any nongovernmental entity. [42 USC § 9620].

F. FEDERAL FACILITY COMPLIANCE ACT

1. **Background.** Under the Federal Facility Compliance Act enacted in late 1992, federal agencies are now included in the definition of "person" for purposes of RCRA. This amendment to RCRA is intended to ensure greater compliance by federal facilities with the requirements of RCRA for the management, treatment, storage, and disposal of hazardous wastes. The act recognizes that federal government facilities, both civilian and military, routinely generate, manage, and dispose of large quantities of hazardous wastes containing acids, nitrates, radioactive materials, and heavy metals.

2. **General.**

a. Federal facilities are subject to enforcement sanctions, including penalties, for violations of all solid or hazardous waste statutes and regulations, including violations of compliance schedules for corrective actions.

Note that any penalties assessed are to be paid from an agency's appropriation. Congress thought that this approach, rather than allowing payments from the Judgment Fund, would provide a measure of accountability for federal agencies.

b. A state may now conduct an inspection of any federal facility for purposes of enforcing the facility's compliance with the state's hazardous waste program.

IV. POLLUTION PREVENTION INITIATIVES

Although the environmental laws enacted in the 1970s and 1980s are responsible for the substantial improvements seen in environmental quality, Congress, EPA, and others have come to realize that future improvements will require a new focus on preventing pollution before it is generated. Laws have been passed by Congress and policies have been developed throughout the federal government to implement pollution prevention concepts.

A. RCRA AMENDMENTS

1. **Background.** Waste minimization is a policy specifically mandated by the 1984 amendments to RCRA, known as the Hazardous and Solid Waste Amendments (HSWA) of 1984. In these amendments, Congress declared it to be the national policy that, wherever feasible, the generation of hazardous waste is to be reduced or eliminated as expeditiously as possible.

2. **General.** Among the waste minimization requirements found in the HSWA are:

a. the manifest required to be prepared by a hazardous waste generator must contain a certification that the generator has a program in place to reduce the volume or quantity and toxicity of such waste to the extent economically feasible.

b. a permit issued for the treatment, storage, or disposal of hazardous waste on the premises where such waste was generated must contain a certification from the permitee that the generator of the hazardous waste has a program in place to reduce the volume or quantity and toxicity of such waste to the extent economically feasible.

B. POLLUTION PREVENTION ACT

1. **Background**. The Pollution Prevention Act was passed by Congress in 1990. In this act, Congress recognized that the U.S. produces millions of tons of pollution each year and spends tens of billions of dollars a year to control that pollution. In addition, Congress found that there were significant opportunities for industry to reduce or prevent pollution at the source through cost-effective changes in production, operation, and raw materials use and specifically stated that source reduction was more desirable than waste management and pollution control. [42 USC § 13101(a)]

2. **General**.

a. Policy -- The act establishes a hierarchy of pollution prevention:

- pollution should be *prevented or reduced* at the source whenever feasible;
- pollution that cannot be prevented should be *recycled* in an environmentally safe manner whenever feasible;
- pollution that cannot be prevented or recycled should be *treated* in an environmentally safe manner whenever feasible; and
- *disposal or other release* into the environment should be employed *only as a last resort* and should be conducted in an environmentally safe manner.

[42 USC § 13101(b)]

b. Definitions

i. The meaning of the term "source reduction" is obviously an important one given its emphasis in the statute. Congress defined the term as meaning

ii. "any practice which (i) reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment, or disposal; and (ii) reduces the hazards to public health and the environment associated with the release of such substances, pollutants, or contaminants."

iii. The term includes equipment or technology modifications, process or procedure modifications, reformulation or redesign of products, substitution of raw materials, and improvements in housekeeping, maintenance, training, or inventory control.

iv. The term does not include any practice which alters the physical, chemical, or biological characteristics or the volume of a hazardous substance, pollutant, or contaminant through a process or activity which itself is not integral to and necessary for the production of a product or the providing of a service.

[42 USC § 13102(5)]

c. Strategy. To implement this pollution prevention policy, Congress called upon EPA to establish a pollution prevention office. EPA's administrator, through the pollution prevention office, is directed to develop and implement a strategy to promote source reduction. This strategy must, among other things,

i. establish standards by which to measure source reduction;

ii. ensure that EPA considers the effect of its programs on source reduction efforts;

iii. facilitate the adoption of source reduction techniques by businesses through the use of a Source Reduction Clearinghouse and matching grants to states to foster the exchange of information;

iv. establish a training program on source reduction opportunities;

v. identify opportunities to use federal procurement to encourage source reduction; and

vi. develop, test, and disseminate model source reduction auditing procedures.

[42 USC § 13103]

d. Reporting

i. *Owners and Operators* -- In addition to defining a pollution prevention policy and requiring EPA to develop a pollution prevention strategy, the statute also compels owners and operators of facilities required to file an annual toxic chemical release form under the Emergency Planning and Community Right-to-Know Act (EPCRA) for any toxic chemical to file along with the annual filing a toxic chemical source reduction and recycling report. The source reduction and recycling report must cover each toxic chemical required to be reported in the annual toxic chemical release form and must include:

- The quantity of the chemical entering any waste stream or otherwise released into the environment prior to recycling, treatment, or disposal and the percentage change from the previous year;
- The amount of the chemical from the facility that is recycled at the facility or elsewhere and the percentage change from the previous year;
- Source reduction practices used with respect to that chemical during the year at the facility;
- Amounts expected to be reported under the first two paragraphs in the next two calendar years;
- A ratio of production in the reporting year to production in the previous year (calculated to most closely reflect all activities involving the toxic chemical); and
- Techniques that were used to identify source reduction opportunities.

The data collected under this provision is made publicly available. [42 USC § 13106]

ii. *EPA*. EPA is required to report to Congress every two years on matters relating to the implementation of the act including a description of the actions taken to implement the source reduction strategy; an assessment of the effectiveness of the clearinghouse and grant program in promoting the goals of the act; and an analysis of the data collected from owners and operators regarding their source reduction efforts. [42 USC § 13107]

3. **Legislative History**. The Pollution Prevention Act has a very short legislative history. It was purportedly inspired by a 1987 report by the congressional Office of Technology Assessment, and was supported by groups as diverse as the Chemical Manufacturers Association and the National Wildlife Federation. Cynics have suggested that the bill was not opposed by anyone because there was nothing in it to oppose: it was merely a statement of policy and required some data collection and exchange. On the other hand, it has been suggested that by requiring data collection and dissemination, the bill used the power of public opinion and the market to aid the environment by giving the public a more complete picture of how a company manages or prevents the generation of waste.

4. **EPA Implementation to Date**

a. Pollution Prevention Strategy. EPA's strategy, released in February 1991, provides guidance on incorporating pollution prevention into EPA's ongoing environmental protection efforts and includes a plan for achieving substantial voluntary reductions of targeted high risk industrial chemicals. A major component of the strategy is the Industrial Toxics Project in which the agency has set the goal of reducing environmental releases of 17 high risk industrial chemicals by 33% by the end of 1992 and by at least 50% by the end of 1995 (the 33/50 program).

b. Pollution Prevention Clearinghouse. EPA has created a Pollution Prevention clearinghouse which is a multi-media clearinghouse of technical, policy, programmatic, legislative, and financial information dedicated to promoting pollution prevention through efficient information transfer. It consists of a reference library, a computerized conduit to databases, and a hotline.

c. Report to Congress. EPA has issued one report to Congress on its pollution prevention efforts.

d. "Statement of Definition" of pollution prevention. In May, 1992, EPA issued a memorandum to EPA personnel providing the EPA definition of pollution prevention "to guide more consistent use of the term in [EPA's] activities and written materials." In this memorandum, EPA states that

"Pollution prevention means 'source reduction' as defined under the Pollution Prevention Act, and other practices that reduce or eliminate the creation of pollutants through:

-- increased efficiency in the use of raw materials, energy, water, or other resources, or

-- protection of natural resources by conservation."

C. CEQ POLLUTION PREVENTION GUIDANCE

1. **Background**. In early 1993, CEQ issued guidance to the federal agencies on incorporating pollution prevention principles, techniques, and mechanisms into their planning and decisionmaking processes and evaluating and reporting those efforts in documents prepared pursuant to NEPA.

2. **General**.

a. Defining "pollution prevention". CEQ defines and uses the term broadly. As used in the guidance, the term includes reducing or eliminating hazardous or other polluting inputs; modifying manufacturing, maintenance, or other industrial practices; modifying product designs; recycling; preventing the disposal and transfer of pollution from one media to another; and increasing energy efficiency and conservation.

Note that CEQ's definition is not the same as EPA's definition which describes pollution prevention in terms of source reduction and other practices which reduce or eliminate the creation of pollutants through increased efficiency in the use of raw materials.

b. Types of actions. Pursuant to the procedural requirements found in NEPA and in the CEQ regulations, federal agencies should take every opportunity to include pollution prevention considerations in the early planning and decisionmaking processes for their actions and, where appropriate, should document those considerations in any NEPA document prepared for those actions. In this context, federal actions encompass policies and projects initiated by a federal agency itself, as well as activities initiated by non-federal entities which need federal funding or approval.

c. Incorporating pollution prevention in the NEPA process. NEPA and the CEQ regulations establish a mechanism for building environmental considerations into federal decisionmaking.

- *Integrating the NEPA process with other planning* at the earliest possible time can allow incorporation of pollution prevention in early stages of planning and design.
- Developing the *scope of an EIS* can give the public the opportunity to participate in discussions of pollution prevention
- Pollution prevention also should be an important component of *mitigation*.
- Requirements for the *record of decision* at the conclusion of the EIS and for monitoring and enforcement can be an effective means to inform the public of the extent to which pollution prevention is included in a decision.

- Pollution prevention measures which contribute to an agency's *finding of no significant impact* after the preparation of an environmental assessment must be carried out by the agency or made part of a permit or funding determination.

D. RELEVANT EXECUTIVE ORDERS

1. **E.O. 12088** -- Federal Compliance with Pollution Control Standards (1978)

   Federal agencies are responsible for ensuring that all necessary actions are taken for the prevention, control, and abatement of pollution at federal facilities.

2. **E.O. 12580** -- Superfund Implementation (1987)

   Among other things, prior to selection of a remedial action by EPA at a federal facility, federal agencies must have the opportunity to present their views to EPA using the procedures in E.O. 12088; the Office of Management and Budget shall facilitate resolution of any issues.

3. **E.O. 12759** -- Federal Energy Management (1991)

   Each agency shall , among other things, develop and implement a plan to meet energy management goals and reduce overall energy use, seek to minimize use of petroleum products by switching to alternative fuels, adopt an implementation strategy, select for procurement energy efficient goods and products.

4. **E.O. 12780** -- Federal Agency Recycling and the Council on Federal Recycling and Procurement Policy (1991)

   Federal agencies are required to promote cost-effective waste reduction and recycling of reusable materials, encourage economically efficient market demand for designated items produced using recovered materials, provide a forum for the development and study of policy options and procurement options that will promote waste reduction, and integrate cost-effective waste reduction and recycling programs into all federal agency waste management programs.

5. **E.O. 12856** -- Federal agencies to comply with toxic release inventory (TRI) reporting and Pollution Prevention Act requirements.

6. **E.O. 12902** -- Energy efficiency and water consservation at federal facilities (1994).

E. DOD POLLUTION PREVENTION POLICY

DOD and EPA have entered into a joint pollution prevention initiative known as Toxics Reduction in the Military (TRIM). DOD has stated its commitment to stewardship of the environment and recognizes that the key to a cleaner environmental future is pollution prevention.

- "By reducing the entry of hazardous and toxic material into the system, DOD will not only reduce emissions and disposal problems, but improve worker safety, limit potential environmental damage, and increase efficiency."

- DOD will "initiate voluntary reporting of all Toxic Release Inventory chemicals for DOD's major, government-owned/government-operated (GOGO) facilities...beginning in CY 1993. Additionally, the Department will work to achieve a 33 percent reduction in releases and transfers of the 17 priority chemicals in [EPA's] 33/50 program by CY 1997."

- "By the end of 1993, [DOD will] complete the current review of military specifications and standards that require substantial DOD use of the 17 priority chemicals identified in EPA's 33/50 program and identify opportunities to substitute or reduce usage. Where technically feasible, [DOD will] make revisions to the appropriate specifications and standards by the end of 1995, on a priority basis."

feasible, [DOD will] make revisions to the appropriate specifications and standards by the end of 1995, on a priority basis."

F. AIR FORCE POLLUTION PREVENTION POLICY

Action Memorandum -- The Department of the Air Force issued an Action Memorandum on January 7, 1993 relating to its pollution prevention program. The memorandum outlines six objectives:

1. Reduce the use of hazardous materials in all phases of new weapons systems from concept through production, deployment, and ultimate disposal. Find alternative materials and processes, and measure their life cycle costs.

2. Reduce the use of hazardous materials in existing (deployed) weapons systems by finding less hazardous materials and processes and integrating them into TOs, MILSPECS and MILSTDS.

3. Reduce hazardous materials use and waste generation at all installations (civil engineering, vehicle and aircraft maintenance, administrative facilities, family housing, etc.) and government-owned/contractor-operated facilities (GOCOs).

4. Acquire state-of-the-art pollution prevention technologies from outside the Air Force and Air Force model installation, crossfeed the ideas through a technology information center, and aggressively market them Air Force-wide. Identify, implement, and evaluate new, innovative ideas to reduce hazardous material use and waste generation from community activities at model installations, from GOCOs and from industrial activities and report semiannually the status of each project to other MAJCOMs and the AFCEE.

5. Apply new technology to pollution prevention; searching outside sources first, and conducting Air Force research where no alternatives exist.

6. Establish an Air Force investment strategy to fund the Pollution Prevention Program.

G. ARMY POLLUTION PREVENTION POLICY

1. **Army Regulation 200-1** (32 CFR Part 650) prescribes policies, assigns responsibilities, and establishes procedures for the protection and preservation of environmental quality for the Department of the Army. Provisions in this regulation relating to pollution prevention include

a. "It is the Department of the Army's goal to plan, initiate, and carry out all actions and programs to minimize the adverse effects on the quality of the human environment without impairment to the Army's mission. Inherent in this goal is the requirement to achieve the following objectives:

"eliminate the discharge of potentially harmful pollutants produced by Army activities...."

b. All material and energy resources will be procured and used in a manner that will minimize the emission of pollutants and the production of wastes in keeping with the national policies for energy conservation. Wastes generated will be reprocessed or reclaimed for other productive uses to the maximum extent practicable."

c. "For planning purposes, the environmental system will be regarded as closed; nothing can be thrown away. Wastes must either be recycled and reclaimed or confined and contained so they will not migrate to re-emerge in pollutant form."

d. "Pollutants are potential resources which are out of place."

Note that this regulation is in the process of being revised.

2. **Army Strategy for the 21st Century.** The Army's environmental strategy has four "pillars": compliance, restoration, prevention, and conservation. The prevention pillar focuses on

eliminating pollution to the greatest extent possible, including reducing hazardous materials use and hazardous waste generation. Its focus of prevention objectives has four components:

a. Use a holistic approach to pollution prevention which looks at all environmental media collectively.

b. Systematically eliminate hazardous materials use and operations or processes that produce hazardous/solid waste and other emissions.

c. Minimize environmental risks to operating personnel and visitors at Army civil works facilities.

d. Instill the pollution prevention ethic throughout the entire Army community and all mission areas.

H. NAVY POLLUTION PREVENTION POLICY

The Navy has developed an environmental program which focuses on four areas: installation restoration, compliance (ashore and afloat), pollution prevention, and stewardship.

1. **Shore Pollution Prevention** includes two programs

a. Hazardous Material Control and Management

The program identifies, manages, and controls hazardous materials from "cradle to grave." The program integrates environmental protection into the acquisition process, the supply and procurement process, and worker safety and occupational health.

b. Hazardous Waste Minimization

This program is directed toward a reduction in the generation, treatment, and disposal of hazardous wastes at Navy installations. Elements of the program include source reduction or elimination, recycling or reuse, and effective waste treatment.

2. **Ship Pollution Prevention**. The Navy has a comprehensive Shipboard Pollution Abatement Program. The strategy is to design and operate ships to minimize waste generation and optimize waste management, and to develop shipboard systems that will destroy or appropriately treat shipboard wastes.

V. SUMMARY

This lesson presents an overview of the federal environmental statutes pertaining to pollution prevention, and pollution prevention initiatives being taken by DOD and throughout the federal government. Understanding environmental laws and regulations is the first step in complying with those requirements. Noncompliance means not only adverse effects on the environment, but also potential liability and fines. Federal facilities are subject to environmental laws and regulations almost to the same extent as nongovernmental entities. Reducing the amount of pollution produced will reduce costs for environmental compliance (if you do not produce it, you do not have to report it) and for environmental cleanup.

BLOCK 3: DoD and AIR FORCE POLICY

1.0 Introduction

Block 3 presents DoD Directives and initiatives that guide near and long term pollution prevention activities. Air Force policy, in response to DoD, State and Federal regulatory requirements as well as the Air Force's leadership commitment to enhancing the environment, is also reviewed. The focus is on Federal and State requirements that have resulted in DoD and Air Force pollution prevention policy. Current DoD and Air Force policy applicable to pollution prevention.

2.0 Objective

To review DoD Directives and initiatives that guide near- and long-term pollution prevention activities. To review Air Force policy in response to DoD, State and Federal regulatory requirements, as well as the Air Force's leadership commitment to enhancing the environment.

The focus of this unit of instruction is on introducing DoD and Air Force policy with regards to pollution prevention.

1. Students will know Federal and State requirements that have resulted in DoD and Air Force pollution prevention policy.

2. Students will learn current DoD and Air Force policy applicable to pollution prevention.

3. Students will know the main points made by the governing regulations to include regulatory trends.

3.0 Key Concepts

I. INTRODUCTION

Successful pollution prevention efforts require the contributions of considerable knowledge and technical skills by many personnel. Policy statements issued by senior headquarters furnish the "macro" view of the topic. They give overall direction to the efforts. Armed with the policy directives, technical experts can apply their knowledge and experience to problem solving.

The purpose of this block of instruction is to provide an introduction to the "macro" level. This kind of instruction serves two purposes. For those who are unfamiliar with the topic, it helps put it in perspective. This gives better understanding of the "big picture." For those who have dealt with pollution prevention, this is a refresher to their store of knowledge.

Three important directives on pollution prevention policy will be reviewed: the DoD policy, the Air Force policy, and the installation-level program manual implementing Air Force pollution prevention policy.

II. DOD POLICY

The principal authority controlling DoD's hazardous material pollution prevention program is found in Department of Defense Directive 4210.15 ("Hazardous Material Pollution Prevention," July 27, 1989). This directive establishes policy, assigns responsibilities, and prescribes procedures for HMPP. The program direction which it sets in motion applies to OSD, Departments, JCS, etc, including Military Services, and extends to both appropriated fund and nonappropriated fund operations.

A. DoDDir 4210.15 contains a concise, useful statement of the Department's policy:

"It is DoD policy that hazardous material shall be selected, used, and managed over its life cycle so that the Department of Defense incurs the lowest cost required to protect human health and the environment. The preferred method of doing this is to avoid or reduce the use of hazardous material. Where use of hazardous material may not reasonably be avoided, users shall follow regulations governing its use and management as required by appropriate DoD issuances. In the absence of regulations, users shall apply management practices that avoid harm to human health or the environment. Emphasis must be on less use of hazardous materials in processes and products, as distinguished from end-of-pipe management of hazardous waste."

B. The directive assigns specific roles to several echelons of Defense officials:

1. Heads of DoD Components -- shall know how the regulation of hazardous material affects their operations and how their decisions relative to hazardous material affect subsequent operations.

2. Assistant Secretary of Defense (Production and Logistics) [ASD (P&L] -- shall promote hazardous materials pollution prevention within DoD.

3. Department Secretaries and Agency Heads -- Develop and revise, as necessary, a Hazardous Material Pollution Prevention Plan to implement this Directive, monitor implementation, and ensure subordinates' appropriate actions to carry out DoD policy.

C. The DoD Directive tasks specific procedures to be accomplished by certain officials to carry out the directive's intent.

ASD (P&L) shall:

Ensure that appropriate OSD functional guidance exists on HMPP

Ensure a reporting mechanism exists monitoring implementation

Schedule and preside over annual status briefings presented by the Military Services and Defense Agencies

Heads of DoD Components shall:

Modify functional area efforts, procedures, guidance documents, or common practices to improve the way that hazardous material or the issues caused by hazardous material are managed

Where a document allows for the use of hazardous material or a process is using hazardous material and a less hazardous substitute is, or could be, available, revise the document, process or operating procedure, to facilitate the use of the substitute, in accordance with the [DoD] policy

Heads of Military Services and Defense Agencies shall:

Designate a lead office to coordinate their actions on this Directive

Cooperate with the ASD (P&L) effort to obtain current information that describes the value of actions taken under this Directive

Provide an annual briefing on selected aspects of actions taken to achieve hazardous material pollution prevention

D. Enclosure (1) to DoDDir 4210.15 provides definitions for major terms related to hazardous material pollution prevention. The definitions give excellent insight into the parameters of DoD's efforts toward pollution prevention. Moreover, the definitions include amplifying information which helps to put subordinates' efforts in context.

1. Alternatives. "Ways of reducing the adverse effects of hazardous material." They include:

Substituting less hazardous or nonhazardous material

Redesigning a component such that hazardous material is not needed in its manufacture, use, or maintenance

Modifying process or procedures

Restricting users

Consumptive use

On-demand supply

Direct ordering

Extending shelf-life

Regenerating spent material

Downgrading and reuse of spent material

Use of waste as raw material in other manufacturing

Combinations of those factors

2. Cost factors. "The expenses and cost avoidances associated with hazardous material that may be reduced to monetary terms, which includes future liability."

> Direct and indirect costs attributable to hazardous material encountered in operations such as acquisition, manufacture, supply, use, storage, inventory control, treatment, recycling, emission control, training, work place safety, labeling, hazard assessments, engineering controls, personal protective equipment, medical monitoring, regulatory overhead, spill contingency, disposal, remedial action, and liability
>
> Accounting requires application of risk and uncertainty analysis

3. Economic Analysis. "An evaluation of the costs associated with the use of hazardous material and potential alternatives, which is conducted in accordance with DoD Instruction 7041.3 (Economic Analysis and Program Evaluation for Resource Management ([October 18, 1972]))"

> Not a specific, step-by-step procedure that can be applied by rote to all cases
>
> "... organizations shall be guided by basic principles of economics and informed judgment."
>
> "There is no one formula. There is no absolutely right way to do it."

4. Functional Areas. "The operations or areas of responsibility that affect or are affected by the use of hazardous material." These include

> Budget and fiscal planning, legal support, research and development, weapons systems acquisition, weapons systems maintenance, material and performance specifications and standards, design handbooks and technical manuals, maintenance and repair procedures, industrial processes, procurement policy, contracting provisions, new material identification, public works operations, construction, management of munitions, chemical agents, and propellants, medical and other personnel support, safety and occupational health, transportation, logistics analysis, supply, warehousing, distribution, recycling, disposal, spill prevention, control, and cleanup, contaminated site remediation, staffing, education and training, information exchange, public affairs, general administration, and oversight.

5. Hazardous Material. "Anything that due to its chemical, physical, or biological nature causes safety, public health, or environmental concerns that result in an elevated level of effort to manage it."

The Directive establishes no new technical definition of hazardous material

"What matters is not whether something fits precisely in a definition or whose definition it is, but whether it may be better managed to mitigate the problems it causes and improve the quality of defense."

6. Intangible Factors. "Influences bearing on the use or effects of hazardous material, which may not be reduced to monetary terms."

7. Life Cycle of a Hazardous Material. "The period starting when the use or potential use of hazardous material is first encountered and extending as long as the actual material or its after effects, such as a discarded residual in a landfill, have a bearing on cost."

8. Hazardous Material Pollution Prevention Plan (HMPPP). Typically a plan including action and milestone, responsibilities, regulations, and other variations under an appropriate formal, issued implementing document. Required elements of a HMPPP include:

Procedures for informing Service or Agency line commanders of issues and progress

Participation of critical functional staff offices such as systems acquisition, design, specification proponents, etc.

Participation of major commands or primary field activities

Provisions for reviewing functional issuances and making appropriate modifications

A process for analyzing existing operations or processes for waste minimization potential

A method of funding waste reduction projects

A process for subordinate commands to report data that measures progress

A commitment to information exchange

A policy of cooperation with public agencies involved in waste reduction, pollution prevention, or waste minimization

III. AIR FORCE POLICY

Four principal sources provide Air Force policy on pollution prevention. These are the Pollution Prevention Program - Action Memorandum and the Ozone Depleting chemicals - Action Memorandum, both issued in January 1993, and Air Force Policy Directive 19-4 and Air force Instruction 19-40, both of which are pending issuance.

A. Air Force Pollution Prevention Program - Action Memorandum. The Air Force formally established its policy concerning pollution prevention with joint issuance on January 7, 1993, by the Secretary and Chief of Staff of a memorandum for all major commands, entitled Air Force Pollution Prevention Program - ACTION MEMORANDUM. The memorandum stated the Air Force's goal and objectives:

"Our goal is to prevent future pollution by reducing use of hazardous materials and releases of pollutants into the environment to as near zero as feasible. To achieve this, we must quickly move from dependence on hazardous materials, actively reduce our waste streams, to reuse the wastes we do generate, recycle what we cannot reuse, and expand purchasing program for recycled products."

The Action Memorandum transmitted the Pollution Prevention Program Action Plan. It recited the strategic goal of reducing hazardous material use and environmental releases to near-zero. It then listed six objectives. These best exemplify the policy direction of the Air Force in pollution prevention efforts.

Objective 1. Reduce the use of hazardous materials in all phases of new weapon systems from concept through production, deployment and ultimate disposal. Find alternative materials and processes, and measure their life cycle costs.

Objective 2. Reduce the use of hazardous materials in existing (deployed) weapons systems by finding less hazardous materials and processes and integrating them in TOs, MILSPECS, and MILSTDS.

Objective 3. Reduce hazardous materials use and waste generation at installations (civil engineering, vehicle and aircraft maintenance, administrative facilities, family housing, etc.) and government-owned/contract-operated facilities.

Objective 4. Acquire state of the art pollution prevention technologies, and distribute them throughout the Air Force.

Objective 5. Apply new technology to pollution prevention, searching outside sources first, and conducting Air Force research where no alternative exists.

Objective 6. Establish an Air Force investment strategy to fund the Pollution Prevention Program.

Sub-objectives, many with "by dates," accompany each major objective.

B. Ozone Depleting Chemicals (ODCs) - Action Memorandum. The Air Force addressed ozone depleting chemicals on the same date as it issued the pollution prevention program action memorandum. The Ozone Depleting Chemicals - Action Memorandum provides:

"Effective January 1, 1993 we are instituting the attached Air Force policy governing the purchase, use, and management of controlled ODCs."

The ODC Action Plan pertains to

Halons 1211, 1301, 1202, 1011, and 2402

Chloroflurocarbons (CFCs) -11, -22, -113, -114, -115, -13, -111, -112, -211, -213, -214, -215, -216, and -217

Carbon tetrachloride and methyl chloroform

Methyl bromide

Halon policy: The purchase of newly produced halons is prohibited as of June 1, 1993, unless a waiver is approved.

CFC refrigerants policy: The acquisition of facility air conditioning systems, AGE equipment, and other refrigeration and support equipment using ODCs is prohibited as of January 1, 1993.

CFC solvents policy: Effective April 1, 1994, the purchase of ODC solvents, and equipment/systems/products requiring ODC solvents for maintenance or operation is prohibited.

Per Public Law 102-484 (National Defense Authorization Act for Fiscal Year 1993 (Section 326), "No contract awarded after June 1, 1993 shall include a requirement to use ODCs or any requirement that can be met only through the use of ODCs, without approval of SAF/AQ."

C. Air Force Policy Directive 19-4 (Pending). Presently in the works is Air Force Policy Directive 19-4. Its purpose is:

> "To demonstrate environmental leadership to meet all federal pollution prevention objectives by eliminating or reducing, to as near zero as feasible, hazardous substance use and waste releases to the environment."

The Directive will address two broad, important areas:

Waste releases

- Hazardous waste
- Municipal solid waste
- Air pollution control
- Water pollution control

Hazardous substances

- Ozone depleting chemicals
- EPA 17 industrial toxics
- EPA Toxic Releases Inventory

D. Air Force Instruction 19-40. This pending Air Force instruction will identify requirements of the Pollution Prevention Program. It will apply to all personnel involved in acquisition, use, and disposal of environmentally harmful substances at Air Force installations and facilities including the Air Force Reserve, Air National Guard, and government-owned/contract-operated facilities.

Air Force Instruction 19-40 will interface with AFPD 19-4 and implement the Federal Pollution Prevention Act of 1990, SARA, the Toxic Substances Control Act, the Clean Air Act Amendments of 1990, the Clean Water Act, the Montreal Protocol on Substances that Deplete the Ozone Layer, Executive Order 12580, and DoD Directive 4210.15 (Hazardous Material Pollution Prevention, July 27, 1989 (discussed above)).

The Instruction will:

- Outline functional area responsibilities in Pollution Prevention Program implementation
- Direct commanders to develop and implement Pollution Prevention Management Plans
- Identify program elements and provide implementation instructions

Program elements will extend to:

- Ozone depleting chemicals

Hazardous substance management

Hazardous waste minimization

Municipal solid waste management

Affirmative procurement

Nonpoint source pollution

Air pollution emissions

Education and incentives

IV. AIR FORCE POLLUTION PREVENTION PROGRAM

In January 1992, the Air Force issued the U.S. Air Force Installation Pollution Prevention Program Manual (IPPPM). This manual, preceding the January 1993 policy memorandum by a full year, sets forth precisely the same major objectives as the Secretary and Chief of Staff.

The IPPPM's utility is in its helpfulness to commanders who must grapple with a potentially huge topic. It manages to operate on both the macro and mundane levels.

A. The IPPPM outlines what pollution prevention practices include:

Reducing the use of HM through source reduction

Recycling unavoidable wastes in a sound manner and treating wastes that cannot be recycled

Conserving energy

Controlling nonpoint source pollution

Procuring products made with recovered and recycled materials

Environmental education and training for all personnel

B. By its terms, the IPPPM tasks commanders to undertake action:

> "Under the Pollution Prevention Policy, each installation, including those outside the U.S., is expected to develop and execute a PPP that addresses source reduction, recycling, and treatment opportunities for major pollutant sources. The PPP should also evaluate the potential impact of other activities, such as volume of base traffic, water use, and resource management, to determine how to reduce risks to human health and the environment."

C. A major driver in issuance of the IPPPM concerns the Air Force's desire to predict and comply with regulatory influences:

> "The Air Force has developed its Pollution Prevention Program to implement the federal regulatory mandate of the Pollution Prevention Act of 1990....The Pollution Prevention concept is designed to engender actions and incorporate existing activities at Air Force installations that will reduce and prevent harmful releases of hazardous and toxic materials to air, land, groundwater, and surface water."

D. Under the IPPPM, activity must occur in three areas:

Base management support/command structure

Development of the Pollution Prevention Management Plan defining scope and objectives of the program

Base survey/audit to define HMs and waste management practices

E. The key players at the installation level are the

PPP Coordinator (typically the Base Environmental Coordinator)

Assessment Team (consisting of the PPP Coordinator, key installation function representatives, and technical consultants), and

Working Group, or policy setting and decisionmaking body which directs and reviews the Assessment Team

F. Per the IPPPM, each installation is to develop a local Pollution Prevention Management Plan. Minimum contents of such plans include:

Statements of goals, objectives, strategies, program scope, and projects

Selection criteria and prioritizing scheme for equipment upgrades and facility projects

Summary of prevention opportunities

Procedures to measure reductions

Methods for tracking and reporting progress

Applicable sections

Introduction (organization, goals, etc.)

Industrial, maintenance, and cleanup operations (HW, air, wastewaters, other wastes)

Municipal solid waste

Nonpoint source reduction

Hazardous materials

Integration with existing programs (comprehensive planning, energy conservation, natural resources, water conservation, spill prevention and response, IRP, pest management, noise abatement)

Education and incentives

G. Funding and priorities for pollution prevention efforts fall into three kinds of investment areas: foundation, alternative technologies, and execution. Among all the varieties of measures that might be taken to reduce pollution, the IPPPM establishes a hierarchy for approval of funding:

Reduction of ozone depleting chemicals, and of EPA's 17 industrial hazardous toxics, or other extremely hazardous toxics

Reduction of volume or toxicity of HW being disposed

Reduction of volume of nonhazardous solid waste disposed , volatile or other hazardous air emissions, or contaminated water (point or nonpoint source).

Education, training, and awareness programs

Interim fixes

Among competing projects within each category, both tangible paybacks (time required to achieve savings) and intangible paybacks (e.g., reduced worker risks, improved image, reduction of cleanup potential liability, etc) are to be considered.

Requirements reporting for pollution prevention projects must, of course, be uniform across the Service if they are to be fairly evaluated and selected. Reporting must be in sync with the Federal Facilities Pollution Abatement Plan (A-106 process). Hence, real time reporting is done via the Work Information Management System Environmental Subsystem (WIMS-ES) module of A-106.

H. The IPPPM contains other significant areas that must be considered in successful pollution prevention efforts. Briefly, these are:

Opportunity assessments

Regulation of environmental pollution

Air emissions

Releases to water

Releases to land

RCRA

Air and water permits

SARA Title III "Air Force installations are currently exempt from SARA/Title III regulations, but there is a good chance that they will be required to comply with these regulations in the future."

Integrated waste management

Measuring success

Pollution prevention reporting (via WIMS-ES into Defense Environmental Management Information System)

Base Comprehensive Plan ("addresses all land areas under AF control and all AF activities affecting land use ... also the current and projected capability of local communities to provide service to AF people")

Technology transfer

V. SUMMARY

DoD and Air Force policies on pollution prevention have, for the most part, been developed and issued for your use at the local level. The "final" version of pollution prevention concepts has not been issued. What is available today, however, will give you plenty of areas to explore and apply at your installation.

A basic tenet of pollution prevention is that fiscal resources will not be needed to remedy a problem if good planning avoids that problem in the first place. Money spent on cleaning up pollution is money that cannot be spent training aircrews. If you figure out ways to avoid generating pollution, then you directly contribute to maintaining the finest aircrews in the world.

Implementing pollution prevention is not easy. The concept employs a lot of terms. It is a big problem that invites problem solving from many angles. The DoD and Air Force policy statements only suggest the unusual degree of coordination and liaison needed among agencies to achieve pollution prevention. If pollution prevention is to work, you have to get involved.

BLOCK 4: OPPORTUNITY ASSESSMENTS

1.0 Introduction

Block 4 reviews generalized approaches for identifying opportunities to reduce hazardous material/waste in system/product maintenance, facility construction and maintenance, solid waste management, and other processes. The review addresses the necessity for management commitment, goal setting, and the appropriate organization of a task force for adequately addressing defined pollution prevention objectives. Block 4 also includes an interactive field exercise, Dining Hall Assessment, which allows students to apply the knowledge and skills gained in the Block. The Dining Hall Assessment is designed for students to gain hands-on experience performing opportunity assessment in a DoD environment. The assessment teams will present their findings from the field exercise to the class followed by instructor feedback.

2.0 Objective

To review generalized approaches for identifying opportunities to reduce hazardous material/waste in system/product maintenance, facility construction and maintenance, solid waste management, and other processes. The review addresses the necessity for management commitment, goal setting, and the appropriate organization of a task force for adequately addressing defined pollution prevention objectives.

1. Students will understand what is involved in an opportunity assessment and learn how to apply approaches for reducing hazardous material/waste.

2. Students will learn opportunities for reduction of hazardous materials/wastes.

3. Students will learn the basic concepts embedded in an opportunity assessment.

4. Students will know the steps of the assessment process and learn how to apply them to typical DoD activities.

5. Students will learn how to organize a task force to address defined pollution prevention objectives.

6. Students will be taught methods of "selling the opportunity".

3.0 Key Concepts

I. TOTAL QUALITY ENVIRONMENTAL MANAGEMENT

Any program, particularly one to be conducted on such a large scale as pollution prevention requires solid planning and organization. Environmental managers have adapted Total Quality Management principles to a variety of environmental management activities and issues. The resulting programs, which have been generally referred to under the title of "Total Quality Environmental Management (TQEM)", cover a variety of approaches and issues, including:

A. Support of pollution prevention programs from the top officers:

> Pollution prevention frequently requires capital investment, which implies that the managers need to be willing to commit upfront financial resources.
>
> Often, these programs either completely change or modify existing procedures. If the base commanders are unwilling to change, then the implementation of these programs is difficult to achieve.

B. However, procedural and behavioral changes also requires support and willingness from all base personnel. The majority of the waste is not generated directly by the top brass, but by the lower ranks. It is useful to increase awareness of the benefits of pollution prevention through educational activities and to encourage the involvement of everyone at the site.

C. Establish pollution program work group to oversee the entire process, beginning with the selection of site assessment teams and the establishment of goals.

D. Select Site Assessment Teams--part of the overall pollution prevention program group, but set up to focus on specific areas of concern. An AFB contains a multitude of waste streams. It is difficult for a single, small group to examine every waste stream in the detail necessary to develop the optimum approach. Divide the base into subunits characterized by similar location and purposes and distribute these subunits between the Site Assessment Teams.

Involve people who work directly with processes and materials of concern. They are the ones most familiar with the practices and where and how changes can effectively be made.

Involve members from each organizational command on the base. Waste streams do not necessarily adhere to organizational boundaries. For example, the material may originate in one unit, such as maintenance, proceed through another unit, perhaps air operations, before being discharged under the jurisdiction of a third unit, such as support.

Include people with a wide variety of backgrounds to gain different perspectives and approaches to problem solving. This problem requires a creative approach!

E. Set goals - elimination or reduction of waste generation rates and hazardous materials use; decreased overall contamination of the environmental media (air, water and soil). These goals will provide the Site Assessment Teams, and the base overall, with a destination towards which to strive.

Goals may be either qualitative or quantitative.

"It is better to establish measurable, quantifiable goals, since qualitative goals can be interpreted ambiguously. Quantifiable goals establish a clear guide as to the degree of success expected of the program." (EPA/625/7-88/003, p.7)

Flexibility - review the goals as the program evolves in order to ensure that the objectives are consistent with the current situation.

F. Identify the Potential Barriers. There are a variety of obstacles which can impede the implementation of pollution prevention measures. Early identification of these barriers can expedite the resolution process, facilitating a smooth and more efficient attainment of the pollution prevention goals. Examples of the barriers include:

Attitudes: resistance to change; fear that product quality may be reduced. For effective pollution prevention, it is necessary to encourage people to adopt a "cradle-to-grave" thought process. When an item is tossed into the dumpster, where does it go? How was the material produced - did its production create hazardous waste? Such a thought process takes time to develop.

Inability of current infrastructure to assimilate the process changes: space requirements of new equipment; increased loading on the wastewater treatment plant. For example, when an aqueous degreasing method replaces solvents, the flow of greaseladen water to the wastewater treatment plant is increased. Since grease interferes with treatment processes, it must be removed in a pretreatment unit. Does the current wastewater treatment facility have the capability to pretreat this new waste stream?

Existing stocks of hazardous materials or binding contracts.

Enhanced or altered quality control requirements.

Money

G. Comprehensive approach. Look at the entire site, do not segment it. Involvement of Air Force Materiel Command has the potential for furthering pollution prevention throughout other aspects of the Air Force.

Their production and supply practices affect air base waste generation. For example, paint is supplied through Air Force Materiel Command. If lead and chromium based paints are purchased, then a lead and chromium contaminated waste stream is created at the Air Force Base during paint removal.

Air base product requirements affect Air Force Materiel Commnd methods. The anti-corrosion requirements for airplanes affect the electroplating methods and materials employed by Air Force Materiel Command.

Where possible, involve the suppliers of the various materials. The Air Force can encourage their suppliers to adopt pollution prevention programs. Other "outsiders", such as consultants or trade organizations, can provide a different perspective and specialized expertise on the various processes.

H. Since a thorough, basewide site assessment requires much time, in order to expedite implementation of pollution prevention methods, some site assessment teams can concentrate on the major streams of concern while the rest of assessment proceeds more slowly. Choose either a worst first scenario or processes which require minimum modifications at low cost to receive the biggest bang for the buck (to use a cliche).

I. Program Longevity: Pollution prevention should not be implemented as a one-shot deal. As knowledge and technology develop, the current PP processes may be rendered obsolete, in terms of waste generation and product use. As time proceeds, the pollution prevention methods should be reviewed against new techniques to determine if further or new opportunities exist.

II. THE ENGINEERING CONCEPTS

A. Reduction

One of the simplest methods to achieve waste reduction is to reduce the amount of material being applied to or being used in the process.

For example, in the plating processes, when metal is transferred from the plating bath to the rinse tank, the plating solution drips onto the floor. The floor is then flushed with copious quantites of water. However, a drip pan can be placed between the tanks to reduce the need to flush the plating solution from the floor.

Another example is the choice of solvents. Methylene chloride, carbon tetrachloride and methyl ethyl ketone, to mention a few, are highly volatile. A significant fraction of the material is lost to volatilzation prior to its effective use. Replacement of highly volatile compounds with semivolatiles decreases the amount of material required due to reduced evaporation rates.

If maintenance is slack, materials may be wasted by leaks or spills, potentially resulting in soil contamination. One example is leaking underground storage tanks, which has been recognized as a national problem.

Simply put, reduced material use results in reduced waste generation. Reduced waste generation yields decreased treatment and disposal requirements.

B. Recirculation

The effluent waste stream from one process can become the influent stream for the same or another process. This technique can also be called recycling. Some treatment of the material is often required. For example, if a wastewater, such as a washwater, contains primarily low levels of suspended solids, it is possible to remove the solids in a filter and then pump the water to another process. Solvents can be captured and distilled to remove the impurities. This process can be applied to the use of solvents to clean small, sensitive parts.

Direct recirculation, or reuse (no intermediate treatment), is appropriate if there is a process which does not require water, air, solvent or some other material of a high purity or cleanliness. For example, the rinse water in electroplating can be directly reused. In nickel production, instead of discharging the rinse water to the drain after one use, the water can be pumped back to the acid rinse tank. The nickel that was dragged out of the process during the rinse is returned to the production stream. This process can reduce water consumption by as much as two-thirds and can improve the efficiency of the rinse process.

C. Segregation

Frequently, the individual waste streams will contain varying types of contaminants. For example, electroplating wastewaters will consist of primarily cadmium, cyanide, nickel and other inorganics. Effluents from degreasing operations will contain high amounts of petroleum hydrocarbons and solvents. For the following reasons, the segragation of various waste streams can provide a means for pollution prevention:

Different compounds are amenable to various treatment methods. For example, precipitation is one way of removing metals. The amount of chemicals required and the removal efficiencies depend on the concentration of the inorganics. If a concentrated stream is diluted by combining it with the rest of the site wastewater, chemical requirements, and thus sludge production, would increase while efficiency would decrease.

Often it is easier to remove compounds from a small, concentrated stream than from a large, dilute flow. This technique has the potential to use fewer chemicals and to produce less sludge. Sludge requires treatment and disposal.

Combinations of varied waste streams can allow mixing of chemicals which interfere with the treatment processes. For example, chlorine and sodium hydroxide can be used to convert cyanide into the significantly less toxic sodium cyanate. However, organic compounds impede the conversion. Organics react with free chlorine, increasing the amount of chlorine required for the reaction and yielding trihalomethanes. Trihalomethanes are potential carcinogens.

If the waste stream contains material which can be recycled, the material must be separated from the rest of the waste prior to processing for reuse. Separation techniques consume energy, potentially other materials, and are not completely efficient.

Illustration of Advantages of Stream Segregation:

When people throw away paper, glass and aluminum, they often do not put the waste in separate containers. When the waste is combined, it has little value. The only places the materials could go without separation is either an incinerator or a landfill. Once the waste is separated into its constituents, paper, glass and aluminum, the material can be sold to companies for recycling.

A typical separation process is depicted in Viewgraph 6. Each step of the process requires energy. If the materials had not been combined in the first place, this energy consumption would be eliminated. The process cannot achieve 100 percent efficient separation. Thus a fraction of the potentially recyclable material cannot be reclaimed and must be disposed of as waste. Of course, there is also a monetary cost associated with mechanical separation.

As the compound becomes more dilute and the waste stream becomes more varied, the difficulty of treatment is increased.

D. Disposal

Sometimes a waste effluent may be present in a semisolid state. Under these conditions, the material should not be removed by water and flushed to the sewer. Such a transfer to the wastewater system contaminates large quantities of clean water. The waste is also significantly diluted. Instead, the material can be directly placed in a package for transfer to either treatment or disposal units.

E. Substitution or Elimination

This category encompasses two related ideas: the use of benign or less hazardous chemicals in the same process; and replacement of the process with a different technology.

1. Substitution of relatively benign chemicals or chemicals which produce less sludge or waste volumes without altering the process can be readily implemented. The capital investment is typically low. The cost aspect can make substitution attractive as a means for quickly eliminating very hazardous chemicals while better, nontoxic techniques are being developed.

   For example, in some cases 1,1,1-trichloroethane replaced chloroform in cleaning and degreasing procedures. Although 1,1,1-trichloroethane depletes ozone, the induced depletion rate is less than that associated with the original solvent. Meanwhile, aqueous cleaning systems are being tested and installed.

2. Replacement of the original method by a technique which does not use hazardous materials, does not create a hazardous working environment, and does not generate hazardous waste is the optimum approach from the perspective of pollution prevention.

For example, degreasing can be performed with an aqueous system, where the impact and agitation can physically remove the hydrocarbons. Although this process may not be appropriate for sensitive machine parts, the majority of the solvents can be eliminated from use.

F. Points to Keep in Mind When Performing Assessment

1. Easier to reduce or eliminate waste at the beginning of the process than to treat or clean contaminated material.

2. Cross-contamination of waste streams will render treatment more difficult.

3. Dilution is not the solution to pollution. Dilution can make some treatment methods less efficient.

4. Do not simply switch the pollution from one media to another. For example, substituting air pollution for water pollution (which is what happens when airstripping is performed without air pollution controls). The goal is to reduce the overall pollution of the environment.

Transition: Now that we are in the pollution prevention frame of mind, it is time to determine where the opportunities for implementing the above concepts exist on bases.

III. Assessment

Before one can determine which processes and procedures are amenable to waste reduction strategies, it is necessary to know the types and quantities of materials used at the installation and how these materials are processed and discharged at the base. Ideally, the entire site would be characterized by a complete materials and flow diagram prior to option generation and alternative screening. However, given the time required to obtain the necessary data and the need to expedite the implementation of pollution prevention technologies, it may be preferable to address the major pollutants, determined by toxicity and/or volume, before the entire base is characterized.

A preliminary qualitative assessment can be performed in order to identify the areas of either greatest need or greatest potential. When it is necessary to prioritize capital expenditures, one should focus on either reducing the most hazardous waste streams, due to either volume or contents, or implementing the simplest, least costly methods first.

Assessment Components:

A. Identify the various processes which occur on the site. Processes include components as diverse as laundry facilities, food preparation, airplane degreasing, fuel storage, etc. The ones which should be focused on quickly include, but are not limited to: paint removal, painting, degreasing, and coolant systems which use ozone depleters. The EPA's list of 17 Target Chemicals can be used as a tool for prioritizing the initial assessment.

B. Identify the influent and effluent streams (air, water, other materials, products, waste, etc.) which are associated with each process.

1. With each process, one should identify if there are any influent requirements in terms of water quality, air quality, solvent quality, etc., or product requirements, such as no damage to metal structure of planes, etc.

2. The above quality control requirements can influence the applicability or technical feasibility of various pollution prevention methods.

C. Quantify and characterize the above influents and effluents.

1. To obtain all the data it may be necessary: to walk around the installation and note where tanks, pipes, drains, vents, etc., are located and which ones leak; install flowmeters; check inventories and other operation logs; survey the process managers and operators concerning standard operating procedures; perform dye studies to determine where various pipes lead; conduct effluent and influent sampling and analysis; and observe the processes in action, noting quantities and types of materials used and spilled. This list does not encompass all of the possible data collection methods.

2. If little data are available, it might be prudent to proceed through a preliminary opportunity screening before detailed characterizations are performed. Analytical methods are expensive and timeconsuming. Once one has identified the exact processes to be initially targeted, the specific data that are needed and the analytes for which to test, the sampling and analysis can be performed in a less costly, more effective manner. Initial planning allows the data collection to be performed efficiently.

D. From the information, develop a flow and material balance diagram. All flows (volumes and concentrations of constituents, influent and effluent) associated with each process are depicted on the diagram.

1. This diagram demonstrates where the various influents and effluents are located, whence they came, where sent, and at what points various streams are combined.
2. The diagram allows one to identify where possible stream recirculation or separation should be located, where volumes could be reduced, where hazardous substances amenable to substitution are used, etc.

3. This diagram is the heart of the assessment process. Obtaining the data will identify the areas which require improved inventory and recordkeeping in order to demonstrate what is actually occurring onsite.

4. Analyzing the data will promote the use engineering concepts of pollution prevention in an optimum manner.

5. All environmental media affected by normal operations (water, air, and soil) are included, ensuring that the remedies do not merely substitute contamination of one media for another.

6. Before one can change processes to make more efficient use of resources, it is necessary to know of what the current use consists. The flow and materials balance diagram fulfills that need.

E. Based on the flow and materials balance diagram, generate options for the various techniques of reduction, recirculation, segregation, disposal, and substitution.

1. Option generation is the creative part of pollution prevention. An initial brainstorming session by the site assessment team generates possibilities for evaluation.

2. A preliminary screening and evaluation of the ideas will narrow the alternatives to the most promising ones. The evaluation process should consider whether the options will eliminate or significantly reduce the amount of hazardous materials consumed and the quantity of hazardous waste generated. The simplest method of pollution prevention is to not cause the pollution in the first place.

3. After the preliminary screening, the options are evaluated on the basis of more stringent requirements, such as availability and reliability of techniques, process or product requirements, and generation of secondary waste streams.

F. Perform feasibility analyses: technical, environmental, and cost. The analyses will be discussed in more detail shortly.

G. Obtain approval and funding. Since there might not be enough capital funding to allow implementation of every finalized option, it could be necessary to prioritize the projects. The following considerations should influence the prioritization process:

Complexity of the process change. Simple behavioral change, such as placing glass or paper in a recycling bin, versus addition of new piping and pumps to recirculate fluids?

Generation of secondary waste streams that would require treatment beyond the capacity of the existing system?

Worker health and safety improvements or hazard reduction?

Degree of pollution prevention in terms of waste volumes and material use?

Cost and payback?

H. Implement plan.

IV. FEASIBILITY ANALYSES

A. Screening - preliminary phase

Since indepth analyses require much time and money, the preliminary evaluation should use existing information to remove from further consideration those ideas which seem to be the least appropriate. Those alternatives which are readily identified as impractical for the current technology, difficult to implement and inferior in terms of waste reduction potential should be eliminated in this step. The questions asked during this screening can include:

What are the main benefits?

Does the technology exist? Has it proven to be reliable?

Cost effective?

Ease and time of implementation?

Probabilty of success? Innovative technology should not be neglected due to lack of process knowledge. As a government agency, the Air Force has greater opportunities than private industry to encourage the use of, and reap the benefits from, innovative technologies.

After the initial screening, the indepth evaluations for option selection will be performed. This step constitutes a preliminary design phase.

B. Technical Feasibility of Screened Alternatives

This evaluation process constitutes the next step in the option selection phase. The following questions are among those areas which should be considered:

1. Is the alternative compatible with the process requirements?

If the current procedure is to be replaced with a new technique, one should determine the characteristics of the product which cannot be adversely affected by the method. For example, depainting methods which use physical impact or abrasion can damage sensitive airplane parts.

If the alternative is to reduce input materials, substitute materials or recirculate waste streams, then one should identify what influent characteristics are necessary to maintain the quality of the endproduct. For example, before recirculating metalplating rinse water, one must ensure that the recycled fluid will not contain materials which will interfere with the plating.

Will the process rate be reduced to unacceptable levels?

It is possible to modify or replace the old techniques with pollution prevention measures and maintain, or potentially improve, the level of quality.

2. Availability of other chemicals/processes which are less toxic? Are the new chemicals difficult to obtain? Is the new equipment easy to maintain, or will replacement parts be difficult to find?

3. The status of promising innovative technologies? Any pilot scale studies which have proven successful?

4. Worker safety and health considerations - will the alternative improve those conditions?

5. Is specially trained labor necessary for effective operation, or can anyone work the process? If specialized skills are required, what is the availability of the appropriate training or work force?

6. Ease of implementation:

Is much installation and startup time required?

Will the implementation be obstructed by the barriers mentioned earlier?

The degree of renovations required to install? If a physical cleaning method is to replace solvent use, how much equipment needs to be removed and installed? Will a wastewater stream be produced that would require new piping and pumps for discharge to the wastewater treatment facility?

The degree of attitude change necessary for effective use of the technique? For example, the effectiveness of paper and aluminum recycling depends on people's willingness to place the waste in the appropriate containers.

C. Environmental Feasibility

The environmental effects of the proposed alternatives must be analyzed in order to ensure that the new method is less damaging to the environment. Some methods generate secondary waste streams that require further treatment and disposal. For this analysis, a "cradle-to-grave" attitude should be adopted.

1. Will the proposed change result in the contamination of other materials and environmental media which would require further treatment?

For example, ion exchange is used to remove metals from water and concentrate them on a resin. During regeneration, the metals are transferred from the resin into a concentrated stream, from which they can be recovered for reuse. The regenerant is very briny. The entire process creates secondary waste streams which must be treated.

2. Will the new method increase demands on water supplies? Water treatment generates sludges which require treatment and disposal and consumes energy.

3. Will the proposed change cause energy demands to increase? Power plants are major sources of pollution.

4. If secondary waste streams are produced, are there methods which minimize the production of sludge or the use of treatment chemicals, such as activated carbon?

5. It is necessary to consider not only the direct, short-term results, but also the indirect (frequently offsite), long-term, less apparent effects. For example, how much hazardous and nonhazardous waste does the manufacturing process generate? Can the AFB waste become an raw material for private industry? Both adverse and beneficial affects of all possible methods should be compared.

D. Economic Feasibility

1. Cost analysis - inclusion of direct and indirect; capital, operation and maintenance costs. Examples of the various cost factors include:

Materials (piping, pumps, equipment, recycling bins)

Sitework (removal of old equipment)

Installation

Water, electricity, labor (hours to collect waste from recycling bins and transfer to a central storage facility) and materials for operation

Treatment and disposal of secondary waste streams

2. Benefits Analysis - direct and indirect benefits should be considered. Since some pollution prevention measures require some capital investment, the benefits become more apparent over the long-term. Some of the benefits may be difficult to define with a monetary amount. Examples of benefits include:

Reduced volume of material sent to landfill. The fees of landfilling waste is increasing. Less land area removed from recreational, residential, commercial and agricultural use.

Less hazards experienced by Air Force personnel - reduced medical costs in the long-term.

Reduced input material requirements.

Reduced liability. Unremediated contamination of the environment is considered a crime by both the public and the law.

Improved public and Congressional perception.

3. A required payback time in order to find the funding?

4. Consideration of long-term societal costs caused by not adopting pollution prevention - what role should these external factors play? Some examples of long-term societal costs are:

Long-term, low level air pollution dispersed off base to public receptors.

Future costs of remediation, including current landfills. Current landfills are designed for a life of 50 years. Although they will likely last longer, what will happen to the landfills and their contents in the future?

Accelerated closure of current landfills and siting of new ones.

Increased use of incinerators resulting in increased air pollution, not necessarily the hazardous organics typically perceived by the public (they are usually destroyed or removed), but carbon monoxide and carbon dioxide production.

V. FUNDING AND APPROVAL

Once the optimum alternative, from technical, environmental and economic perspectives has been selected, it is necessary to obtain the funding. The results of the feasibility analyses will aid in this process. After all, the reasons why the option were preferred were because of the benefits which it presented. Although in the near future, there is a financial cost associated with pollution prevention, the benefits of implementation rapidly accrue:

Improved worker health and safety

Decreased treatment and disposal requirements

Reduced potential for environmental contamination

Decreased need for landfill (municipal and hazardous wastes) capacity.

Reduced liability

Improved public perception

VI. SUMMARY

The final step of this process is to implement the plan. However, a discussion of implementation is not within the scope of this lecture. There are a few main points to summarize:

Pollution prevention requires a commitment from all site personnel.

Often PP requires a change of attitude - thinking in terms of the consequences of one's everyday actions. For example, tossing oil filters into the recycle bin instead of the dumpster; using recycled paper and other materials.

Waste minimization ranges from using less water to clean the floor to installing small treatment/recycle units for segregated waste streams.

Much of opportunity assessment is common sense - a degree in rocket engineering or equivalent is not necessary. A creative and flexible approach is useful!

You will become more and more familiar with what actually goes on with the various base processes and what materials are used. And with that familiarity you will know what health hazards are posed by these materials and how much waste is generated and what happens to it.

Find out how materials and resources are used on your base and then assess what can be done to prevent pollution and to minimize waste production.

BLOCK 5: RECYCLING AND AFFIRMATIVE PROCUREMENT

1.0 Introduction

Block 5 presents information on recycling as a pollution prevention reduction strategy. Both "use and reuse" and "reclamation" of wastes or spent products that commonly exist in the DoD environment are addressed. In particular, emphasis is on purchasing recycled materials for commissaries and dining halls. Block 5 covers the entire acquisition system life cycle (concept exploration, demonstration and validation, development, production and deployment, and operations and support). Case studies are presented of successfully implemented opportunities.

2.0 Objective

To review recycling as a pollution prevention reduction strategy in detail, and address both "use and reuse" and "reclamation" of wastes or spent products that commonly exist in the DoD environment. This review will include affirmative procurement policies as included in the Base Comprehensive Plan. Emphasis will be on purchasing recycled materials for commissaries and dining halls. Instruction covers the entire acquisition system life cycle (concept exploration, demonstration and validation, development, production and deployment, and operations and support). Provides case studies showing opportunities that worked.

1. Students will understand the basic concepts of recycling, affirmative procurement, and become familiar with current procurement practices.

2. Students will know the benefits of affirmative procurement and the three levels of procurement.

3. Students will know the entire acquisition system life cycle and how it can integrate with affirmative procurement.

3.0 Key Concepts

I. RECYCLING

A. What is Recycling and How Does it Fit Into the Pollution Prevention Program?

Recycling is the recovering of a waste from one process and reusing it in the same process or in another process in an environmentally safe manner.

Recycling reduces waste, saves energy, reuses resources, and creates jobs. Commercial recycling is already prominent because of its cost effectiveness. Experience has shown that curbside collection of recyclables and the use of curbside boxes is necessary to divert substantial amounts of municipal waste. Newly emerging trends in curbside collection present increasing opportunities for people within a community.

Recycling is a reduction strategy. However, it differs from source reduction. Recycling involves the use, reuse, and reclamation of materials, whereas source reduction consists of product, material, and technology changes and good operating practices, as displayed in Viewgraph 2.
Pollution prevention encompasses recycling as one of its environmental management techniques. The EPA's definition of pollution prevention makes it clear that recycling is the second priority within a management hierarchy that includes:

prevention
recycling
treatment
disposal or release

Under Section 6602(b) of the Pollution Prevention Act of 1990, Congress established a national policy that:

pollution should be prevented or reduced at the source whenever feasible;

pollution that cannot be prevented or recycled should be treated in an environmentally safe manner whenever feasible; and
disposal or other releases into the environment should be employed only as a last resort and should be conducted in an environmentally safe manner.

The recycling of solid and hazardous waste is important when trying to divert waste out of the waste stream. Prior to developing a recycling program it is important to understand the types of wastes and the market value for each constituent part of the waste stream. Implementing an effective and efficient recycling program is not only a matter of economics, ecology, and education, but also involves a fundamental change in behavior (society and individual) habits and attitude. Public education and promotion are essential. This public education effort and strive for behavioral change must be a continuing commitment.

II. RECYCLING MUNICIPAL SOLID WASTE

A. Introduction

Making an effort to reduce the volume and toxicity of ones waste is a legal requirement at the federal and most state levels. Generators of solid and hazardous waste must make every effort to minimize the amount of waste generated, and must select the best waste management practices that are economically feasible. Recycling, which involves the re-use of waste materials, is a very effective waste minimization technique that (1) reduces the risk to human health and the environment, and (2) is very beneficial to the generator of the waste material. The re-usable output stream is not considered hazardous, and the cost of virgin raw materials is reduced in proportion to the amount of material recovered.

Recycling of common solid wastes is an easy way to reduce the amount of waste that would otherwise be disposed of in landfills. This helps to increase the life of existing landfills as well as reduce the consumption of finite natural resources. In addition, recycling conserves energy during the reprocessing of recycled materials, which in turn helps reduce air and water pollution. Some recycling costs may be recovered through the sale of recyclable materials. A partial list of recyclable items is presented in Viewgraph 4.

B. Non-Market Based Recycling Programs

Recycling is a fundamental part of an integrated solid waste management program. While recycling alone cannot solve the solid waste disposal problem, it does divert a significant portion of the waste stream from disposal.

Since recycling saves landfill space, energy, and natural resources; provides useful products; and reduces long-term liability, many states and local communities are implementing recycling programs based on criteria other than immediate savings. In non-market based recycling programs, expenses may exceed revenues. Therefore, appropriated Operation and Maintenance funding may be required to operate the program, and funding must be programmed through the Base Civil Operation and Maintenance Engineer. Non-market based programs may be implemented where:

1. State or local law requires recycling. Such laws often require recycling a minimum fixed percentage of the Municipal Solid Waste stream. Market conditions may prohibit doing this profitably.

2. The cost of recycling is less than the cost of landfilling, but recycling expenses exceed revenues. This may occur in areas with high tipping fees.

3. A superior directs a non-market based program due to local environmental, legal, or other reasons.

C. Types of Recycling Programs

Recyclable materials can be collected through one of several types of recycling programs. The most effective way to recycle is to separate materials from other wastes prior to disposal source separation. Source separation ensures that materials such as paper, glass, and aluminum will be of the purest and highest quality possible to increase their value for remanufacture into new products. The separated materials can then be taken to either drop-off or buy-back locations. An advantage of the buy-back center is that they offer cash payments for materials brought by residents or businesses. Many buy-back centers are operated by local wastepaper, scrap, or multiple-materials recycling businesses. Aluminum companies also operate buy-back programs for aluminum cans.

Entities with large quantities of recyclable materials may find companies that provide technical assistance in setting up recycling programs, containers (and other equipment), and pick-up services. Some recycling businesses have regular routes to collect glass bottles and aluminum cans from restaurants and bars, or corrugated cardboard from retail, office, and industrial businesses. Others can help offices set up paper recycling programs for employees and will make regular pickups of the accumulated paper.

Recycling of household and office waste can be made easy for residents by using curbside collection along with the installation of an intermediate processing site called a Materials Recovery Facility (MRF). The MRF accepts, separates, and performs intermediate processing of base mixed waste, usually bottles and cans, relieving base personnel of this responsibility. MRF personnel separate out newspapers, place all recyclable cans and bottles, including plastic bottles, in one container for pickup, and dispose of all other trash. MRFs usually are built to handle recyclables from large scale curbside collection programs and are often regional facilities.

D. Recyclable Materials

1. Paper

Paper, in the form of newspaper, corrugated, and high grade office paper, represents the bulk of waste from households and businesses, and is a steady component of installation waste streams. Much of it can easily be recovered through source separation. The benefits of recycling paper include conservation of trees and valuable landfill space, and energy savings realized through use of recycled fiber rather than virgin fiber in manufacturing new paper products.

Newspaper is the easiest paper to recycle and is typically the largest portion of recyclable material in households. Most old newspapers can be collected and sold to de-inking newsprint mills and remade into newspaper. Newsprint can also be made into products such as packing materials, insulation, and roofing materials. An increasing percentage of recycled newsprint is exported for remanufacture into newspaper or other products.

Corrugated cardboard boxes also account for a major portion of recycled paper; typically, it is baled and shipped to mills where it is made into new corrugated boxes or paperboard for cardboard boxes.

High grade office paper may be one of several grades or types. To be recycled at a high grade, it must be free from contaminants such as tape, metal objects, gummed labels, plastic, string, and carbon paper. Computer paper, tab cards, stationery bond, and miscellaneous plain paper are among the types of recyclable high grade paper. Magazines and slick advertising from newspapers are difficult to recycle and market demand is low because of the high clay content which gives them their shiny appearance.

Many offices have recycling programs where employees collect white paper at their desks and take it to a central storage point in the office. From there it is taken to a storage area and is picked up by a waste paper dealer or recycling business when a sufficient quantity accumulates.

The price paid by buyers of waste paper depends on the demand for products made out of recycled paper, the type or grade of paper (e.g., corrugated and newspaper are lower grades than white office paper), and the quality of paper (amount of contamination). Paper grades are established by the Paper Stock Institute of America, a division of the Institute of Scrap Recycling Industries.

2. Glass

Recyclable glass consists mainly of clear (flint), brown (amber), and green glass containers. About 2.5 billion pounds of glass containers are collected annually. The glass is crushed into cullet (crushed glass) and purchased by glass container manufacturers, who make it into new bottles and jars. Every pound of cullet used saves approximately the same amount of raw materials used to make glass, namely sand, soda ash, and limestone.

Cullet prices are generally highest for clear glass, and lowest for mixed colored glass. Prices paid by glass companies for large quantities of crushed cullet fluctuate depending on demand and freedom from contamination. Demand for cullet sometimes depends on what color glass a company produces (e.g., a company may only make brown beer bottles so it does not need to buy green glass).

3. Aluminum

Aluminum is one of the most important materials collected in recycling programs because the demand and high prices paid by aluminum manufacturers make it profitable for groups and recycling businesses. Aluminum is easily remelted and remolded into new products. It requires 95 percent less energy to process aluminum metal from scrap than to produce it from raw resources. Recycling eliminates all of the energy required for major steps in aluminum production, from the mining of the bauxite ore through the reduction process.

Aluminum beer and soda cans have become the largest source of aluminum scrap used by the aluminum industry. Aluminum manufacturing plants purchase large quantities of aluminum cans from recycling businesses and programs.

Other all-aluminum items such as TV dinner and foil pie plates, foil food wrap, aluminum siding, storm doors, windows, and lawn furniture also can be recycled. These items are recycled separately from aluminum cans because of their different aluminum composition.

4. Tin and Bi-Metal Cans

Cans made of tin-coated steel (food cans) and bi-metal cans (which are tin-coated steel with an aluminum end, usually a beverage can) are recyclable. Tin-coated and bi-metal cans can be used directly as steel scrap in steel manufacturing furnaces. The material must be baled and delivered in truckload quantities. Only a small percentage of bi-metal cans can be used in steel furnaces because of the aluminum content of the cans.

5. Scrap Metal

Ferrous metal items (other than cans) which are made of cast iron and steel sheet metal, and nonferrous metal items made of nickel, bronze, copper, brass, and lead can be recycled. Most ferrous and nonferrous metal is collected by scrap metal dealers from industrial businesses. There are a number of small businesses, however, which collect much metal scrap from non-industrial sources. The price paid by scrap dealers depends on the market price for the various types of metal and their priority of scrap.

6. Plastics

Plastics recycling generally fits into three main categories:

Polyethylene which can consist of:

HDPE (high-density polyethylene).
PET (polyethylene terepthalate).
LDPE (low-density polyethylene).

Polyethylene plastics are obtained from many sources including milk jugs, plastic oil bottles, laundry detergent containers, soft drink bottles, and plastic bags.

Mixed plastics Consists of items made from various combinations of HDPE, PET, LDPE, PVC, polystyrene, and polypropylene. They may be recycled to produce a variety of products such as cable reels, paving blocks, flower pots, drain pipes, and fencing.
Polyvinyl chloride (PVC) Used primarily for piping and is not a major component of plastic recycling.

Collected PET and HDPE are generally sold in baled form, but can also be chopped into small flakes or granules, or pelletized (most closely approximating the component resins). The primary consumers of old plastic beverage containers are plastic fiber manufacturers. PET scrap is successfully being employed in the manufacture of fiber fill for jackets, pillows, and sleeping bags, as an interliner in upholstery, as a fiber in carpet construction, and as filler media. Additional end uses include the manufacture of industrial strapping, wall tile, flooring, and tail light lenses. HDPE plastic can be used to make lumber boards for boat piers and garden furniture, flower pots, toys, trash cans, and plastic containers for sorting recyclable materials at home.

The use of these types of plastics is quite common. Learning to identify when this material is ready for replacement, how it can be segregated as waste, and what to do with it involves dealing with scheduling, procurement, contractors, and administration.

7. Used Oil

The recycling and reuse of used oil is a waste minimization effort widely used throughout. Recycling of used oil from the crankcases of cars, motorcycles, boats, and lawnmowers keeps the oil out of waterways and saves energy over the use of virgin oil. Oil can be turned in at all auto-hobby shops and base services stations for recycling. Most collected used oil is cleaned and recycled into industrial fuel oil.

Waste oil is not considered a hazardous waste under federal regulations if it is recycled. Waste oil contaminated by other hazardous wastes (such as solvents) cannot be recycled, and disposing of such oil is very expensive. Precautions should be taken to properly segregate waste oil from other materials to prevent it from becoming contaminated.

Under some states' regulations, used oil is regulated as a hazardous waste. Air Force installations that are located in these states are required to comply with state guidelines concerning the management of hazardous waste (i.e., hazard determination, manifesting, labeling, recordkeeping) when handling waste oil.

8. Household Yard Wastes

Leaves, grass, clippings, prunings, wood waste, and other vegetative debris can exceed 20 percent of municipal solid waste in many urban areas, especially during the autumn leaf season. Volume varies by geographic location, but the cumulative volume represents a significant single waste source.

Leaves and other yard clippings can best be recycled by composting. Compost provides excellent soil conditioner and mulch, and adds important nutrients to soil. Compost can be sold to landscape contractors and nurseries as a soil conditioner. A list of such establishments may exist or be developed for the communities around a base. This provides a good public relations opportunity.

9. White Goods

The term "white goods" refers to bulky items such as large electrical appliances (e.g., refrigerators, stoves) and metal furnishings which are occasionally discarded by homes and businesses. These items are usually recyclable as low grade scrap metal. The collection of white goods for recycling typically occurs at waste disposal facilities, such as landfills, rather than at community recycling centers.

White goods contain increasing amounts of plastics and other non-metal parts which has lessened the demand for white goods as a source of metal scrap. Some scrap processors no longer accept white goods on a regular basis or have become more cautious about which items they will accept because of potential problems with hazardous materials in certain items. For example, some refrigerators made before 1979 might have polychlorinated biphenyls (PCBs) in their electrical components. Some scrap processors will only accept such appliances if the electrical components have been stripped out, or will accept them but will not pay for them.

10. Tires

Tires can be recycled in many ways. They can be:

- Retread.
- Split and die punched to make assorted products such as gaskets, bumpers, and mats.
- Ground into a fine crumb rubber for use in tire manufacturing (limited use), molded products, paved sports surfaces, roofing materials, and asphalt road paving materials.

Shredded or cut into small chips for use as a fuel, usually for co-burning with wood waste, coal, or solid waste.
Thermal processed (pyrolysis) to recover oils, gas, carbon, and other products.
Burned whole as a fuel to produce steam and electricity.
Used for miscellaneous projects such as flower pots and fishing reefs.

Considerable sources and amounts of tires end up as bulk waste every year.

11. Clothing, Furniture, and Other Reusable Items

In addition to organizations involved in recycling materials for processing into new manufactured goods, there are organizations that specialize in collecting particular items for direct reuse, sometimes after repairing them. These include charitable organizations such as the Salvation Army, AmVets, and Goodwill, as well as commercial organizations such as used clothing and furniture stores, and local flea markets. Thrift and consignment shops and used book and furniture dealers are usually identified in telephone directory yellow pages. Used books and records can sometimes be donated to libraries, schools, day care centers, senior citizen centers, and other charitable organizations, depending on organization needs.

Some communities have developed special programs for using surplus (usually not used) materials. Lumber, plumbing fixtures, doors, windows, and other materials which have been donated are distributed to non-profit organizations. Instead of being discarded, these miscellaneous items may be reused or may benefit local communities, hospitals, schools, and churches.

Create a list of recycle/re-use possibilities and conduct a public outreach campaign. It will serve as positive public relations and provide additional information and potential business to your solid waste management program, and will also help focus other components of the Pollution Prevention Program (PPP) at the same time.

E. Guidelines for Preparation of Recyclable Materials

Recycling centers and curbside collection systems generally require some minor preparation of materials before acceptance for recycling. This preparation is necessary to meet buyer specifications or the specifications of manufacturers who will make new products out of the recycled materials. Basic preparation may involve separation of different types of materials and removal of contaminants such as food wastes. General guidelines for each material are listed below.

1. Paper Products

a. Newspaper

Tie with twine in a bundle about 1 foot high or put in brown grocery bags (check with collection center to see if they accept bagged newspapers).

b. Corrugated Cardboard Boxes

Flatten, remove tape and bundle.
Do not include plastic coated corrugated.
Brown grocery bags and brown wrapping paper are sometimes accepted. If they are, keep separate from corrugated.

c. High Grade Office Paper

White typing, bond, and photography paper, tablet paper, computer printout, and tabulating cards can be recycled.
Ask collection center about specific instructions and types of paper accepted.
Do not include colored paper, carbon paper, tape, gummed labels, window envelopes, plastic coated paper, cardboard, or magazines.
Remove large staples and paper clips.

d. Magazines, Telephone Books, Miscellaneous Paper

Bundle separately from newspapers or office paper.

Do not include carbon paper.
Ask collection center for specific instructions and types of paper accepted.

2. Cans

a. Aluminum Cans

These are usually cans without side seams, which often say 100 percent aluminum.
Cans should be reasonably clean (no dirt or food residue).

b. Bi-Metal Cans

These are usually beverage cans with steel seamed sides and one or two aluminum ends.
Bi-metal cans must be kept separate from aluminum cans.
Markets are limited, so check with the recycling center to see if they are accepted.
To determine metal type, test with magnet. Magnets will not stick to aluminum.
Remove the ends.
Flatten.

c. Tin (Steel) Cans

Rinse to remove food residue. This is very important, because excessive contamination interferes with the recycling process.
Remove paper label, if possible.
Storage is easier if ends of can are removed and flattened.

3. Glass Bottles and Jars

Rinse to remove food residue.
Paper labels may be left on.
Remove metal caps and lids.
Some collection centers require removal of metal neck rings on glass beverage containers. Checkwith your collection center to be sure what their requirements are.
Leave glass containers intact and separate by color. some collection centers will accept mixed brown and green glass.
Do not include milk-white glass, plate glass, dinnerware, and light bulbs.

4. Scrap Metal

a. Aluminum Scrap

Rinse foil food wrap, TV dinner trays, and aluminum pie pans to remove food residue.
Call collection center for specific preparation instructions for aluminum siding, storm doors, windows, and lawn furniture.

b. Other Metal Scraps

Ask collection center for specific preparation instructions.
Do not mix ferrous (steel, cast-iron) and nonferrous (brass, copper, lead, aluminum) scrap.

5. Plastic Soft Drink and Milk Bottles

Very few collection centers accept plastic. Find a collection center before saving plastic bottles.
Remove metal rings and caps; rinse.
Flatten to use less storage space.
Separate PET (soft drink) and HDPE (milk) containers.

6. Used Oil

Drain oil into a non-breakable container with a tight-fitting cap, such as a sturdy plastic bottle.
Do not mix with gasoline, antifreeze, solvents, brake fluid, or refrigerator oil.
Do not put in garbage cans, pour down sewers or storm drains, or dump on the ground or in streams, rivers, or lakes.
Take oil to a local collection center such as a participating service station.

F. Materials Specifications

Recyclable materials recovered from solid waste must meet certain quality and purity specifications if they are to be utilized in current manufacturing processes. The condition of the materials plays a key role in setting the buyer's price.

G. Selling Recyclable Materials

A necessary component of recycling programs is finding buyers for recovered materials. Prices fluctuate so it is important to check prices prior to making an economic assessment of the feasibility of a source separation project. The cost of transporting recyclable materials to a market is often a major expense of the program.

Buyers may sell or loan equipment such as balers or crushers to recycling programs, but for some programs it may be more economical to receive a lower price for less prepared materials (e.g., whole bottles or aluminum cans) than to spend time and money to partially process materials (e.g., crush glass and compact cans).

H. Market Demand

A demand must exist for recyclable materials before they can be reused in other products. Demand for recyclable materials is influenced by the availability of substitute materials, industry's overall ability to use those materials, the state of the economy, and energy costs. Affirmative procurement, which is discussed later, plays a major role in increasing the demand for recycled products.

I. Recycling Options for Hazardous Waste

Recycling options can be listed in the following order of preferability:

1. Direct reuse on-site
2. Additional recovery on-site
3. Recovery off-site
4. Sale for reuse off-site
5. Energy recovery

Recycling options following a recycling process are provided in Viewgraph 16.

J. Reuse

Reuse involves finding a beneficial purpose for a recovered waste in a different process. Three factors to consider when determining the potential for reuse are:

1. The chemical composition of the waste and its effect on the reuse process.
2. Whether the economic value of the reused waste justifies modifying a process in order to accommodate it.
3. The extent of availability and consistency of the waste to be reused.

K. Additional On-Site Recovery

Recycling alternatives can be accomplished either on-site or off-site and may depend on a company's staffing or economic constraints. On-site recycling alternatives directly result in less waste leaving a facility and an associated reduction in the reporting and manifesting for that waste. The disadvantages of on-site recycling lie in the capital outlay for recycling equipment, the need for operator training, and additional operating costs. In some cases, the amount of waste generated does not warrant the costs for installation of in-plant recycling systems. In general, however, since on-site alternatives do not involve transportation of waste materials and the incurred liability therein, they are preferred over off-site alternatives.

L. Recovery Off-Site

If an insufficient amount of waste is generated on-site to make an in-plant recovery system cost-effective, or if the recovered material cannot be reused on-site, off-site recovery is preferable.

Some materials commonly reprocessed off-site are oils, solvents, electroplating sludges and process baths, scrap metal, and lead-acid batteries. The cost of off-site recycling is dependent upon the purity of the waste and the market for the recovered material.

M. Sale for Reuse Off-Site

As an alternative to both on-site and off-site recycling, the generator may transfer waste to another facility for use as a raw material in its manufacturing operations. Facilities receiving the waste either use it as is or subject it to a minimal amount of pretreatment. Supply and demand is the key criterion for the success of waste transfer, but there needs to be a method for marketing the waste by determining the existence of a facility capable of utilizing the waste. This need has purportedly been fulfilled by waste exchanges, which serve as brokers of wastes or clearinghouses for information on the availability of wastes. Waste exchanges can be either privately owned or government-funded organizations that facilitate waste transfer by identifying potential users. This exchange often proves to be economically advantageous to both firms involved, since the generator experiences a reduction in waste disposal costs and the purchasing firm experiences a reduction in raw material costs. However, liability concerns remain with this option.

N. Energy Recovery

Recycling can also be achieved in the recovery of energy through the use of waste as a fuel supplement or fuel substitute. Waste may be processed in fossil-fuel-fired plants or in incinerators equipped with an energy recovery system. Note that processes with overall energy efficiencies of less than 60 percent are generally regarded strictly as an incineration and not energy recovery. Usually, a variety of high-Btu wastes with different compositions are blended to produce a fuel with a certain specification. (Theodore, 1992)

III. PLANNING FOR RECYCLING

Dozens of different recycling options are available, and recycling program development will require strategic planning. When properly implemented, a recycling program can become a popular waste management activity among participants. The following are some strategic ideas on how to enhance a recycling program.

- Assess the waste stream of the installation
- Augment existing programs
- Set realistic goals and objectives
- Periodically evaluate the program

A. Access the Local Waste Stream

Planning any waste management program requires a knowledge of the local waste stream. This is true of recycling. Choosing which materials to recycle and designing the logistics of the program are important parts of the planning process that require local waste stream information. Waste stream assessments in support of recycling programs can be targeted by analyzing post-consumer materials markets to determine which materials have potential outlets.

B. Augment Existing Programs

Many recycling programs have been operated for years by private entities such as manufacturing facilities, waste haulers, scrap dealers, transfer station operators, and landfill operators. In most cases, these groups recognized the revenues that could be generated by selling secondary materials. Other programs are run by local volunteer organizations as a community service and to raise funds. These programs are important planning considerations; the community's recycling program should augment the success that has been attained by these other groups.

C. Set Realistic Goals and Objectives

Part of the planning process involves setting goals and objectives. For example, after evaluating remaining landfill capacity and performing a preliminary assessment of the local waste stream, decisionmakers may find it helpful to set long-term goals for the community. For example, a community may set a goal of recycling 30 percent of the residential waste stream within the next five years. Specific planning objectives in support of this goals will also be helpful. Planning objectives may include determining which waste stream components should be part of the program (based on market analysis and the make up of the local waste stream), investigating the feasibility of a comprehensive curbside collection program, developing a pilot-scale curbside program, investigating public outreach avenues, etc. When a plan is decided and a program is being implemented, new, more specific objectives should be set. An example could be working towards 90 percent participation.

Decisionsmakers should be as realistic as possible when setting goals and objectives. Recycling is not a "miracle solution" any more than waste-to-energy or landfilling. The community will benefit from carefully developed, achievable goals and objectives and an integrated approach to waste management.

D. Program Evaluation

Planning for recycling is never actually completed; it is an ongoing process. Because new programs and technologies are developing continuously, decisionmakers should experiment with and evaluate new options. Even the best recycling programs experiment with new techniques to improve on their current efforts.

The following program options have been shown to increase participation in recycling:

Mandatory participation
Curbside collection (rather than drop-off)
Provision of special containers
Collection of recyclables on the same day as regular trash pick-up
Comprehensive and integrated public education

E. Costs and Benefits of a Recycling Program

1. Costs

The costs of recycling programs vary greatly because the economics are specific for each local area and a wide variety of program structures are used.

Start up costs are one-time costs to initiate the program. These include:

Planning costs for activities such as market assessments, waste stream assessments, rerouting collection vehicles, planning any new facilities, and negotiating contracts;
Publicity costs to develop, print, and distribute information (this will also be an ongoing cost); and
Capital costs if additional collection and/or processing equipment is needed.

Operating costs are usually addressed in normal accounting procedures. These include:

Annual costs for labor;
Equipment operation and maintenance;
Fuel;
Supplies;
Debt service;
Administrative and overhead costs; and
Marketing costs.

2. Benefits

Economic analysis should also include potential revenues and benefits of recycling. The most obvious source of revenues if from the sale of recovered materials. These revenues are often less than the costs of operating the program.

Disposal cost savings, which are increasingly important, are equivalent to how much it would have cost to dispose of the recyclables at the local disposal facility. Disposal cost savings may be calculated by estimating the total tipping fee avoided through diverting waste from disposal. In some communities, the funds saved through avoided costs are returned to the specific recycling programs. These "refunds" are called cost-avoidance credits or diversion credits.

Recycling programs can also be a source of local economic stimulus, especially if there is growth in local business handling or processing collected materials.

F. Education, Behavior, and Participation

Implementing new waste management programs requires education of the public, especially for programs where citizen participation is needed. Education information for the public should answer the questions of "where?, when?, why?, and how?". The education program should be positive, and provide simple instructions on how to participate. Opportunities for communicating with and involving the public should be established early in the planning process. For example, if a neighborhood drop-off site for recyclables is going to be established, the decisionmaker should promote it to build citizen interest and support, even before it is in place. Communication with the public and promotion of the program should be ongoing. Media events, posters, newsletters, are all good tools to use in a continuing education program.

An effective education and promotion program should be planned with the community's needs in mind. But it is not necessary to "reinvent the wheel." A significant amount of time and energy can be saved by examining the public education activities that other communities have initiated -- borrowing from their successes and learning from their failures. Decisionmakers can review activities and educational materials used in other public awareness programs, such as seat belt safety campaigns. Techniques used in these campaigns to promote an idea or suggest a new behavior can be modified to express a municipal solid waste management theme.

The Ocean State Cleanup and Recycling (OSCAR) Program of the Rhode Island Department of Environmental Management offers the following suggestions from "The Handbook for Reduction and Recycling of Commercial Solid Waste" for source reduction at the office:

Encourage reuse of paper for scrap paper: for messages, calculations, etc.
Cut down on paper for memos: use computerized mail, central bulletin boards, routing slips.
Maintain central files instead of filing everything in multiple files.
Institute maintenance practices to prolong the life of copiers, computers, and other equipment.
Ask suppliers to send you products in less packaging, or order supplies in bulk.
Purchase reusable mugs and utensils to replace disposable ones.
Ask to be removed from junk mailing lists.
Use white paper instead of colored, white paper is a higher grade than colored ledger on the recycling market and sells for many times the price.

These suggestions for source reduction at the office will not only decrease the amount of waste which enters the waste stream, but also help change behavioral patterns of the populace at the work place. When people begin to participate in source reduction techniques and recycling programs awareness of the importance of these actions will increase.

Building a successful public participation program will be assisted by explaining to the public how the parts of the integrated plan were decided upon, who participated in the decisionmaking, and what was taken into consideration. Also, the public has a right and responsibility to understand the full costs and liabilities associated with management of the waste they generate. This information will help the public understand the importance of the municipal waste management issues, assist in gaining community support and help individuals take responsibility for the waste they generate.

Dr. Hodge made the following statement in a hearing before the Subcommittee on Natural Resources, Agriculture Research and Environment:

> "Education will play a key role in the success of any resource recovery and recycling initiative. The lessons we must learn waste reduction, resource recovery and recycling, are an intelligent blend of economy and ecology. Education is essential, but education alone cannot address the current crisis we face in waste management. Clearly, education plus a sound nation solid

> waste policy is what is desperately needed as we move into the 21st century... On the national level, we are looking to you to forge waste reduction, resources recovery and recycling laws and policies which protect the environment and promote the economy of ecology."

Dr. Hodge makes it clear that education is very important when developing a recycling program. Furthermore, to facilitate a successful program, it is necessary that policies and regulations are modified to encourage and motivate society to recycle. Although the United States is changing, the U.S. still exemplifies a "throw away society." This is evident by the growing cost of landfilling. Educational, behavioral, and participation as well as political changes will help to bring about a society interested in the environment and their role in reducing the waste they generate and recycling the waste that is generated.

IV. DEVELOPING A RECYCLING PROGRAM

Five important steps in developing a quality recycling program are as follows:

- Assign a recycling coordinator
- Design the most effective recycling system
- Identify all available services provided by recyclers
- Encourage employee participation in the recycling program
- Encourage user and visitor cooperation

A. Assign a Recycling Coordinator

A recycling coordinator is responsible for doing necessary research, designing the recycling program, implementing and managing the program, and acting as a liaison between management, employees, visitors, and recycling contractors.

B. Design the Most Effective Recycling System

Most recycling programs follow a four-part process. There are, of course, many possible variations of this basic approach:

- The facility recycling coordinator conducts a waste stream analysis to determine which wastes comprise the largest portion of the total waste stream. These wastes should take priority when establishing your facilities recycling program.
- Each person separates recyclables from trash. Use one container for non-recyclable trash and several containers for the recyclables.
- Maintenance personnel transport materials from recycling containers to centrally located recycling dumpsters. Materials are stored in a dry location until collected.
- A designated hauler empties the recycling dumpsters and hauls the materials to a recycling facility.

It is important to regularly monitor and evaluate the recycling system to gauge its successes and failures. You may need to occasionally change your program to accommodate the participants.

C. Identify All Available Services Provided by Recyclers

Reverse vending machines have been developed by the aluminum industry. Some recyclers have multi-bin trucks available to ensure material separation during collection. For further information, contact local recycling contractors and local and state governments

D. Encourage Employee Participation in the Recycling Program

Encouraging participation to increase the amount of recovered waste can be the greatest challenge to any recycling program. There are many ways to increase recovery and participation, including:

- Ensure that all employees understand the program. Schedule an education seminar for management, employees, and maintenance staff.
- Hang posters, send memos, and conduct meetings in the office that explain the program's operating procedures.
- Provide special containers for recycling and clearly mark and label them with recycling do's and don'ts.

The key to any pollution prevention effort is employee participation. Training and educational programs can inform employees about pollution prevention concepts. Public recognition, awards programs, and a suggestion box can also encourage participation.

E. Encourage User and Visitor Cooperation

In the case of parks and recreational facilities, concession stands, and other facilities used by the public, managers must tailor their source reduction and recycling programs to two different populations: facility employees and the visiting public, who may dispose of wastes at the facility.

As a manager, you need to be aware of the different strategies available to you in encouraging the public's cooperation. In many cases, recycling programs can be geared directly to facility visitors and users. Remember that it is often necessary to "sell" the program to the public. To encourage their participation:

Inform visitor about your recycling program and explain its importance in preserving the environment.
Develop and display eye-catching posters and other promotional material to stimulate interest in recycling.
Keep recycling collection stations clean. If the area appears dirty, visitors will not bring their recyclables.
Let visitors and users know that you appreciate their cooperation.

F. An Example of an Implemented Recycling Program

Washington State Launches Innovative Used Oil Programs

Washington recycled 21 percent more used oil in 1987 than in 1986. This success is attributed to increased public awareness along with flexible and innovative problem solving. Washington is implementing an awareness campaign to promote the proper recycling of used oil and is actively executing creative solutions to specific used oil disposal problems.

Washington State's awareness campaign, to encourage the recycling of do-it-yourselfers (DIY) used oil, is the result of the used Automotive Oil Recycling Act of 1983. This state law requires sellers of 100 gallons or more of oil per year to post signs on used oil recycling and to identify the nearest oil collection center.

The Department of Ecology (Ecology) began the campaign in the fall of 1987 and is planning to hold similar education campaigns every fall. Ecology developed and disseminated information brochures and posters to educate the public about the proper way to handle used oil. Ecology sent display materials to more than 10,000 retailers selling over 100 gallons of oil per year and has decals and signs available for collectors to post on or over their used oil tanks. Articles about used oil recycling were released in newsletters, newspapers, magazines, and trade journals, and public service announcements were made on radio and television. Washington's educational program emphasizes the protection of water quality through proper handling of used oil. Also, all of the information addresses the need to keep used oil free from other wastes.

The state maintains a toll-free Recycling Hotline to provide the public with information about haulers and collection locations, which are mostly service stations, transfer stations, and landfills. The number of calls received by the hotline concerning used oil went from 25,000 in 1986 to 45,000 in 1987. In the first 6 months of 1988, the hotline received 46,000 calls concerning used oil. Ecology saw the largest increase in calls requesting information about collection locations after sending notices about used oil recycling in the Department of Licensing's license renewal forms.

Along with the awareness campaign, Washington's used oil program is providing creative solutions to used oil disposal problems specific to the State. This type of flexibility and innovation is necessary to ensure a successful used oil recycling program. Two of these most notable projects are discussed here.

The Washington Department of Ecology identified used oil and other wastes dumped into storm drains going directly to the nearest waterway as a major environmental problem in the area. Of the more than 4.5 million gallons of used oil dumped in Washington every year, it is estimated that more than 2 million gallons end up in Puget Sound. In an effort to stop individuals from improperly disposing of used oil into storm drains, the Department of Ecology, aided by the Department of Fisheries, has developed an education campaign to eliminate these wastes from storm drains and the streams and bodies of water into which storms drains flow.

The campaign includes a stencil designed to print a message next to drains that states "Dump No Waste, Drains to Stream." Groups from school systems to fishing clubs have been using the stencil to print the message next to storm drains all over the state.

Another problem facing Washington concerned DIY used motor oil from boaters in Puget Sound's Port of Seattle. Several years ago, the Port of Seattle installed used oil collection tanks at the city marina to reduce contamination of the water. Boat owners utilized the tanks, but difficulties were encountered in the program when other materials, such as paint thinners and cleaning fluids, were found in the oil. In an effort to keep used oil free of contaminating substances, the Port of Seattle:

> Organized a separate permanent facility for the collection of chemical wastes, such as chlorinated solvents, paint, gas, and batteries.
>
> Educates boat owners through mailings, marina newsletters, and flyers to handle their wastes separately.

Since the implementation of this separate collection system for non-used oil wastes, the Port of Seattle has not reported any further contamination problems. Washington's success in significantly increasing used oil recycling is attributed to public education and creative problem solving.

G. The Loop of Recycling and Affirmative Procurement

Recycling is more than the separation and collection of post-consumer materials. These are only the first steps; post-consumer materials must also be reprocessed or remanufactured, and only when the materials are reused is recycling achieved. Furthermore, when affirmative procurement is implemented on a national scale the recycling loop will be complete.

V. AFFIRMATIVE PROCUREMENT

A. Introduction

Affirmative procurement is the purchase of supplies and services utilizing recycled products and minimizing the amount of waste generated or supplies listed. It is an integral part of a Pollution Prevention Program.

The standard three-arrow recycling symbol represents not only *collection* of recyclable materials, but also *manufacturing* and *use* of recycled products. Recycling can succeed in diverting materials from landfills only if markets for products made from recycled materials expand.

One of the intriguing aspects of waste management is that since everyone helps to create the problem by generating garbage, everyone can have a hand in solving the problem as well. What each of us purchases and what each of us throws away determines how much garbage there is. Some of what is needed is social change toward a recycling ethic, and away from needlessly consumptive patterns of behavior. Government, through policy and law, can help direct some of these social changes through taxation and legislation. In the end, economics contributes to many of society's choices with regard to waste disposal, as higher prices stimulate other ways of doing business: creating less waste in the first place, and finding products and processes that make greater levels of recycling possible. Purchasing recycled goods and services affirmative procurement will increase the market demand for recycled products and stimulate the public to recycle.

B. Procurement and Pollution Prevention at Installations

Affirmative procurement is an integral part of a PPP. The policy must be implemented at three levels of procurement to accomplish the goals of the PPP. The procurement levels in order of ease of implementation are:

> Supplies/services at base or installation
> Support systems at command level
> Weapons systems at service level

The procurement practices at all three levels are directly influenced by the identification of waste streams at each installation. Therefore, close coordination of procurement and environmental personnel is essential to successful implementation of the affirmative procurement policy.

Energy conservation programs at the base, command, and service level also require affirmative procurement polices in order to be successful because an energy conservation program must address current equipment at the base and all future equipment additions. In some cases, energy conservation and pollution prevention can be accomplished concurrently in one procurement policy.

The benefits of affirmative procurement can be seen in reduced energy and waste disposal costs. The three levels of affirmative procurement are discussed in more detail below.

C. Supplies and Services

Procurement actions to prevent pollution and conserve energy are most easily implemented at the base or installation level. The procurement policy will be formulated based on the environmental and energy conservation audits for each installation. Environmental auditing will identify the waste streams at the installation and environmental personnel will determine which of the waste streams can be eliminated or minimized by revisions in procurement practices or specifications the energy audit will accomplish the same objective in terms of energy conservation.

Examples that will directly and effectively relate to Pollution Prevention include:

Purchase of products and materials which have a recycled content
Reduction of VOC content in paints (high solids coating)
Reduction in purchase of coatings containing toxic metals
Reduction in use of CFCs for refrigeration and air conditioning
Inventory control of chemicals on base; transfer between shops as an alternative to disposal
Purchase of low sulfur fuel oil or coal for boiler plant

Recycling by vendor of solvents and lubricants
Purchase of special fuel oil burners for boiler plant that produce low levels of nitrogen oxides
Calculation of material balance on base; use of inventory control to reduce amount of chemicals that require disposal due to shelf life expiration

Energy conservation measures can also be supported by several types of procurement practices, including the following examples:

Building specifications -- selecting more insulation; more energy efficient windows
Solar hot water systems
Efficiency specifications on furnaces for residences; boilers for power plants.
Purchase of vehicles with greater fuel economy and use of alternative fuels
Conversion of boiler plants from coal or residual fuel oil to natural gas
Computer control of heating/cooling in buildings

The example of procuring alternative fuels powered vehicles accomplishes the objectives of both energy conservation and Pollution Prevention because fuels such as LPG and electricity provide greater economy and less pollution than comparable gasoline or diesel fuels.

D. Support Systems

Systems and system components are purchased to support the weapon systems and/or mission at each installation. Examples include power plants, incinerators, painting/degreaser operations, printing operations, electroplating, and fueling systems. Due to the size of procurement, many of these support systems are procured at the command level with development of specifications coordinated between base and command staff personnel.

Procurement policy at command level should also be directly tied to the data generated at the installation level for energy conservation and Pollution Prevention. Specifications can be tailored to the base or installation receiving the equipment or system. Examples include:

Heat recovery boiler on new incinerator system
Vapor recovery system on POL tank farms
Use of different solutions and equipment in printing operation
New boiler in power plant fired by natural gas versus coal or (No. 6) fuel oil

Dry plastic media blasting process for paint stripping operations
Purchase of vehicles for flight line using alternative fuels or electricity fore power
Purchase of low sulfur coal for all coal fired plants to reduce sulfur oxide emissions

E. Weapons

During the design and testing phases of a new weapon system, the logistics support personnel that are part of the project team must review the specifications for the system and its support equipment to determine if the system operation and/or maintenance presents significant environmental problems for the bases slated to receive the weapon system. Life cycle costs must include environmental control costs, including disposal. The following areas should be reviewed from an environmental perspective for any new weapon system during development:

Maintenance systems/equipment and intervals
Use of solvents, paints, and lubricants
Disposal of obsolete ammunition, propellants, etc., at end of life cycle
Engine testing/overhaul equipment
Fueling procedures

Procurement policies at this level are important because bases will be required to support weapon systems for life cycles of 10 to 20 years and will have to resolve environmental problems posed by the fielded systems and their support equipment for that period of time.

F. Market Development

Because of the quantity of recyclable materials now being removed from the waste stream, and the amount anticipated to be removed from additional programs, attention has turned to the need for increased development of markets for recyclables.

Traditionally, scrap markets are very cyclical. Wide price fluctuations are destabilizing to community recycling programs. There is no reason for secondary materials industries to try to absorb what may be market gluts, since, for many of the industries, their production is driven by demand for products, not supply of recyclables. Those who seek to use recycled products, such as paper, often find it is unavailable or too expensive compared to virgin paper. To a large extent, market development is a phenomenon of national and international *economics*.

G. Procurement of Recycled Materials

Government spending is close to 20 percent of the gross national product. It is estimated that government purchases 10-15 percent of all paper products consumed in the United States. Entities with so much purchasing power can go a long way toward creating market demand by purchasing and using recycled materials. The federal government, as required under the Resource Conservation and Recovery Act (RCRA), has prepared four sets of procurement guidelines for purchase of recycled materials (paper, lubricating oils, retread tires, and building insulation products). All procuring agencies are directed to follow these guidelines. Many state and local governments are examining their procurement practices to determine how they can increase the demand for recycled goods.

So far, 25 states have passed some type of "buy recycled" legislation. There are several variations in these laws. Some simply suggest the purchase of recycled goods if they are available at competitive prices. Some are for paper only, others cover additional products. Those that are more specific identify minimum content standards; for example, with paper, almost all grades have some recycled fibers in them, so it becomes important to specify content parameters. Some go further to express the amount of post-consumer waste content in purchased materials. Maryland has used a set-aside that gradually raised the amount of recycled bond paper purchased by the state from 5 percent to 40 percent of the total paper purchased. Recycled paper was defined as 80 percent recycled content including 80 percent post-consumer waste. In Maryland, these standards have been exceeded. Several states have adopted *price preferences* that permit procurement officers to pay up to 5 to 10 percent more for particular products as long as they are made from recycled materials.

Several cities and counties have passed procurement regulations, including Washington, D.C.; Philadelphia; Portland, Oregon; New York City; Anne Arundel Country, Maryland; and Suffolk County, New York. There is a sort of *quid pro quo* inherent in "buy recycled" programs. If governments are going to require collection of recyclables, it is especially important for governments to purchase recycled products. One obstacle is a lock of uniformity in state and local recycled content definitions and percentages. The Northeast Recycling Council has developed some consensus definitions and the EPA guidelines are helpful. But, more standardization is needed for manufacturers to be able to meet the requirements of so many different purchasers. Procurement is not only a government issue. Business, too, can be encouraged to buy recycled goods.

With the passage of the Pollution Prevention Act of 1990, Federal procurement has become a means to encourage source reduction. As a buyer of large quantities of supplies, governments can enhance the market for products containing recycled materials. The Resource Conservation and Recovery Act (RCRA) also establishes the Federal government as the leader in stimulating markets for recyclable materials and the use of recycled products throughout the nation. To help foster markets for recovered materials, consumers need to buy products manufactured from recovered materials. Such a commitment from corporations and governments sends an important message to industry that markets for recovered materials exist.

The Air Force plans to collect and recycle all waste paper and to increase the market for products containing recycled paper by procuring to the maximum extent possible, products having the highest possible content of recycled material.

Based on paper use at the Pentagon, a 50 percent procurement rate of recycled paper will save more than 1,300 cubic yards of landfill space, almost 7,300 mature trees, 3 million gallons of water, 162,500 gallons of oil and 1.75 million kilowatts of energy (enough to power over 200 average homes for one year). In addition, increasing by 50 percent the amount of recycled paper used will remove 25,600 pounds of air pollutants released to ambient air from industrial emissions each year. (Pro-Act Fact Sheet, Recycled Paper Products)

H. The Air Force and Affirmative Procurement

Air Force Policy Directive 19-4 states that the Air Force will be proactive in the procurement and acquisition of recycled products to support customer requirements. A graph of the desired trend in Air Force purchases of products with recycled content is shown in.

The Air Force will implement affirmative procurement programs for materials with recycled content according to RCRA Subtitle F (Section 6002) and Executive Order (EO) 12780. Acquisition of recycled materials will be based on the EPA's procurement guidelines (40 CFR 247-252) for purchasing products with recovered materials content.

Each activity will review and revise specifications for the designated items to allow procurement of products containing recoverable materials.

I. Acquisition System Life Cycle Weapons

Every acquisition program has a series of defined steps which must be accomplished. Pollution prevention is not an independent effort but a systems engineering task that should be handled within the existing acquisition process. The following are a list of phases which would occur on a "model" acquisition program that requires some type of pollution prevention action. The acquisition phases are:

Concept exploration
Demonstration and Validation
Development
Production and Deployment
Operations and Support

Each procurement agency may design its own program, so long as it meets the requirements of RCRA. All affirmative procurement programs must have four elements:

(1) a preference program
(2) a promotion plan
(3) procedures for obtaining and verifying estimates and certifications of the content of recovered materials
(4) annual review and monitoring.

A program to get reusable materials back into the system as raw materials now the recycling loop needs to be complete by maximizing the purchase of products made from recycled materials. Effective immediately, it is AFMC policy to use products containing recycled materials, when available. The only exception to this policy is if the recycled product does not meet the minimum quality standard for its intended use.

Two key procurement goals are established. The first is that at least 10 percent of all nonpaper products purchased will contain recycled materials. Specific categories targeted include cement, building insulation, retread tires, and lubricating oils. Second, 50 percent of all paper products purchased will contain recycled materials. These goals are depicted in a graph in Viewgraph 36. The Headquarters focal point for this effort is AFMC/CE who will institutionalize this requirement through the Environmental Protection Committee and provide additional, specific information on metrics.

We have some existing avenues to get started in meeting the new goals. GSA has established national stock numbers for recycled products. Everyone who specifies products for purchase should check the GSA "Recycled Products Guide" for the availability of recycled products already in the system. To promote awareness of your efforts, letterhead printed on recycled paper will be identified either in words or by displaying the recycle logo.

Procurement agencies may choose not to purchase a guideline item containing recovered materials if:

a guideline item's price is unreasonable
applying minimum-content standards results in inadequate competition
obtaining designated items results in unusual and unreasonable delays, and (4) guideline items do not meet all reasonable performance specifications.

Air Force policy is to use products containing recycled materials, when available. An exception to this policy is granted only if the recycled product does not meet the minimum quality standard for its function. Specific categories targeted within the policy include paper, cement, retread tires, building insulation, and lubricating oils. On 5 Nov. 92, General Yates promulgated the policy for AFMC and tasked AFMC/CE as the command OPR.

J. Establishing an Affirmative Procurement Program

If no local program is in effect, the following may be used as a guide to establish your program. The AFMC/LGS policy will encompass retread tires, paper products, lubricating oils (we are currently working with DLA on identification of recycled lubricating oil), and building insulation.

K. Identify Recycled and Like Nonrecycled Items

Assign a local application code to all items that are recycled. As an example, AGMC has assigned application code 'RC' to their recycled items. Also assign a local application code to nonrecycled items. Also assign a local application to nonrecycled items falling in the Recycled Program categories, for example, 'NR'. Assignment of recycled/nonrecycled application codes will build a base for comparison. Continue to assign these application codes to new item record loads that fall in the recycling program categories.

L. Identify Credit Card Purchases

It will be the customer's responsibility to inform CE if recycled items are purchased with the credit card. Since the Logistics Material Control Activities (LMCAs) are major users of the credit card, this issue will be addressed at the upcoming LMCA Conference scheduled for 19-23 Apr. 93.

M. Collect Base Organization's Comments

To aid in building a valid recycled products stock, garner customers' opinions of the recycled items already stocked to ensure those products meet the standards required by their organization. Also, identify customer requirements for nonrecycled items for which the recycled counterpart does not meet their standards. This will help eliminate stocking recycled products that will not be used.

N. Decrease Current Levels of Nonrecycled Stock

Transfer demand data from nonrecycled to recycled stock number. To ensure that 50 percent usage is met on recycled paper, we strongly encourage you to transfer your nonrecycled paper stock from the Base Service

Store warehouse to the main warehouse and remove the IEX K. Those customers justifying the requirement for nonrecycled paper should order it through the Demand Processing Unit.

Give wide publicity at the installation (including associates) to purchase and use products containing recycled materials. This is the proper thing to do to complete the recycle loop. Apart from the environmental payoffs, this will improve the markets for our own recycling programs.

O. Reporting on Procurements

The reduction for nonpaper products will be determined as an aggregate--weighted average of all categories of recycled nonpaper products purchased (include items identified as nonpaper products). The template for tracking this objective is the percentage of recycled products purchased [see Viewgraph 37].
Each installation will submit a quarterly report using the format shown in Viewgraphs 38 and 39. The report will include the dollar amount spent on purchase and percentage of total dollars spent on recycled products for each category.
The quarterly reports will be submitted by the end of the month following each quarter (30 Apr,l 31 Jul, 31 Oct, and 31 Jan) to HQ AFMC/CEVV.

P. Comptroller's General Decision on Affirmative Procurement

The Comptroller General Decision No. B-238290 set a precedent when it denied the protest of Victor Graphics, Inc. Victor Graphics, Inc. bid was rejected because the paper products that were furnished did not contain a minimum of 50 percent waste paper (i.e., recovered/recycled materials).

The terms of the solicitation for the contract included a clause in the bid schedule that required bidders to "certify that the paper supplied under any contract resulting from this solicitation, will meet or exceed the minimum percentage of recovered materials below"; the clause went on to specify a minimum 50 percent waste paper content and provided a space for the offeror to indicate its proposed percentage.

This Controller General Decision held that in any case, agencies may require a specific wastepaper content as a means of implementing the recommendation of EPA Guidelines.

VI. SUMMARY

Recycling will be a fundamental part of any integrated waste management plan. Recycling alone cannot solve a waste management problem, but it can divert a significant portion of the waste stream from disposal in landfills, incinerators, or permitted hazardous waste disposal facilities. EPA has set a national goal of 25 percent reduction of the waste stream through source reduction and recycling by 1992 (EPA, Agenda for Action). Currently, only 10 percent of products discarded are recycled, so significant progress needs to be made. Some existing programs, however, have already achieved or, in fact, exceeded this 25 percent goal. As new post-consumer materials markets, programs, and processing equipment develop, the nation will move towards this and higher goals.

Legislation on affirmative procurement has escalated in the past several years. Governments, companies, and the community will begin to procure more recycled products as political decisions in favor of affirmative procurement become more numerous; this will trigger market forces. Participation, in recycling programs, will typically escalate due to the increased demand and increased monetary value of recycled goods. As participation expands, the behavioral patterns of society will change to a recycle ethic, consequently increasing the use, reuse and reclamation of recycled materials and products. As recycling procedures become more widely practiced, the flow of recyclables to the consumer will accelerate, thus completing the loop of recycling and affirmative procurement.

This lecture has served to try to heighten awareness of recycling issues and possibilities, so that you will be familiar with the current issues when making decisions about both recycling and purchasing recycled materials at your installation. If you have not implemented a recycling program at your installation, you are now familiar with the issues for trying to implement one.

BLOCK 6: SOURCE REDUCTION

1.0 Introduction

Block 6 details source reduction as one aspect of pollution prevention, and as defined by the Environmental Protection Agency. The review will address the Military supply system, and include product and process changes, material substitution, introduction of more efficient and effective technologies, and good operating practices, (such as inventory control, production scheduling, and improvements in material handling), and any in-process recycling that qualifies as source reduction activities. Emphasis is placed on processes commonly found in DoD environments.

2.0 Objective

To review source reduction as one aspect of pollution prevention as defined by the EPA. To address product and process changes; material substitution; introduction of more efficient and effective technologies, and good operating practices; and any in-process recycling that qualifies as source reduction activities.

1. Students will understand the importance of getting management commitment, setting assessment program goals, and considerations associated with forming an assessment team.

    Setting up the program
    Setting overall goals
    Getting people from affected departments or groups

2. Students will understand the approach for collecting process and facility data, and how to set priorities for assessment targets.

    What are the wastes?
    What operations or processes do they come from?
    What input materials generate waste?
    How efficient is an operation or process?
    Is waste generated by mixing materials?
    What controls are available for improving process efficiency?

3. Students will know how to review data, inspect sites and develop options.

    Collecting and Compiling Data
    Prioritize Waste Streams and/or Operations to Assess
    Selecting the Assessment Teams
    Site Inspections
    Generating Options
    Screening and selecting options for further analysis

4. Students will know how to conduct technical and economic evaluations and select options for implementation.

    Presentation of technical evaluation criteria
    Developing economic feasibility of options

5. Students will understand the key elements of implementation to include justification of the project, obtaining funding, equipment installation, implementation procedures, and performance evaluations.

    Obtaining funding
    Demonstration and follow-up
    Measuring waste reduction
    Waste minimization assessments for new production processes
    Ongoing waste minimaztion programs

3.0 Key Concepts

I. PLANNING AND ORGANIZATION

A comprehensive waste minimization program will affect many groups within an organization. The program needs to bring different groups together to reduce waste. The formality and structure of the programs should be tailored to the size and complexity of the organization and be flexible enough to deal with a variety of issues. The developmental activity of the program includes:

getting management commitment
setting waste minimization goals
staffing the program

A. Getting Management Commitment

Management will support a program if it is convinced that benefits outweigh costs. Potential benefits include:

Economic advantages
Compliance with regulations
Reduction in liabilities associated with waste generation
Improved public image
Reduced environmental impact

The existence of an in-place formal policy or the development of a formal policy statement on waste reduction and pollution prevention is an effective tool in expressing the organization's commitment to waste minimization.

Once the policy is in place it is necessary to develop employee cooperation and interest in the program. Methods of encouraging employee interest include:

Bonuses
Awards
Plaques
Other forms of recognition

Another method of incorporating waste minimization is its use in evaluating job performance.

B. Setting Waste Minimization Goals

Establishing measurable, quantifiable goals should be the first priority of the program task force. Quantifiable goals provide a clear guide as to the degree of success expected from the program. Goals should possess certain qualities including:

Flexibility
Measurable
Motivational
Suitable
Understandable
Achievable

The goals of the program should be open to periodic review.

C. Staffing the Program

Formation of a program task force should include people of any group or department in the organization that has interest in the program. The responsibilities of the Task Force or Assessment Team would include:

Get the commitment and a statement of policy from the management if is does not exist.
Establish overall program goals.
Establish a waste tracking system.
Prioritize the waste streams or facility areas for assessment.
Select assessment teams.
Conduct assessments.
Conduct technical/economic feasibility analyses of favorable options.
Select and justify feasible options for implementation.

Obtain funding and establish schedule for implementation.
Monitor implementation progress.
Monitor performance of the option, once is operating.

II. ASSESSMENT PHASE

A. Collecting and Compiling Data

Some questions that information gathering will attempt to answer.

Benefits of options?
Is development an option?
What's the cost?
Can it be reasonably implemented?
It there evidence that it will work?
Is there a chance of success?
Other benefits?

B. Prioritize Waste Streams and/or Operations to Assess

One of the first tasks of the program is to identify and characterize the facility waste stream. Information on waste streams can come from several sources including:

Hazardous waste manifests
Biennial reports
NPDES monitoring reports
Toxic substance release inventories
Waste evaluations
Routine sampling programs

Flow diagrams and material balances can be important tools for monitoring waste reduction programs. They can provide information on:

Baseline for tracking progress
Data to estimate the size and cost of additional equipment and other modifications
Data to evaluate economic performance

C. Selecting the Assessment Teams

The waste minimization task force is concerned with the whole organization. However, the focus of assessment team is on a particular waste stream or area of the plant. Teams should include people with direct responsibility and knowledge of the particular waste stream. Additional team members may include outside people such as:

Association representatives
Consultants
Experts from within the organization

D. Site Inspections

Becoming familiar with the specific area is important in collecting the operating and design data. Basic guidelines for site inspection are:

Preparing agendas covering all points
Scheduling inspections to coincide with particular operations
Monitoring the operations at different times
Interviewing personnel in the specific area
Photographing areas of interest
Observing the housekeeping aspects of the process
Assessing the organizational structure and coordination of environmental activities
Assess administrative controls

E. Generating Options

The team will begin to identify possible ways to minimize waste in the assessed area. Identifying options relies on expertise and creativity, however, use of technical literature, contacts and other sources. Additional background information on waste minimization is also available from:

Trade associations
Plant engineers and operators
Published literature
State and local environmental agencies
Equipment vendors
Consultants

Waste minimization options should follow a hierarchical form in which source reduction is considered first, followed by recycling options.

F. Screen and Select Options for Further Study

Screening procedures of desirable options will identify selected options as suitable for detailed technical and economic evaluation. The selection process may range from informal review to use of quantitative decisionmaking tools. Any screening process should answer the following questions:

What is the main benefit gained by implementing this option?
Does the necessary technology exist to develop this option?
How much does it cost? Is it cost effective?
Can the option be implemented in a reasonable amount of time?
Does the option have a good track record?
Does the option have a good chance of success?
What other benefits will occur?

III. FEASIBILITY ANALYSIS PHASE

A. Technical Evaluation

The technical evaluation determines whether a proposed option will work in a specific application. Evaluation criteria take the form of the following questions:

Is the system safe for workers?
Will product quality be maintained?
Is the new option compatible with production operating procedures, work flow, and production rates?
Is additional labor required?
Are utilities available? Or will they require installation thereby raising capital costs?
How long will production be stopped to install the system?
Is special expertise required to operate or maintain the system?
Does the vendor provide acceptable service?
Does the system create other environmental problems?

B. Economic Evaluation

The economic evaluation is carried out using standard measures of profitability, such as payback period, return on investment, and net present value. Determining value on large projects will be more involved than small ones; however, the basic areas to be considered include:

Capital costs, direct and indirect
Operating costs and savings
Profitability analysis
Adjustments for risks and liability

IV. IMPLEMENTATION

A clear description of both the tangible and intangible benefits can help edge a proposed project past competing projects for funding.

A. Obtaining Funding

An evaluation team made up of financial and technical personnel can balance objectivity in relation to the project and the funding.

B. Installation

Projects involving changes not related to modifications or additions to equipment should be made as soon as possible. Other projects should be phased in as any other capital improvement project would be.

C. Demonstration and Follow-up

Follow-up is important to demonstrate the effectiveness of the project and provide a source of information for other facilities.

D. Measuring Waste Reduction

The easiest way to measure waste reduction is to record quantities before and after the implementation. Waste reduction is directly dependent on production ratios.

E. Ongoing Programs

These techniques for evaluating and implementing waste reduction options can be incorporated into new projects. Planning or design teams should examine and address waste reduction practices during the appropriate phases. Waste reduction should be an ongoing process within any organization.

V. SUMMARY

Source Reduction is the best option to reduce pollution. The Air Force Pollution Prevention Program is based on reducing the amount of materials and wastes by using source reduction. **Pollution Prevention will require a cultural change**. In the common sense words of Benjamin Franklin, "An ounce of prevention is worth a pound of cure." Now that the students have a basic understanding of source reduction, they are ready for a more detailed study of source reduction procedures. Pollution Prevention is the most desirable option.

BLOCK 7: POLLUTION PREVENTION AND ENERGY CONSERVATION

1.0 Introduction

Block 7 presents information on energy conservation techniques including energy audits. Clean energy sources, production, storage, and reduction of energy usage, as well as how to conduct energy balance and cost accounting are reviewed. The Block is followed by an exercise on home and energy usage.

2.0 Objective

To review energy conservation techniques, and their relationship to pollution prevention within the DoD. Included is clean energy sources, production, storage, and reduction of the amount of energy used.

1. Students will understand the basic concepts of energy conservation, and become familiar with current energy recovery techniques.

2. Students will learn what constitutes clean energy and become familiar with sources of this type of energy, and how it is produced and stored.

3. Students will become familiar with energy reduction techniques, as a means of conservation and preventing pollution, by reviewing applicable techniques and their net pollution reduction benefit.

4. Students will know the basic interaction between energy management and pollution prevention.

3.0 Key Concepts

Energy Conservation is a people problem first and then a technical problem.

I. Energy Conservation Reduces Pollution

It helps to:

- reduce greenhouse gas emissions
- protects stratospheric ozone
- prevents acid precipitation

Electricity is generated by burning fossil fuel, or operating nuclear reactors, both of which generate pollution. Generating electricity also produces emissions of trace metals, such as beryllium, cadmium, chromium, copper, manganese, mercury, nickel and silver. Reducing energy generation decreases boiler ash, and scrubber and spent nuclear wastes. It also lessens the need to mine and transport virgin fuels, and dispose powerplant wastes, preventing pollution associated with those activities.

Every kilowatt hour of electricity generated produces 1.5 pounds of carbon dioxide, 5.8 grams of sulfur dioxide and 2.5 grams of nitrogen oxide emissions.

II. Current Energy Use

A. US Energy Consumption (1991)

Petroleum	40.14%
Natural Gas	24.73%
Coal	23.07%
Nuclear	8.03%
Hydro-electric	3.78%
Other	0.25%

B. Total DOD Energy Consumption (1990)

Petroleum	77%
Electricity	10%
Natural Gas	9%

Coal	3%
Steam	1%

C. Total DOD Consumption by Component (1990)

Air Force	54%
Navy	31%
Army	14%
Marines	1%

D. Air Force Energy Consumption (1991)

Petroleum	87%
Electricity	6%
Natural Gas	5%
Coal/Other	2%

E. Air Force Energy Consumption by Type (1991)

Mobility Fuels	83%
Facility	17%

F. Air Force Energy Consumption by MAJCOM (1991)

AFMC	19%
AMC	12%
USAFE	10%
ACC	21%
ATC	7%
SPACECOM	7%
AFRES	8%
PACAF	11%
OTHER	7%

III. Energy Directives

A. Executive Order 12759 (Federal Energy Management, signed April 17, 1991)

Key Points

Each agency shall develop and implement a plan to meet 1995 energy goals and by the year 2000 reduce overall use of BTU's per gross square foot by 20 percent from 1985 energy use levels.

Each agency shall adopt an implementation strategy, that includes, changes in procurement practices, acquisition of real property, and investment in energy efficiency measures.

B. Energy Policy Act of 1992 (P.L. 102-486, signed October 24, 1992)

Energy efficiency and renewable energy received a major boost in the recently enacted, 350-page Energy Policy Act of 1992. Here are some of the bill's highlights:

Energy Efficiency. The bill uses a mixture of voluntary and mandatory measures to encourage energy efficiency. The bill also requires the Secretary of Energy to create a voluntary home energy rating system for prospective home buyers.

Title I requires new energy efficiency standards for lamps, utility transformers, electric motors, and commercial heating and cooling plus new efficiency standards for shower heads, urinals, faucets, and toilets. It also requires states to adopt energy-efficiency standards for commercial building codes. And the bill sets up an R&D program to promote energy efficiency.

Renewable Energy. Title XIX provides a mixtures of tax credits, payments, and federal loan support to encourage wind, closed biomass, solar and geothermal energy facilities and demonstration projects. The bill also creates a renewable energy research program.
Key Points:

- Requires federal agencies to implement all measures which have a ten year payback or else by 2005.
- Agencies are to budget separately for energy and energy projects
- Requires each agency to designate trained energy managers to manage federal facilities and to report on an annual basis the progress of training in the following areas:

  - fundamentals of building energy systems
  - building energy codes and applicable professional standards
  - energy accounting and analysis
  - life cycle cost methodologies
  - fuel supply and pricing
  - instrumentation for energy surveys

- DoD and DLA to identify energy efficient products and improved procurement procedures
- Establishes cash award for outstanding energy managers.

C. DMRD 907 (Energy Resource Management)

1. Responds to Congressional direction for increased emphasis on energy reduction.
2. Establishes $290 million DoD MILCON fund for projects, FY 91-97. (includes $10 mil FY 91 seed money from Congress)
3. Assumes 3 to 4 year payback.
4. Withdraws 1/3 of projected savings from Total Obligation Authority (TOA), FY 91-97
5. Identifies Operation & Maintenance (O&M) funds needed for implementation.

IV. Energy Conservation Measures/Energy Savings

A. Energy Conservation Measures

Conserving energy can be as easy as turning off a light or turning down the heat. Examples of simple conservation measures include:

turning off unneeded lights
reducing inside temperature
insulating walls, ceilings, floors
installing storm doors and windows
installing weather stripping and caulking
keeping furnace serviced
let the sunshine in
plant evergreens and shrubs around windy side of building to block wind and decrease heat loss from both conduction and convection

Examples of energy conservation measures that are more technical in nature include:

automatic energy control systems and associated equipment
furnace modifications, including replacement burners, furnaces and/or boilers; devices for modifying flue openings, and electrical or mechanical furnace ignition systems
replacement or modification of lighting systems to improve energy efficiency
energy recovery systems
cogeneration systems
solar energy systems

B. Sample Savings

include sample calculations comparing energy cost/total cost for incandescent and fluorescent light bulbs include sample calculations comparing energy cost/total cost for fluorescent bulbs of different wattages

C. Energy Balance and Cost Accounting Exercise

(Covered in the Home and Energy Usage Exercise)

V. Energy Audit - How to identify present energy end-uses and establish achievable goals for improving energy efficiency.

- Preliminary or walk-through audits
- building/system audits
- end-use/equipment audits

Class Exercise: walk through portions of sample audit conducted at "typical" air force base (i.e., review sample data) to determine where energy goes, when energy is used, and identify where greatest energy/cost savings potential might be), assuming such information is readily available. A handout covering energy audits will be provided at this time.

(Also will be covered in the Home and Energy Usage Exercise)

VI. Statements of Challenge Facing Us Today and Accomplishments to Date (including identification of net pollution reduction benefit)

A. DOD Energy Goals (FY 2000 vs FY 1985)

1.	Existing Buildings	-20%BTU/sq.ft.
2.	Industrial Process	-20% BTU/indicator
3.	New buildings	10% Design Efficiency
4.	Increased Coal Usage	1.6 mil. tons/yr by 94
5.	Conversion Energy	+ 5% by FY 95
6.	Mobility Fuels	-10% by FY 95

Summary of Statements of Challenge and Accomplishments identified by EPA for nation as a whole.

A. Lighting - accounts for 20-25 percent of the electricity used in the United States. Inefficient lighting systems:

- waste electricity
- increase ratepayer electricity bills
- cause air pollution and greenhouse gas emissions.

Energy efficient lighting can:

- cut lighting electricity use and the pollution caused by lighting by 50 percent
- Free $18.6 billion from ratepayer bills for investment
- Allow $60 billion of capital to be invested in new jobs rather than new power plants.

Accomplishments: EPA Green Lights Program

Lighting accounts for over 20 percent of total U.S. electricity consumption and was responsible for 120 million metric tons of carbon emissions in 1990. Available technology can reduce the electricity used for lighting by 50-70 percent. These efficient technologies also provide excellent investment opportunities--in fact a typical lighting upgrade yields an internal rate of return (IRR) of 20-30 percent--a payback of about 3-4 years.

Green Lights provides companies and governments the opportunity to invest in energy-efficient lighting. Launched in January 1991, Green Lights is a voluntary, non-regulatory program designed to reduce pollution through the initiative of organizations across the country. All Green Lights participants sign a Memorandum of Understanding (MOU) with EPA, agreeing to (1) survey all of their domestic facilities, (2) upgrade their lighting where profitable, and (3) complete their lighting upgrades within 5 years. By signing this agreement, participants also agree to assign a Green Lights implementation manager responsible for ensuring timely implementation of lighting upgrades. Finally, participants agree to work with EPA in publicizing the benefits of energy-efficient lighting. Green Lights does not require participants to install specific lighting technologies. To meet their MOU obligation, participants invest in whatever technologies maximize energy savings while maintaining or improving lighting quality. As of September 30, 1992, Green Lights participants numbered 651, including 296 corporate Partners, 24 state and local government Partners, 42 utilities, 195 lighting manufacturers, 55 lighting management companies, and 40 Endorsers. These organizations have committed over 2.8 billion square feet of facility space to the program, over 3 percent of the national total. Expected from these commitments:

- 12.4 BkWh/yr Energy savings
- 67,500 metric tons avoided sulfur dioxide emissions
- 28,700 metric tons avoided nitrogen oxide emissions
- $870 million reduced electricity bills (at 7.0 cents/kWh)

Green Lights Tomorrow: 2000 projects 24-60 billion square feet committed. Expected from these commitments:

- 104-226 KkWh/yr energy savings
- 22-55 MMT avoided carbon emissions
- 1.3 MMT avoided sulfur dioxide emissions
- 600,000 metric tons avoided nitrogen oxide emissions
- $7 - 15.8 billion reduced electricity bills (at 7.0 cents/kWh)

B. BUILDINGS

Commercial buildings account for approximately 15 percent of all U.S. energy consumption. Proven energy-efficient technologies can reduce 30-50 percent of building energy use. Upgrading existing buildings can:

- save money
- reduce pollution
- increase comfort
- improve indoor air quality

Technology options for commercial buildings include the following:

1. Load Reduction

    Lighting (Green Lights - discussed above)
    Energy Star Computers (discussed below)

Green Lights helps reduce electric and cooling load. Energy Star Computers helps reduce costs of energy for PC's and peripherals (i.e., drives down plug loads), and reduces electric and cooling load.

2. Air Handling (discussed below)

    Variable speed drive fan motor controls
    Smaller, high-efficiency motors and fans
    High-efficiency diffusers

    Will reduce air handling energy and reduce cost of Variable Speed Drive (VSD) technology.

3. Chiller Plant

    Replace older inefficient chillers or retrofit with CFC substitute refrigerants
    VSD on compressor where appropriate
    Downsize pump
    VSD on pumps and cooling tower fans
    Heat pipes and desiccant dehumidification

Will eliminate CFCs, reduce chilling energy, reduce reheat, reduce dehumidification costs, avoid disruption of service, and reduce technology costs.

4. Heating

Heat recovery
Heat pumps
Gas

Reduce electric resistance use and lower electric and thermal load. Opportunities for reducing space heating loads may exist with heat recovery of heat pumps.

5. Hot Water

Heat recovery
Heat pumps
Cogeneration

Improve thermal efficiency and reduce electric resistance use. Heat recovery or heat pumps can provide hot water with less energy than conventional electric resistance water heaters. Cogeneration may improve overall system efficiency.

Accomplishments

1. EPA's Variable Speed Drive (VSD) Demonstration Study (improves efficiency by varying the speed of the fan motors)

   Prospects for 1993:

   - Complete VSD demonstration study
   - Organize mass purchase of VSDs by Buildings program participants to create economies of scale and increase market penetration of this energy-saving technology.

2. Chillers and Cooling Systems - prototype "Golden Carrot" rooftop air conditioning system will be designed for high efficiency

   a. analysis concludes that HCFC-123 is safe substitute for CFC-11 in chillers
   b. studies indicate that HCFC-123 is the most energy-efficient CFC-free building cooling system currently available
   c. surveys show air condition units typically used on rooftops to cool small office buildings and shopping malls have worst efficiency of all systems on market

C. Efficient Office Equipment

Office equipment is the fastest-growing electricity load in the commercial sector:

- computers systems account for 5 percent of total commercial electricity consumption (indicate how much in Air Force?).
- the vast majority of nation's 30-35 million person computers are left turned on while not in use
- 30 to 40 percent of personal computers are left running overnight and on weekends.

To reduce wasted electricity, we must

- develop products which use less energy, especially when not actually producing work
- make consumers aware of energy-efficient products and their benefits
- create a new market for energy-efficient office equipment

Accomplishments: EPA creates Energy Star Computers Program

D. CFC-Free, Energy Efficient Refrigerator/Freezers

Household refrigerators:

- consume 15-20 percent of all electricity used in U.S. households (include how much on Air Force base?)
- use chlorofluorocarbons (CFCs) - ozone-depleting substances that will be phased out of production by 1995

Accomplishments

1. Golden Carrot Super-Efficient Refrigerator Program
2. Lorenz Cycle Refrigerators (reduce energy consumption by 8-16 percent)
3. Improved door seals - increases energy efficiency by up to 8 percent
4. Super insulation
5. Carbon Black Insulation

E. Efficient Space Conditioning Equipment

Heating and Cooling homes:

- accounts for 9 percent of U.S. Energy consumption (include how much of air force base)
- emits over 400 million metric tons of CO_2

Advanced electric and gas heat pumps and furnaces heat and cool homes efficiently, save consumers money, and reduce air pollution and greenhouse gas emissions. Nevertheless, advanced space conditioning technologies face significant market barriers:

- higher installation costs
- consumers' unwillingness to pay more up front for long-term savings
- manufacturers' and dealers' lack of inventory or promotion of advanced technologies
- consumers lack of awareness of efficient alternatives.

Accomplishments

- EPA draft report compares costs and environmental impacts of residential space conditioning systems
- EPA draft study demonstrates cost-effectiveness of advanced space conditioning technologies. Encourages utility promotion.

Prospects for 1993:

- Launch major national initiative to promote advanced heat pumps with a group of utilities.

F. Refrigerant Technology (air conditioning)

Replacing CFCs in refrigeration technologies will have implications for the energy efficiency of these technologies; the direct effects of refrigerant emissions and their greenhouse and ozone depletion contributions; and the usefulness of existing equipment.

A variety of problems impede the rapid and efficient replacement of CFCs. For example: no replacements for HCFC-22 are available; oils for new refrigerants are not always compatible with new equipments; and some replacements raise safety or toxicity concerns. Replacement requires combined analysis and decision-making for industry and safety organizations.

Accomplishments:

- EPA report confirms efficiency gains from HCFC-22 replacements.
- Results indicate some refrigerant blends can be used to retrofit existing systems.
- Testing of CFC and HCFC alternatives accelerated by EPA efforts to supply refrigerants and data to industry.

G. Other Actions - including any that might be specific only to DOD

- Low Flow Showerheads
- Solar thermal water heaters

VII. SUMMARY

We have covered the basic concepts of energy conservation, and have become familiar with current energy recovery techniques. The student understands the basic interaction between energy management and pollution prevention. You are now familiar with energy reduction techniques as a means of conservation and preventing pollution by reviewing applicable techniques and their net pollution reduction benefit. So in closing you won't necessarily have to eat more carrots to see with less light.

BLOCK 8: TODAY'S HOT ISSUES - 90'S PROBLEM CHEMICALS

1.0 Introduction

Block 8 presents information on the Environmental Protection Agency's seventeen targeted chemicals and the 33/50 Program. Block 8 is designed to inform the student of the priority chemicals and chemical classes designated for special action and to discuss current uses, efforts to eliminate/reduce their use by either conservation, recycling, or substitution particularly as it relates to the DoD environment.

2.0 Objective

To identify the EPA's seventeen targeted chemicals (based on the volume of use, toxicity, persistence, and mobility) for reduction or elimination of their use in private and DoD environments. These chemicals were given the highest priority for reduction or elimination based on the hazards they can present to workers, the public, and the environment. Classes of chemicals, such as chlorofluorocarbons, and halons, are also targeted for reduction and or elimination. This block of instruction is designed to: inform the student of the priority chemicals and chemical classes designated for special action; and to identify the targeted chemicals and chemical classes; and discuss current uses, and efforts to eliminate/reduce their use by either conservation, recycling, or substitution.

1. Students will identify the targeted chemicals and chemical classes.

2. Students will learn current uses of the chemicals by DoD installations.

3. Students will learn examples of efforts at various DoD installations in reducing consumption, recycling, or substitution of less toxic/hazardous materials.

3.0 Key Concepts

I. OVERVIEW OF THE EPA 33/50 PROGRAM

The EPA 33/50 Program is a voluntary pollution prevention initiative to reduce national pollution releases and off-site transfers of 17 toxic chemicals by 33 percent by the end of 1992 and by 50 percent by the end of 1995. The program was initiated in February 1991 by EPA Administrator William K. Reilly. Initially, 600 U.S. companies, identified by TRI as the largest discharges to the environment, were contacted by EPA and asked to reduce their releases of these 17 toxic chemicals. Since that time, EPA has contacted thousands of additional companies to request their participation. All U.S. companies are encouraged to participate in the program.

Pollution prevention should be considered the first step in a hierarchy of options for reducing the generation of pollution. *Pollution prevention* is defined as the use of substitute materials, processes or practices to reduce or eliminate the creation of pollutants. The next step in the hierarchy is responsible recycling of any wastes that cannot be reduced or eliminated at the source. Wastes that cannot be recycled should be treated in accordance with regulatory standards and Best Demonstrated Available Technology (BDAT).

The EPA 33/50 Program has many positive attributes. The first is that the program is national. This approach will allow EPA to measure success of the program according to nationwide reductions, rather than for each company or facility. The first goal of a 33 percent reduction was met ahead of schedule in 1991 as measured by TRI reporting requirements.

The voluntary aspect of the program allows companies to decide how to participate in the reduction process in a manner which is cost-effective and tailored to their specific needs. Other positive aspects include a multi-media approach to encompass all environmental pathways and a prevention-oriented approach aimed at source reduction and recycling.

As stated previously, the Air Force is committed to participation in this program, and monitors the reduction of these constituents at AF installations. An Executive Order requiring the federal facilities that manufacture, process, or use toxic chemicals to comply with TRI reporting requirements is anticipated in the near future. The TRI reporting requirements include information on source reduction and recycling activities; thus, participation in this program will prepare the AF for these reporting requirements.

II. SELECTION OF THE 17 TARGET CHEMICALS

The 17 chemicals targeted for reduction by the 33/50 Program include several organic solvents used in plastics production, fuels, paints and cleaners. Examples of these solvents include methyl ethyl ketone, methylene chloride, and toluene. Several prevalent metals in this list include lead, mercury and cadmium.

The 17 target chemicals were selected because: a) they are produced in large quantities and subsequently released into the environment in large quantities; b) they are generally identified as toxic or hazardous pollutants and significant environmental and health benefits can be achieved by reducing their releases; and c) the potential to reduce their releases through pollution prevention practices.

The remainder of this presentation will address each compound individually to cover:

1. Description of current Air Force uses

2. Introduction to chemical's physical, chemical and toxic properties. The goal is to describe why the compound has been targeted by the EPA and to introduce the student to the chemical's basic properties.

3. Describe proven and potential methods for reducing the use of the chemical.

SEVENTEEN TARGET CHEMICALS

Organic Compounds

The targeted list of chemicals includes 11 organics. These compounds are primarily used as solvents, either for paint removal or grease removal, because of their physicochemical properties, such as polarity.

I. Benzene

A. Description of uses:

Potential uses of benzene by the AF include cleaning of parts and structures with solvents containing benzene and the use of paint strippers containing benzene. Additionally, fuels, plastics and tires also contain benzene (Proctor et al., 1988).

B. Basic description of chemical properties/toxicity, and environmental concerns:

The primary chemical characteristics affecting environmental fate of benzene include high volatility and high solubility in water (ATSDR, 1989). In surface and groundwater, benzene exhibits a relatively short half-life. Since benzene has a relatively low soil sorption coefficient, indicating low affinity for soil particles, it has a fairly high potential to leach into the groundwater from contaminated soils. Benzene is also highly mobile in contaminated groundwater and has the potential to migrate significantly. In waters with adequate gas exchange, the majority of benzene is released into the atmosphere due to its high volatility. In the air, benzene has a relatively short half-life due to reduction by hydroxyl radicals. Benzene is highly mobile in the air and can be transported rapidly under favorable wind conditions. Benzene also has the potential to bioaccumulate.

Benzene is detected at approximately 20 percent of the sites on the EPA National Priorities List (NPL).

The primary route of exposure to benzene occurs from inhalation. Like most solvents, benzene will cause central nervous system (CNS) effects following relatively high acute exposures. These effects usually are not permanent and include drowsiness, dizziness, and headache (ATSDR, 1989).

The primary non-carcinogenic effect of benzene from chronic exposure is anemia. The target organ of benzene is the bone marrow. The bone marrow produces cells which are the precursors of red and white blood cells. Benzene migrates to the bone marrow and attacks these precursor cells. The result is a reduction in circulating blood cells and anemia. The condition has been documented in occupational workers who are chronically exposed to benzene (Amdur et al., 1991).

Benzene is a demonstrated carcinogen in humans. Several epidemiological studies in workers have shown a high incidence of leukemia from chronic exposure to benzene.

Data from animals studies indicate that benzene produces adverse effects in fetuses, including low birth wight, delayed bone development, and bone marrow damage.

The Occupational Safety and Health Administration's (OSHA) legally enforceable limit is an average of 1.0 ppm over the standard of 8-hour work day. The EPA Maximum Contaminant Level for benzene in drinking water is 5 ppb (NIOSH, 1991).

C. Potential reduction/recycle methods:

Recycling methods for benzene include the recycling of used fuels (currently implemented at AF installations), tires and plastics. Potential reduction methods include utilization of media blasting as a method of paint removal.

II. Toluene

A. Description of uses:

As with benzene, potential uses of toluene by the AF include cleaning of parts and structures with solvents and the use of paint strippers containing toluene. Additionally, toluene is added to fuels to achieve a higher octane. Plastics also contain toluene. Unlike benzene, toluene is still very frequently used in cleaning agents and paints (Protor et al. 1988).

B. Basic description of chemical properties/toxicity and environmental concerns:

Similar to benzene, the primary chemical characteristics affecting environmental fate include high volatility and high solubility in water (ATSDR, 1993a). Like benzene, toluene exhibits:

A relatively short half-life in air and water

A relatively low soil sorption coefficient, indicating a fairly high potential to leach into the groundwater from contaminated soils

High mobility in contaminated groundwater and the potential to migrate significantly.

Toluene has been detected at approximately 65 percent of the sites on the NPL.

The primary route of exposure to toluene occurs from inhalation; however, toluene can also be dermally absorbed from skin contact with cleaning solvents or paint thinners. The primary health effect of toluene is in the central and peripheral nervous systems. Acute exposure to toluene can cause drowsiness, confusion, weakness, dizziness, memory loss, and nausea (ATSDR, 1993a). These symptoms are usually not permanent. The primary target organ of toluene is the brain. Data on CNS effects has been acquired through incidence of solvent sniffing. Breathing extremely high concentrations of toluene can cause death due to the effect on the brain centers which control breathing and heart rate. Due to the high lipophilic (non-polar) characteristic of toluene, it can easily attack brain cells and nerve cells which are have a high lipid content. Chronic exposure to high levels of toluene causes permanent changes in the myelin sheath of nerve cells. The myelin is used to carry messages and impulses from one cell to another (Amdur et al. 1991).

Exposure to moderate to high levels of toluene has also been associated with slight kidney, liver and lung effects in animals. None of the available animal or human data suggest that toluene is carcinogenic.

Toluene has been demonstrated to be a developmental toxicant in both animals and humans. These birth defects included central nervous system disfunction, developmental delays, kidney defects, and skeletal abnormalities (ATSDR, 1993a).

The Occupational Safety and Health Administration's (OSHA) legally enforceable limit for toluene is an average of 100 ppm over the standard of 8-hour work day (OSHA, 1991). The EPA Maximum Contaminant Level for toluene in drinking water is 5 ppb.

C. Potential reduction/recycle methods:

Recycling methods for toluene include the recycling of used fuels (currently implemented at AF installations) and distillation of toluene from cleaning fluids at AF installations. Potential reduction methods include utilization of paints, paint removers, and cleaning fluids which do not contain toluene or only minute amounts of toluene. Additionally, media blasting can be substituted for paint remover.

III. Xylenes (includes ortho-, meta- and para-)

A. Description of uses:

Potential uses of toluene by the AF include cleaning of parts and structures with degreasers and paint strippers containing xylene.

B. Basic description of chemical properties/toxicity and environmental concerns:

The primary chemical characteristic affecting the environmental fate of xylene is its high volatility. In surface and groundwater, xylene exhibits a relatively short half-life. Xylene has a moderate potential to leach into groundwater. In waters with adequate gas exchange, the majority of xylene is released into the atmosphere due to its high volatility. In the atmosphere, xylene has a relatively short half-life due to reduction by hydroxyl radicals (ATSDR, 1990a).

Xylene has been detected at approximately 20 percent of the sites on the NPL.

[VIEWGRAPH 13]

The primary route of exposure to xylene occurs from inhalation. The primary target organs of xylene include the central nervous system, liver and kidney. Both acute and chronic exposure can result in headache, mental confusion, narcosis, alterations in the body balance, impaired short-term memory and tremors. Acute exposure also produces nose and throat irritation. Xylene is believed to interfere with enzyme activity in the brain to induce central nervous system effects. Liver effects observed in animals include increased liver weight and alterations in liver enzyme production. Limited human epidemiological evidence suggests that exposure to xylene causes kidney disfunction (ATSDR, 1990a).

Xylene is "not classifiable" as a carcinogen due to an inadequate database.

Studies in animals suggest that xylene causes birth defects including decreased fetal weight, delayed skeletal development, and skeletal anomalies. The database is inadequate to evaluate the reproductive toxicity of xylene.

OSHA's legally enforceable limit for xylene is an average of 100 ppm over the standard of 8-hour work day (OSHA, 1991). The EPA Maximum Contaminant Level for xylene is 10 mg/L in drinking water.

C. Potential reduction/recycle methods

Reduction methods for xylene include the use of parts washers as a replacement for degreasers. Additionally, media blasting can be substituted for paint remover.

IV. Carbon Tetrachloride

A. Description of uses:

Carbon tetrachloride is contained in cleaning solvents used by the AF to clean engine parts, such as bearings.

B. Basic description of chemical properties/toxicity and environmental concerns:

The primary chemical characteristic of carbon tetrachloride affecting environmental fate is high volatility. Carbon tetrachloride is rapidly released into the atmosphere from soils and surface water. Unlike benzene and toluene, carbon tetrachloride does not react with hydroxyl radicals to breakdown in the troposphere. Carbon tetrachloride that is not removed from the troposphere by rainfall diffuses upward into the stratosphere where it may be photodegraded to form chlorine species that catalyze destruction of the ozone. The persistence of this compound in the atmosphere can range from 30 to 100 years in the atmosphere; therefore, it has the potential for global distribution over time (ATSDR, 1993b).

The primary route of exposure to carbon tetrachloride occurs from inhalation; however, it can also be dermally absorbed from skin contact with cleaning solvents or absorbed by the gastrointestinal system following ingestion of contaminated food or water. The primary target organs of carbon tetrachloride are the brain, kidney and liver. Carbon tetrachloride also has a high tendency to accumulate in the adipose tissue of humans. As with most solvents, high acute exposures to this compound cause central nervous system effects, including dizziness, nausea, and headache. Because carbon tetrachloride is metabolized to harmful compounds in the liver, the liver is can be severely effected by chronic exposure. Adverse effects in the liver include fatty accumulation and necrosis. Injury to the kidney and disruption of function can also be caused by metabolites of this compound. Because the liver and kidney have a large capacity and repair mechanisms, many of the lesser effects on these organs (short of cell death) are either reversed or compensated. Carbon tetrachloride has a depressant effect on the brain and can potentially lead to degeneration of neural cells (ATSDR, 1993b).

Carbon tetrachloride has been shown to cause liver cancer in animals and may be carcinogenic in humans. EPA classifies carbon tetrachloride as a probable human carcinogen.

This compound has been associated with decreased fertility; however, the mechanism of this effect is unknown. In adequate data exists to determine if carbon tetrachloride adversely affects the developing fetus.

OSHA's legally enforceable limit for carbon tetrachloride is an average of 2 ppm over the standard 8-hour work day (OSHA, 1991). The EPA Maximum Contaminant Level for carbon tetrachloride in drinking water is 5 ppb.

C. Potential reduction/recycle methods:

Potential reduction methods for carbon tetrachloride include replacing degreasers with parts washers which rely on an aqueous base soap and water, rather than solvents.

V. Chloroform

A. Description of uses:

Chloroform is contained in cleaning solvents used by the AF to clean engine parts, such as bearings; however, chloroform is not as prevalent in these degreasers as other targeted compounds. Chloroform is also present in packaging which contains fluorocarbons.

B. Basic description of chemical properties/toxicity and environmental concerns:

The primary chemical characteristic of chloroform affecting environmental fate is high volatility. Chloroform is rapidly released into the atmosphere from soils and surface water. Chloroform is slightly reactive with hydroxyl radicals in the atmosphere. The half-life of chloroform in the atmosphere is approximately 80 days; therefore, it has the potential for widespread distribution of the compound exists. Similar to carbon tetrachloride, chloroform can contribute to ozone depletion (ATSDR, 1992a).

The primary route of exposure to chloroform occurs from inhalation; however, it can also be dermally absorbed from skin contact with cleaning solvents or absorbed by the gastrointestinal system following ingestion of contaminated food or water. Similar to carbon tetrachloride, the primary target organs of chloroform are the brain, kidney and liver. The adverse health effects are also similar to carbon tetrachloride, including central nervous system depression following acute exposure and liver, kidney and neurological effects from chronic exposure (ATSDR, 1992a).

Chloroform has been shown to cause liver cancer in animals. Epidemiology studies in humans suggest an association between cancer of the large intestine, rectum, and/or bladder in humans and the constituents of chlorinated drinking water; however, chloroform has not been identified as the primary cause of the cancer. This compound is considered to be a probable human carcinogen.

Inadequate data exist to determine if chloroform adversely affects the developing fetus or fertility.
OSHA's legally enforceable limit for chloroform is an average of 2 ppm over the standard of 8-hour work day (OSHA, 1991). The EPA Maximum Contaminant Level for total trihalomethanes, which include chloroform, in drinking water is 1 ppm.

C. Potential reduction/recycle methods:

Potential reduction methods for chloroform include replacing degreasers with parts washers which rely on an aqueous base soap and water, rather than solvents. Avoiding the use of canisters which contain fluorocarbons is an additional reduction method for chloroform.

VI. Dichloromethane (methylene chloride)

A. Description of uses:

Potential uses by the AF include use as a cold wipedown cleaner for metals. Methylene chloride is also contained in paint removers and aerosol products.

B. Basic description of chemical properties/toxicity and environmental concerns:

The primary chemical characteristic of methylene chloride affecting environmental fate is high volatility. Methylene chloride is rapidly released into the atmosphere from soils and surface water. This compound is slightly reactive with hydroxyl radicals in the atmosphere. The half-life of methylene chloride in the atmosphere is approximately 130 days; therefore, as in the case of chloroform, the potential for widespread distribution of the compound exists. Methylene chloride is not expected to accumulate significantly in the stratosphere and has no significant effect on the ozone layer. Methylene chloride is not expected to bioaccumulate in the food chain (ATSDR, 1992b).

Methylene chloride has been identified at 311 of the 1,300 hazardous waste sites that have been proposed for inclusion on the National Priorities List (NPL).

The primary route of exposure to methylene chloride occurs from inhalation; however, it can also be dermally absorbed from skin contact with cleaning solvents or absorbed by the gastrointestinal system following ingestion of contaminated food or water. Similar to carbon tetrachloride and chloroform, the primary target organs of methylene chloride are the brain, kidney and liver. The adverse health effects include central nervous system depression following acute exposure and liver, kidney and neurological effects from chronic exposure (ATSDR, 1992b).
Methylene chloride has been shown to cause lung cancer in animals and may cause liver tumors, as well. EPA categorizes methylene chloride as a probable human carcinogen.

Methylene chloride does not appear to cause adverse effects in the developing fetus or to effect fertility.

OSHA's legally enforceable limit for methylene chloride is an average of 500 ppm over the standard of 8-hour work day (OSHA, 1991).

C. Potential reduction/recycle methods:

Potential reduction methods for methylene chloride include replacing degreasers with parts washers which rely on an aqueous base soap and water, rather than solvents. Physical methods of paint removal, such as media blasting can also significantly decrease the use paint strippers containing methylene chloride. Avoiding the use of aerosols is an additional reduction method for methylene chloride.

VII. 1,1,1-Trichloroethane (1,1,1-TCA)

A. Description of uses:

1,1,1 - TCA was developed initially as a safer solvent to replace carbon tetrachloride. Potential AF uses include cold cleaning and vapor degreasing. 1,1,1-TCA is also found in aerosols.

B. Basic description of chemical properties/toxicity and environmental concerns:

The primary chemical characteristic of 1,1,1-TCA affecting environmental fate is high volatility. Like all of the other organics we have discussed, 1,1,1-TCA is rapidly released into the atmosphere from soils and surface water. This compound reacts slowly with photochemical produced hydroxyl radicals, resulting in a long half-life of approximately 2-6 years. The potential for migration of 1,1,1-TCA from the point of release is very high. This compound does accumulate in the stratosphere, where it reacts with ozone. 1,1,1-TCA is highly mobile in the and leaches readily into groundwater. The potential for this compound to bioaccumulate in aquatic organisms is low (ATSDR, 1990b).

1,1,1-TCA is detected in approximately 20 percent of the listed NPL sites.

The primary route of exposure to 1,1,1-TCA occurs from inhalation; however, it can also be dermally absorbed from skin contact with cleaning solvents or absorbed by the gastrointestinal system following ingestion of contaminated food or water. The primary target organs of this compound are the central nervous system and the cardiovascular system. The effects in the central nervous system are similar to those previously discussed for other target chemicals; however, only at extreme concentrations. The effects in the cardiovascular system also occur only after exposure to very high concentrations of 1,1,1-TCA vapor. The effects in the cardiovascular system include vasodilation, which can cause low blood pressure. Additionally, this solvent can react with the membranes of cardiac cells and interfere with conduction in heart rate. Effects in the heart can be experience at lower concentrations of some solvents if an individual is predispositioned to heart disfunction (ATSDR, 1990b).

Limited, and inconclusive evidence, suggests that this compound may cause adverse effects in the liver. 1,1,1-TCA is not classifiable as a human carcinogen.

1,1,1-TCA does not appear to cause adverse effects in the developing fetus or to effect fertility; however, more testing is needed to assess the reproductive effects of this compound.

OSHA's legally enforceable limit for 1,1,1-TCA is an average of 350 ppm over the standard of 8-hour work day (OSHA, 1991). The EPA Maximum Contaminant Level for 1,1,1-TCA in drinking water is 0.2 ppm.

C. Potential reduction/recycle methods:

Potential reduction methods for 1,1,1-TCA include replacing degreasers with parts washers which rely on an aqueous base soap and water, rather than solvents.

VIII. Trichloroethylene (TCE)

A. Description of uses:

Potential AF uses of TCE include cold cleaning and vapor degreasing. TCE is also found in paints and paint strippers.

B. Basic description of chemical properties/toxicity and environmental concerns:

The primary chemical characteristic of TCE affecting environmental fate is high volatility. TCE is rapidly released into the atmosphere from soils and surface water. TCE is highly reactive with hydroxyl radicals in the atmosphere and has a relatively short half-life. TCE has a high potential to leach and is highly mobile in groundwater. Bioaccumulation in aquatic life appears to be very low; however, study data suggests that TCE may bioaccumulate in fruits and vegetables (ATSDR, 1992c).

The primary route of exposure to TCE occurs from inhalation; however, it can also be dermally absorbed from skin contact with cleaning solvents or absorbed by the gastrointestinal system following ingestion of contaminated food or water. The primary target organs of TCE are the central and peripheral nervous systems, heart, kidney and liver. The adverse health effects in these organs/systems are similar to those previously discussed for other organics (ATSDR, 1992c).

TCE is not classifiable as a human carcinogen.

Inadequate data exists to determine if TCE adversely affects the developing fetus or fertility.

OSHA's legally enforceable limit for TCE is an average of 50 ppm over the standard 8-hour work day (OSHA, 1991). The EPA Maximum Contaminant Level for TCE in drinking water is 5 ppb.

C. Potential reduction/recycle methods:

Potential reduction methods for TCE include replacing degreasers with parts washers which rely on an aqueous base soap and water, rather than solvents. Physical methods of paint removal, such as media blasting can replace the use of paint removers.

IX. Tetrachloroethylene (PCE)

A. Description of uses:

Potential uses of PCE by the AF include degreasing of metals.

B. Basic description of chemical properties/toxicity and environmental concerns:

The primary chemical characteristic of PCE affecting environmental fate is high volatility. PCE is rapidly released into the atmosphere from soils and surface water. PCE is reactive with hydroxyl radicals in the atmosphere. The half-life of PCE in the atmosphere is approximately 96 days; therefore, the potential for widespread distribution of the compound exists. Like the majority of compounds covered thus far, PCE leaches readily into groundwater and is highly mobile. In areas of low gas exchange, PCE in the groundwater can be relatively persistent (ATSDR, 1990d).

PCE is present in approximately 30 percent of the sites on the NPL.

The primary route of exposure to PCE occurs from inhalation; however, it can also be dermally absorbed from skin contact with cleaning solvents or absorbed by the gastrointestinal system following ingestion of contaminated food or water. Similar to many other compounds we have covered, the primary target organs of PCE are the brain, kidney and liver. As with other compounds, the adverse health effects include central nervous system depression following acute exposure and liver, kidney and neurological effects from chronic exposure (ATSDR, 1990d).

PCE has been shown to cause cancer in the liver and kidneys, as well as leukemia, in animals and is considered to be a probable human carcinogen.

Adverse effects in developing fetuses have been demonstrated in animal studies. These effects include decreased fetal weight and delayed skeletal development. Inadequate data exists to determine if PCE adversely affects fertility.

OSHA's legally enforceable limit for PCE is an average of 100 ppm over the standard 8-hour work day (OSHA, 1991). The EPA Maximum Contaminant Level for PCE in drinking water is 0.005 ppm.

C. Potential reduction/recycle methods:

Potential reduction methods for PCE include replacing degreasers with parts washers which rely on an aqueous base soap and water, rather than solvents.

X. Methyl Ethyl Ketone (MEK)

A. Description of uses:

Potential AF uses of MEK include degreasing and paint removal.

B. Basic description of chemical properties/toxicity and environmental concerns:

The primary chemical characteristics affecting the environmental fate of MEK include high volatility and high solubility in water (Proctor, 1988). In surface and groundwater, MEK exhibits a relatively short half-life. MEK has a high potential to leach into the groundwater from contaminated soils. This compound is also highly mobile in contaminated groundwater and has the potential to migrate significantly. In waters with adequate gas exchange, the majority of MEK is released into the atmosphere due to its high volatility. In the

air, MEK has a relatively short half-life due to reduction by hydroxyl radicals. It is highly mobile in the air and can be transported rapidly under favorable wind conditions.
The primary route of exposure to MEK occurs from inhalation; however, it can also be dermally absorbed from skin contact with cleaning solvents or paint thinners. The primary health effect of MEK is in the central and peripheral nervous systems. Similar to almost all of the solvents that we have discussed, acute exposure to MEK can cause drowsiness, confusion, weakness, dizziness, memory loss, and nausea. These symptoms are usually not permanent. The primary target organ of MEK is the central and peripheral nervous systems. Effects on the peripheral nervous system can cause numbness and impairment of motor skills. MEK is not highly neurotoxic in comparison with toluene; however, in a combined exposure to both substances, MEK may potentiate the neuropathy caused by toluene (Amdur et al., 1991).

None of the available animal or human data suggest that MEK is carcinogenic. MEK has been demonstrated to be a developmental toxicant in animals. Birth defects included delayed skeletal development.

OSHA's legally enforceable limit for MEK is an average of 200 ppm over the standard of 8-hour work day (OSHA, 1991).

C. Potential reduction/recycle methods:

Potential reduction methods for MEK use include the use of parts washers, hot water, and citric-based compounds as a substitute for degreasing operations. Media blasting to remove paint can also be substituted for paint remover containing MEK.

XI. Methyl Isobutyl Ketone (MIBK)

A. Description of uses:

Potential AF uses of MIBK include degreasing and paint removal.

B. Basic description of chemical properties/toxicity and environmental concerns:

The primary chemical characteristics affecting the environmental fate of MIBK include high volatility and high solubility in water (Proctor, 1988). Environmental fate characteristics are very similar to those addressed previously for MEK, including:

- High potential to leach into the groundwater from contaminated soils

- High mobility in contaminated groundwater

- Significant release to atmosphere from surface waters and soils

- Relatively short half-life in the atmosphere due to reduction by hydroxyl radicals

The primary route of exposure to MIBK occurs from inhalation; however, it can also be dermally absorbed from skin contact with cleaning solvents or absorbed by the gastrointestinal system following ingestion of contaminated food or water. The primary target organs of MIBK are the kidney and liver. As with most solvents, high acute exposures to this compound cause central nervous system effects, including dizziness, nausea, and headache. MIBK has demonstrated the ability to cause adverse effects in the liver and kidneys of animals. Adverse effects in the liver include fatty accumulation and necrosis. Injury to the kidney and disruption of function can also be caused by metabolites of this compound (Amdur et al., 1991).

None of the available animal or human data suggest that MIBK is carcinogenic. Existing data suggests that MIBK is neither a developmental or reproductive toxicant.

OSHA's legally enforceable limit for MIBK is an average of 50 ppm over the standard of 8-hour work day (OSHA, 1991).

C. Potential reduction/recycle methods:

Potential reduction methods for MIBK include the use of parts washers, hot water, citric-based compounds as a substitute for degreasing operations. Media blasting to remove paint can also be substituted for paint remover containing MIBK.

Inorganic Chemicals:

The following chemicals are inorganics, primarily heavy metals and predominantly used in electroplating and paints.

XII. Cadmium and Compounds

A. Description of uses:

Potential AF uses include electroplating of steel engine parts for corrosion control

B. Basic description of chemical properties/toxicity and environmental concerns:

The most significant environmental fate characteristics of cadmium are its ability to bioaccumulate and its mobility in an aqueous environment. Compared to other heavy metals, cadmium is mobile in the aqueous environment. Cadmium can exist as the hydrated ion or complexed with carbonate, chloride or sulfate in natural waters. Because of its mobility in surface and groundwater, cadmium can be widely distributed in the environment. Cadmium has a high potential to bioaccumulate. In aquatic organisms, the greatest concentrations of cadmium are found in crustaceans and mollusks. Cadmium is one of the most readily absorbed and accumulated metals in plants grown in contaminated soils. This phenomenon was first discovered during World War II in Japan when skeletal changes were observed in older women and found to be attributable to consumption of rice contaminated with cadmium from smelter fallout in soils (Amdur et al. 1991).

The primary route of environmental exposure to cadmium is ingestion. In industrial settings, the primary route is inhalation. The primary target organs of cadmium include the lungs (for inhalation exposure) and the kidney (for oral and ingestion exposure). Acute inhalation exposure can cause pulmonary edema. Acute oral exposures cause nausea and severe abdominal pain. Chronic inhalation exposure to cadmium results in fibrosis and emphysema in the lungs. Chronic ingestion or inhalation of cadmium results in degeneration of kidney structure and function. Skeletal effects, such as osteoporosis in the women of Japan (previously discussed), are caused by excess loss of calcium in the urine due to kidney malfunction (Amdur et al. 1991).

Cadmium is considered a probable human carcinogen from inhalation exposure. Cadmium has been demonstrated to cause lung cancer in animals. Limited epidemiological evidence from cadmium workers suggests that cadmium is capable of inducing lung cancer in humans.

Cadmium has demonstrated the ability to cause malformations in the developing fetus of animals. Limited evidence suggests that cadmium may produce testicular degeneration in animals.

OSHA's legally enforceable limit for cadmium is an average of 0.2 ppm over the standard of 8-hour work day (OSHA, 1991). The EPA Maximum Contaminant Level for cadmium in drinking water is 0.005 ppm.

C. Potential reduction/recycle methods:

Potential reduction/recycle methods for cadmium include reduction in the amount of water used during electroplating to concentrate the cadmium and removal of cadmium from wastewater for reuse/recycle.

XIII. Chromium and Compounds

A. Description of uses:

Potential AF uses include electroplating of steel engine parts for corrosion control. In addition, chromium is a component of many paints.

B. Basic description of chemical properties/toxicity and environmental concerns:

Chromium is found in two major states in the environment, including chromium (III) and chromium (VI). Cr(III) occurs naturally in the environment, while Cr (VI) is generally produced by industrial processes. Chromium is primarily a concern in water and soils. Most Cr(III) will bind readily with soils. Chromium (VI) will predominantly be present in soluble form. This form of chromium may be stable enough to undergo intramedia transport; however, it will eventually be reduced to Cr(III) by organic matter in natural water. Chromium is very persistent in water and soils, with half-lives of up to 4.6 to 18 years (ATSDR, 1989b).

The primary routes of environmental exposure to chromium are oral (for environmental exposures) and inhalation (for industrial exposures); however, adverse effects are primarily associated with occupational inhalation exposures. In general, Cr(III) is non-toxic and is considered an essential food nutrient in small amounts. Cr (VI) can cause decrease in respiratory function and nasal irritation from chronic exposure (ATSDR, 1989b).

Inhalation of Cr(VI) has been demonstrated in numerous epidemiological studies of workers to cause lung cancer. Evidence for reproductive or developmental effects of chromium is inconclusive.

The Occupational Safety and Health Administration's (OSHA) legally enforceable limit for Cr(VI) is an average of 0.5 ppm over the standard of 8-hour work day (OSHA, 1991). The EPA Maximum Contaminant Level for cadmium in drinking water is 0.1 mg/L.

C. Potential reduction/recycle methods:

Potential reduction/recycle methods for chromium include reduction in the amount of water used during electroplating to concentrate the chromium and removal of cadmium from wastewater for reuse/recycle. The use of paints containing chromium could be used as a method of source reduction.

XIV. Cyanide and Compounds

A. Description of uses:

Cyanide compounds may potentially be used by the AF in electroplating solutions.

B. Basic description of chemical properties/toxicity and environmental concerns:

Cyanide most commonly occurs in the environment as hydrogen cyanide or alkali metal cyanides (potassium cyanide and sodium cyanide). The primary environmental fate characteristic of cyanide is its volatility. At a pH of less than 9.2, most of the free cyanide exists as hydrogen cyanide. Hydrogen cyanide has a moderate residence time in the atmosphere of approximately 2 years; therefore, widespread distribution in the environment is possible. The adsorption of cyanide to suspended solids and sediment is not significant; however, metal cyanides may slightly adsorb to solids. Bioconcentration of cyanide in the food chain is insignificant (ATSDR, 1992e).

The primary route of environmental exposure to cyanide is inhalation. The toxicity of cyanide is primarily due to the inability of the tissues to use oxygen. The primary target organs of cyanide include the central nervous system and the thyroid gland. Acute exposures to cyanide can result in cardiac irregularities, convulsions, coma, respiratory failure and death. Chronic exposure to low levels of cyanide can result in thyroid gland failure and an inability of the body to maintain appropriate iodine concentrations. This effect has been observed in tropical cultures who consume cassava root which contains fairly high levels of cyanide. Cyanide causes degeneration of the central nervous system. Chronic low-level exposure to cyanide causes fatigue, dizziness, headaches, and numbness in the extremities. Behavioral changes have also been observed. Effects on the nervous system may be due to oxygen deprivation caused by cyanide. Cyanide is believed to interfere with calcium flux in neurons, which is essential for transmission of signals in the brain cells and peripheral nerves. Cyanide is believed to cause enzymatic reactions with the heart muscle which lead to irregularities in contraction (ATSDR, 1992e).

Cyanide is not considered to be a human carcinogen. Inadequate data exists to assess the reproductive/developmental toxicity of cyanide.

OSHA's legally enforceable limit for cyanide is an average of 4.7 ppm over the standard of 8-hour work day.

C. Potential reduction/recycle methods:

Source reduction for cyanide may be achieved by avoiding the use of electroplating compounds containing cyanide.

XV. Lead and Compounds

A. Description of uses:

Lead is likely to exist in the paint at many AF installations.

B. Basic description of chemical properties/toxicity and environmental concerns:

In the atmosphere, lead tends to exist mainly in particulate form. Lead is highly mobile in the atmosphere due to transport of minute particles, which may be carried for thousands of kilometers. Lead can also be redeposited to soils and surface waters as a result of rainfall. Lead can exist in several forms in water. Soluble forms are dependent on pH. A significant fraction of lead carried by surface water is in an undissolved form. Lead has a high affinity and persistence in soil. Lead has a high potential to bioconcentrate in plants and aquatic organisms (ATSDR, 1990).

The primary route of environmental exposure to lead is oral. Acute exposure to lead can cause permanent brain and kidney damage, and may result in death. The primary target organ of lead is the central and peripheral nervous systems. Children are particularly sensitive to lead exposure. Young children are generally exposed to lead through hand-to-mouth contact in cases where lead is deposited on soils and lead paint is used in the homes. Central nervous system effects in children can decrease intelligence scores, retard development, and cause hearing deficits. These effects are attributable to lead action in the central nervous system of children, which is not yet fully understood. These effects occur at fairly low levels of exposure. In adults, lead can cause permanent damage to the peripheral nervous system, including reduction in motor function. Lead can also reduce the amount of hemoglobin in the blood and produce anemia. Lead is very persistent in the body and can remain in the bone for over decades (Amdur et al., 1991).

Lead is considered to be a probable human carcinogen, and has demonstrated the ability to induce kidney tumors.

Lead is associated with many adverse effects to the developing fetus, including premature birth, low birth weight, and spontaneous abortion. It has also been associated with reduced reproductive ability in males.

OSHA, legally enforceable limit for lead is an average of 0.05 mg/m3 (OSHA 1991).

C. Potential reduction/recycle methods:

Lead can be reduced at the AF installations by media-blasting of lead-based paint surfaces and disposal.

XVI. Mercury and Compounds

A. Description of uses:

Mercury is used in laboratories at AF installations.

B. Basic description of chemical properties/toxicity and environmental concerns:

Mercury exists in primarily three valence states. The distribution of mercury in the environment is characterized by degassing of the element from soils and surface waters, followed by atmospheric transport, deposition of mercury back to land and surface waters, and sorption of the compound to soil or sediment particulates. Elemental mercury is the most common form in the atmosphere. It is highly mobile and can be carried great distances and redeposited into soil and surface waters through rainfall and dry deposition. Mercuric mercury is predominately in surface water, where it partitions to particulates and settles in sediments. Mercury that is bound to particulates can be converted to insoluble mercury sulfide and precipitated or bioconverted into more volatile or soluble forms that can either enter the atmosphere or be bioaccumulated in food chains. The most common organic form of mercury, methylmercury, is soluble, mobile, and bioaccumulates strongly in aquatic organisms (ATSDR, 1993c).

The primary route of mercury exposure in the environment is oral. Acute exposure to high levels of mercury can permanently damage the brain and kidneys. The most sensitive target organ of low-level exposure to metallic and organic mercury following chronic exposures is the nervous system. The most sensitive target of low-level exposure to inorganic mercury is the kidney. The damage to the kidney is believed to be caused by an autoimmune response to kidney cells. Changes in structure and malfunction of the kidney following chronic mercury exposure have been observed in humans. Neurotoxic symptoms associated with mercury exposure include tremors, irritability, memory loss, impaired peripheral vision, and sleeping disorders. The mechanism of mercury toxicity in the nervous system is not fully understood; however, it is believed to interfere with the ability of the brain and nerve cells to transport signals and to transport nutrients (ATSDR, 1993c).

Insufficient evidence exists for mercury regarding carcinogenic activity; therefore, it is "unclassifiable as a human carcinogen".

Mercury, particularly in the organic forms, is a neurodevelopmental toxin. Mercury inhibits cell division and cell migration in the brain of the developing fetus, resulting in severe brain damage. Mercury has also demonstrated reproductive toxicity through damage to sperm.

XVII. Nickel and Compounds

A. Description of uses:

Nickel is used at AF installations as plating for corrosion control.

B. Basic description of chemical properties/toxicity and environmental concerns:

In the atmosphere, nickel tends to exist mainly in particulate form. Nickel, like lead, is highly mobile in the atmosphere due to transport of minute particles. Lead can also be redeposited to soils and surface waters as a result of rainfall. Soluble forms of nickel in water are dependent on pH. Nickel is carried by surface water in an undissolved form. The affinity of nickel for soil is dependent on organic content of the soil. Nickel does not accumulate significantly in the food chain (ATSDR, 1992e).

The primary route of environmental exposure to nickel is ingestion and dermal. The primary occupational exposure is inhalation. The respiratory system is the primary target of nickel following inhalation exposure. Effects on the respiratory system include emphysema, chronic inflammation, and fibrosis of the lung. The gastrointestinal, hematological and cardiovascular systems in humans are the targets of nickel following oral exposure. Nickel has been demonstrated to cause vasoconstriction in the heart and enlargement of the heart muscle. Gastrointestinal effects include nausea, cramps, diarrhea, and vomiting, and ulcers in the gastrointestinal tract. Nickel can also reduce hemoglobin and white cell counts following oral exposure (ATSDR, 1992e).

Nickel is classified as a human carcinogen. It has been demonstrated to cause lung and nasal cancer in epidemiological worker studies.

Developmental toxicity to the fetus and a decrease in birth rate have been observed in animals following nickel exposure.

OSHA's legally enforceable limit for nickel is an average of 0.1 mg/m3 over the standard of 8-hour work day (OSHA, 1991).

C. Potential reduction/recycle methods:

Potential reduction/recycle methods for nickel include reduction in the amount of water used during electroplating to concentrate the chromium and removal of cadmium from wastewater for reuse/recycle.

CASE STUDY 1: THE ECONOMIC AND ENVIRONMENTAL BENEFITS OF PRODUCT SUBSTITUTION FOR ORGANIC SOLVENTS

<u>Objective</u>: To develop a methodology for evaluating an alternative solvent to be used in the cold cleaning degreasing operations of metal parts.

<u>Background</u>: Stoddard solvent was compared against the class of terpene solvents specified for industrial cleaning operations. The methodology for selecting and evaluating the alternative solvent considers cleaning efficiency, environmental factors and overall costs.

Stoddard solvent is generally a mixture of straight and branched-chain paraffins, naphthenes, and aromatic hydrocarbons. Terpene cleaners, naturally derived and aqueous-based, have been proposed as the substitution for Stoddard solvent. Characteristics such as natural components, biodegradability, low volatility, and reduction for land disposal have made the terpene cleaners a favorable alternative.

Stoddard solvent can be recycled on-site using distillation stills. The portion of the solvent that accumulates on the bottom of the cold cleaning and distillation is not recyclable or reclaimable. It is currently disposed of through incineration, fuel substitution, surface disposal, or sale.

Terpene cleaners cannot be recycled. Most chemical manufacturers suggest terpene cleaners be disposed of in the storm sewer or receiving water, after used emulsions have been allowed to separate and the top layer of oil has been skimmed. Permitted to stand overnight, oil, greases, and carbonaceous particles should rise to the top of a tank, so that residues can be easily skimmed. The accumulation of soil remaining at the bottom of the tank is said to be biodegradable, and therefore easily disposed of in accordance with local, state, and federal EPA regulations.

Installations use Stoddards solvent to perform various functions, such as:

- Restore or maintain the operating efficiency of equipment
- Minimize corrosion and extend equipment life
- Allow for inspection and repair of equipment
- Improve exterior appearances

Stoddard is generally used in cold cleaning processes. Cold cleaning is the major non-vapor, surface preparation process designed to remove grease, oil, carbon, and other soil from parts. During these processes, Stoddard continuously degrades in quality because of accumulation of soluble and insoluble material.

A number of studies have been conducted to evaluate the credibility of new, commercially available terpene cleaners. The testing locations have included the Air Force Engineering and Services Center (AFESC) and Kelly AFB.

Results:

Air Force Engineering and Services Center Study

Hundreds of terpene cleaners were evaluated as potential substitutes for halogenated (chlorinated) and nonhalogenated (Stoddard) solvents used in the USAF in the program titled, "Substitution of Cleaners with Biodegradable Solvents." This program was conducted by the AFESC at Tyndall AFB, Florida. This table presents the results and comments from the AFESC.

Kelly AFB Study

Kelly AFB, Texas, conducted a site-specific study on the use of terpene cleaners in 1988. The study was initiated in the process of identifying less hazardous alternatives to solvents and cleaners currently used on the service equipment a the base.

Selected terpene cleaners have been approved for limited use at Kelly AFB. Cleaning guidelines have been developed for the use of terpene cleaners on jet exterior washing and parts cleaning, cleaning exterior surfaces of selected aircraft, and for aircraft exterior spray-on, wipe off cleaning. This table presents the results and comments from the Kelly AFB study.

CASE STUDY 2: SOLVENT SUBSTITUTION FOR ELECTRONIC ASSEMBLY CLEANING

<u>**Objective**</u>: The Department of Energy (DOE) conducted a study to identify alternate materials/processes to the use of chloroflourocarbon and chlorinated hydrocarbon solvents from weapons production activities.

<u>**Background**</u>: The DOE weapons complex uses chloroflourocarbon and chlorinated hydrocarbon solvents for most cleaning and degreasing operations. Since electronic assembly cleaning processes account for a large percentage of total halogenated solvent usage within the complex, the DOE established a program to identify, qualify, and implement alternative materials/processes that would eliminate halogenated solvents from the cleaning processes. The program focussed on a major electronic system. The fabrication of this system requires 49 separate solvent cleaning steps using TCE. The cleaning steps are primarily for the removal of rosin solder flux residues after soldering, cleaning of competed subassembly and assembly modules, and cleaning of silicone mod release from encapsulated units.

Two separate options were investigated. The first is to use alternative cleaning materials in lieu of the halogenated solvents. The second option involves alternative processing using water soluble soldering fluxes rather than the RMA solder flux that was currently in use. Water soluble fluxes can be cleaned with water, eliminating the use of halogenated solvents. Hot deionized water, followed by isopropyl alcohol, was used to remove residues from both the water soluble solder flux and the silicone module release agent.

<u>**Conclusions**</u>:

An oxo-decyl acetate and terpene cleaner were found to be as effective as TCE in removing the RMA flux, silicone mold release agent, and general production area contaminants. Although the second alternative with DI water/ and IPA was effective, the cleaning process was less effective than the terpene cleaner.

BLOCK 9: STRATEGIC WASTE MINIMIZATION INITIATIVE (SWAMI) WORKSHOP

1.0 Introduction

Block 9 provides students hands-on instruction using the Strategic Waste Minimization Initiative (SWAMI). SWAMI is demonstrated as a tool for using process analysis for identifying source reduction opportunities within DoD, and as a scheme for identifying and prioritizing (on a cost or volume basis) waste reduction opportunities in process units and treatment operations, performing mass balance calculations, drawing process flow diagrams, and directing the selection of candidate source reduction strategies. Students are expected to understand SWAMI and be able to apply this analytical tool in case study Blocks during the Course.

2.0 Objective

To demonstrate SWAMI as a tool for using process analysis for identifying source reduction opportunities within DoD, and as a scheme for identifying and prioritizing (on a cost or volume basis) waste minimization opportunities in process units and treatment operations, performing mass balance calculations, drawing process flow diagrams, and directing the selection of candidate source reduction strategies. Note: Includes computer-based instruction.

Using a combination of listening to a lecture, watching a demonstration, and "hands-on" exercises,

1. Students will become familiar with the SWAMI interface by entering data from a case study;
2. Students will learn the fundamental equations and logic used for the basis of SWAMI functional capabilities, such as the accounting methods used to track materials, treatment costs, and disposal costs throughout the operation comprising a process by entering data from a case study;
3. Students will learn the process analysis capabilities of SWAMI by entering data from a case study;
4. Students will learn to prioritize pollution prevention opportunities using SWAMI by entering data from a case study;
5. Students will learn to use SWAMI to develop pollution prevention strategies by entering data from a case study;
6. Students will learn to use SWAMI to do mass balance considerations by entering data from a case study;
7. Students will learn the limitations of SWAMI, such as its inability to automatically transform waste reduction strategy concepts into specific solutions, and its inability to perform a cost-benefit analysis;
8. Students will learn how to save data, backup data, print reports, and display flow diagrams by entering data from a case study; and then saving data and backing up data to their own individual disks.

3.0 Key Concepts

I. INTRODUCTION

As part of the Air Force's commitment to environmental protection, the Secretary of the Air Force has called for a service-wide commitment to pollution prevention which includes requirements for specific reduction in the generation of hazardous waste and concomitant reductions in the uses of hazardous materials. Specific reduction goals to be achieved are based on FY 1992 actual use and generation rates as baseline. Since pollution prevention activities can only be performed on individual processes (e.g., parts plating, solvent cleaning, paint stripping and repainting, engine overhaul, etc.) the measures of baseline use and generation of hazardous materials and wastes should be on a process-specific basis. The U.S. Environmental Protection Agency and the University of Dayton developed a unique tool in 1990 for supporting several aspects of pollution prevention including: process data gathering, process analysis, pollution prevent opportunity assessments and process mass-balance validation. The existing software tool (called the Strategic WAste Minimization Initiatives or SWAMI) could readily be enhanced to develop base-wide, command-wide and even service-wide data about present generation rates of hazardous and non hazardous waste for individual types of production, rework and maintenance processes with the Air Force. SWAMI was developed by a project team including Mr. Doug Williams as the EPA project officer, Dr. Joseph Swartzbaugh (UD) and Mr. Jeff Sturgill (OpTech) as logic developers, and Mr. Clarence Cross as the software developer. This, however, does not answer the question of what function SWAMI performs. In order to address this question, one must examine the steps required to perform a waste minimization (pollution prevention) audit.

To increase the likelihood of success, a comprehensive waste minimization program should proceed as follows:

1. Begin with the support of top management.
2. Build a team which includes members from any group or department of the company which has an interest in the outcome of the program.
3. Set reasonable and measurable goals.
4. Select a process and collect data.
5. Identify points of opportunity.
6. Prioritize the opportunity points.
7. Develop candidate waste minimization solutions for one or a few selected opportunity points(s).
8. Perform feasibility analyses.
9. Perform a cost benefit study for one or more feasible solutions.
10. Implement the chosen solution.
11. Measure and report results.
12. Repeat steps 3-11.

SWAMI Version 2.0 is a tool which encourages and assists a systems analysis approach to waste minimization and provides features for performing steps 5-7 with guidance for performing steps 8 and 9. In addition to its waste minimization applications, it can be used to develop process flow diagrams and perform mass balances of any industrial process. These features will assist the user in developing pollution prevention plans and in toxic material inventory reporting. SWAMI operates on DOS-based IBM-compatible personal computers (80286, 80386 or 80486) with a hard disk and 640K of RAM (random access memory).

II. SWAMI - GETTING STARTED

A. Installing SWAMI

B. Calling up SWAMI

C. Process description and Main Menu.

Instructor should boot up SWAMI by typing "SWAMI1".

Instructor should mention that at any time, typing <Esc> goes to a previous screen and HELP is always available by typing the F1 key.

III. PROCESS DEFINITION

While running through the following material, the appropriate screens.

A. Unit Operations

Installation of SWAMI is easily performed using the following five steps:

* insert floppy into drive
* create a directory for SWAMI
* configure your files
* run the configuration
* reboot your system

These steps are described in the SWAMI User's Manual.

B. Waste Streams

SWAMI is called up by defining a problem, such as SWAMI1, SWAMI2, etc. When completed with your use, the SWAMI problem can be copied to a disk.

C. Input Materials

One problem frequently encounted when calling up SWAMI is that your files have not been configured properly. This can be solved by changing your file paths and your configurations.

D. Products

Some of the parameters that need to be defined include:

- unit operations
- waste streams
- input materials
- products
- chemical formula rules
- treatments or blends

E. Chemical Formula Rules

F. Treatments/Blends

A blend is different from a treatment in that two waste streams are conformed together.

IV. PROCESS FLOW DIAGRAMS

Instructor should key to process flow diagram screen.

V. MASS BALANCE

Instructor should key to mass balance screen.

VI. PRIORITIZATION

Instructor should key to prioritization - as well as placing figure on overhead projector.

VII. STRATEGIZING WITH SWAMI

VIII. SAMPLE PROBLEM

Instructor:

SWAMI is best learned by using it and for this reason we will work through a sample problem to familiarize you with the various aspects of this software. Later, you will be involved in four separate SWAMI exercises to provide "hands-on" experience with this software.

NOTE: The following sequence of actions are those which should be performed by the instructor. Results and explanations are provided with most actions.

IX. KEY POINTS

People, when first using SWAMI, often have difficulties dealing with the prioritization logic dealing with waste inputs, as well as the difference between blends and treatments. These points should be especially reviewed by the instructor and students.

The mass balance calculations, while not environmentally related, were called for by people in industry. For this reason, they are probably more important to the process engineers. Finally, after working with SWAMI for a long enough period of time, and having become familiar with various pollution prevention strategies, you may find that you don't need SWAMI anymore. This is probably because perhaps the most important feature of SWAMI is that it <u>forces</u> you to perform a good audit of your process. Once these "good habits" are developed, SWAMI users have claimed that they need to implement it less. Now try the exercise in the SWAMI User's Guide .

X. SUMMARY

The exercise was designed to familiarize you with the features of SWAMI for performing particular tasks. Hopefully you will be able to use this exercise when you return to your facilities. In subsequent exercises you will be using SWAMI for specific applications that should be relevant to you. You can take your file with you so you can reconstruct how you solved the problem using SWAMI.

BLOCK 10: CASE STUDIES: REVIEW OF PAINT REMOVAL TECHNOLOGIES

1.0 Introduction

Block 10 overviews case studies that demonstrate waste problems that occur during depainting operations. Current methods of depainting are presented, as well as innovative technologies under development. The use of alternative solvents, alternative depainting media, alternative depainting processes, and enhanced recovery systems are described. Benefits from the reduction of hazardous materials used in depainting, as well as reduction in the amount of hazardous material/waste generated are presented. Block 10 also includes a computer exercise using SWAMI to develop and analyze pollution prevention strategies for a specific paint removal case study.

2.0 Objective

To present case studies that demonstrate waste problems that occur during depainting operations. Current methods of depainting will be presented, and innovative technologies under development will be discussed. The use of alternative solvents, alternative depainting media, alternative depainting processes, and enhanced recovery systems will be discussed. Benefits from the reduction in the amounts of hazardous materials used in depainting, as well as the amount of hazardous material/waste generated, will be presented.

1. Students will learn current and developmental depainting technologies, with an emphasis on reducing the amount of pollutants.

2. Students will be introduced to current and developmental depainting operations.

3. Students will learn the benefits of waste generation from the use of alternate materials, processes, and recovery systems in depainting operations.

4. Students will be presented case studies of DoD depainting activities, with an emphasis on pollution prevention. Developmental depainting operations for unique aircraft, such as the B-2 bomber, will be introduced.

3.0 Key Concepts

I. INTRODUCTION

Paint removal - a major source of hazard waste at an Air Force Base. Depending on the type of paint, especially the lead and chromium based ones, and the removal method, particularly volatile solvent extraction, paint removal can create unacceptable worker conditions and very nasty air and water waste streams. The purpose of this lecture is to present information and case studies on alternative and less hazardous paint removal techniques.

Supplemental product information provided by suppliers of several of the paint removal products/technologies identified here today is included in the course notebook (e.g., typical applications, process features, operating data and performance).

Paint removal technologies currently used at three Air Force Bases, along with ongoing research and development conducted DoD-wide will also be discussed. In general, the trend appears to be away from the chemically-based strippers which can generate air emissions and hazardous waste that is difficult and expensive to control. With respect to the performance results of some of the newer technologies with pollution prevention benefits, there is often conflicting information, i.e., what works well at one AFB or in one type of application does not necessarily work well in another; this will be pointed out during the course. Finally, we will show a 45 minute video that presents in greater detail two alternative methods being used by the Air Force to strip paint without using solvents: (1) the use of a bicarbonate soda (baking soda) stripping system , and (2) CO2 blast paint stripping.

II. PAST PRACTICES - USE OF CHEMICALLY BASED PAINT STRIPPERS

A. General Problem Statement: Conventional paint stripping processes use large volumes of toxic chemicals to strip paint from military hardware. This results in the generation of large quantities of hazardous waste requiring expensive disposal as a RCRA waste for which the Air Force maintains liability in perpetuity. In addition, worker safety is jeopardized by constant exposure to these toxic chemicals. These strippers have been proven toxic to humans even at low levels of exposure. Control equipment is required to capture vapors resulting from use of these solvents.

B. Hazardous Materials of Concern

1. What they include - identify list of chemicals
   a. methylene chloride (CH_2Cl_2)
   b. phenol
   c. formic acid
   d. sodium chromate
   e. sulfuric acid
   f. methyl ethyl ketone (MEK)
   g. methyl isobutyl ketone (MIBK)

2. General concerns
   a. DOD HAZMIN program goals
   b. hazardous waste disposal
   c. air emissions - VOC emissions regulated for overall VOCs and specific compounds
   d. health effects
   e. regulatory trends (Clean Air Act, OSHA, RCRA, Pollution Prevention Act of 1990; state mandated; industrial toxics projects)
   These are becoming more stringent.

3. Concerns specific to Methylene Chloride

Methylene chloride is a colorless liquid with a chloroform-like odor. It is incompatible with strong oxidizers, caustics, and chemically active metals such as aluminum, magnesium powders, potassium and sodium, as well as concentrated nitric acid.

a. Industrial Toxics Project

33/50 goals; one of EPA's 17 targeted chemicals (reference other course)

b. Health Effects (known carcinogen)

A known carcinogen, it causes cancer in rats and mice, attacking the skin, cardiovascular system, eyes, and central nervous system.

c. Compliance with Environmental Regulations (Clean Air, Clean Water, CERCLA, RCRA and local EPA and AQMD rules)

d. Compliance with new permissible exposure limit set by OSHA

The Occupational Safety and Health Administration (OSHA) is promulgating new requirements for methylene chloride, to drop the permissible exposure limit (PEL) from 500 ppm averaged over eight hours to a 8 hour time weighted average of 25 ppm. OSHA is also proposing a Short Term Exposure Limit (STEL) of 126 ppm measured over 15 minutes. If implemented, this will essentially eliminate future use of methlyene chloride, as engineering controls cannot control to that level (it is currently illegal for use in California).

C. Advantages/benefits of using chemically based paint strippers

1. Removal effectiveness
2. Non-abrasive (i.e., does not harm metal surfaces)

D. Examples of Traditional Chemical Paint Stripping

1. DoD installations - Examples

As mentioned previously, the trend is away from chemically based strippers. However, they are still preferred in certain situations.

a. Tinker AFB, Oklahoma City, Oklahoma

Chemical removal issued on primary structures (fuselage and wings) to lessen the risk of material thinning or stressing. Chemical removal agents used at Tinker AFB include Benzylalcohol and methylene chloride. Benzylalcohol is the most commonly used, because it is the least harmful to the environment. It has a one time use, and has an excessive turnaround time of 18 hours. Methylene chloride is used in situations where time is of the essence. Methylene chloride is used to a small degree to strip engine mounts.

b. Charleston AFB, South Carolina

Charleston uses chemicals only for small parts. Some of the chemicals previously used were methylene chloride, phenol-based strippers, and methyl ethyl ketones (MEK). MEK is the chemical that is currently used for small applications. The base purchased a recycling unit that allows reuse of MEK.

c. Offutt AFB, Omaha, Nebraska

MEK is used to a small degree for removing neoprene (a tough, synthetic rubber that resists many solvents).

2. Industry Example - Boeing

The majority of paint removal at Boeing is for equipments on the assembly line which needs to be repainted due to inspection failure. Boeing uses chemical stripping almost exclusively because of its removal effectiveness, and the fact that it does not harm metal surfaces. The FAA does not allow more than one stripping by plastic media before sale to a customer. Apparently, on thin aluminum or magnesium surfaces, plastic blasting can flatten out or mar the surface and might hide surface stress fractures. This is not such a problem with solid pieces such as landing gear. Chemicals currently used are methylene chloride and sulfuric acid based dips. Boeing has evaluated many lower hazard chemical strippers, but virtually no alternative chemical stripper has been found to be effective for its particular applications. Also note R&D being done at Boeing - carbon dioxide still in experimentation; wheat starch is still in experimentation; experimenting with plastic media in limited applications (helicopters, not airplanes).

III. POLLUTION PREVENTION OPPORTUNITIES IN PAINT STRIPPING

In general, all of the pollution prevention opportunities identified below have the following advantages over chemically based paint strippers: reduced employee exposure to regulated solvents and hazardous cleaning formulations; avoidance of regulatory compliance standards governing toxic air emissions and hazardous waste disposal; reduced excess costs for ensuring proper management and disposal of wastes; minimal environmental risks and the potential for costly liabilities.

A. DOD HAZMIN Program

B. Waste Minimization Strategies

1. Maximize stripping efficiency
2. Maximize recycling/reuse
3. Select least hazardous medium
    a. material substitution
    b. process substitution

C. Reuse/Recovery/Recycle

Common sense and good housekeeping measures can go a along way here. For example, Charleston AFB uses methyl ethyl keytone (MEK) as a chemical stripper for small applications. The base purchased a recycling unit that allows reuse of MEK. Over 95 percent of the amount initially applied can be now be recycled for reuse, leaving less than 5 percent as waste.

Closed Loop Mechanical Paint Stripping
Mechanical paint stripping methods, which are discussed later, also offer recycle opportunities. When using plastic media, a liquid density separation process has been shown to allow recovery of the media for reuse, thus reducing hazardous waste volume requiring disposal by 95 percent. Field demonstrations on F-4 aircraft began in 1990.

D. Material Substitutions

An example of this would be the replacement of methylene chloride based strippers with other materials.

1. Alternative Organic Strippers

Description - Methylene chloride based strippers replaced with potentially less harmful organic solvents.

Advantages - commercially available; probably safest

Disadvantages - being tested; long-term health effects unknown; questions concerning effectiveness, speed, depletion, ease of disposal.

Example: Note the use of benzylalcohol as a replacement for CH_2Cl_2 at Tinker AFB discussed in D.1.A above.

Example: The development of non-methylene chloride paint stripper is being performed by the Naval Air Warfare Center Aircraft Division Warminster (NAWCADWAR) and Tyndall AFB in a joint effort.

2. Low emission Methylene chloride based paint stripper

Description - Methylene chloride based paint stripper replaced with low emission methylene chloride solvent.

Advantages - inhibited emission characteristics while maintaining stripping power of methylene chloride; formula design "locks" solvent into engineered matrix which minimizes evaporation; dwell time 15 to 45 minutes.

Disadvantages - cannot be used on plastic fiberglass, plexiglass, rubber and fabrics; rinse water and solid residues must be managed in accordance with required regulatory statutes.

E. Process Substitution

The greatest opportunities appear to be in this area. Process substitutions include variations of Dry Media Blast, Liquid Media Blast, Pulse Media Blast, Enzymatic "biostripping", and others (e.g., salt bath, burn-off, and hot ceramic).

1. Dry Media Blast

a. Plastic Media Blasting

Description

Bombardment of coated media with soft plastic granules. Millions of lightweight plastic particles can be propelled by air pressure, centrifugal wheel or water blast to scrape and chip off paint, coatings and contaminants. Some controversy surrounding potential damage to substrates and recycling opportunities/concerns.

Advantages

- well developed technology
- uses conventional blasting equipment

- no liquid hazardous waste
- safe

Disadvantages

- large amounts of solid waste
- recycle of media difficult
- May contribute to metal fatigue
- Potential crack closure

Specific Examples

Charleston AFB uses plastic media blasting (PMB) for almost all parts, except the small ones (they use chemical for those). They found that CO^2 was too slow and that glass and sand posed waste disposal problems (large quantities). Turnaround time of 30 minutes.

Offutt AFB uses both plastic and glass beads.

Boeing uses PMB to effectively strip paint from helicopters. Plastic media are not presently used to strip paint from airplanes, however, because there is concern that their impact could mar the skin of the plane and obscure indications of metal fatigue. Boeing continues to test plastic-media paint stripping to determine if this process has any further applications. According to Boeing, FAA does not allow a plane to be stripped more than once prior to sale to a customer.

Mechanical paint removal from F-4 aircraft using PMB has been used at Ogden ALC, Hill AFB,UT to save $2.8 million annually (per 205 F-4 aircraft).

McClellan AFB, CA uses recyclable plastic beads, in six major bead blast stations to peel paint from bare metal without harming the aircraft skin. All recycle and recover about 90 percent of the plastic media. PMB produces about 3,000 lbs of solid waste per aircraft compared to 10,000 galls of hazardous waste that would be produced from stripping with CH_2Cl_2. Methylene chloride consumption was reduced from 25,000 lbs in 1986 to 7,400 lbs in 1990.

General Dynamics replaced methylene chloride stripping with a PMB system in 1988. The system had a payback period of 3.6 years based on waste disposal cost savings alone.

b. CO2 Blasting (Dry Ice Blasting)

Description

Bombardment of coated media with solid carbon dioxide pellets, which vaporize, leaving paint chips. Application limitation: should not be used on surfaces susceptible to damage.

Advantages

- Only paint chips require disposal
- No intrusion problems
- Effective against most coatings
- No need to preclean aircraft
- Little masking required

Disadvantages

- Potential surface damage
- Operator needs contained air supply
- Slow stripping rate
- Surface may not be left readily repaintable

- Equipment costly, heavy

Specific Examples

Tinker AFB used carbon dioxide. They found that it was ineffective and have discontinued use. Slow and too abrasive, although a clean operation, according to Boeing. Also, the carbon dioxide vapor cloud can interfere with visibility during operation.

However, the process does have some application. The Norfolk Naval shipyard performed an evaluation in 1989, followed by a comparative study of two commercially available CO_2 blast jet systems in 1991. Results of these studies indicated that solid CO_2 blasting is useful for degreasing operations and for the removal of antifouling and other soft paints.

c. Liquid Nitrogen (Cryogenic Stripping)

Description
Coated fixtures are loaded into a cryogenic chamber and sprayed with liquid nitrogen, causing the paint or coating to become brittle. Centrifugal wheels propel non-abrasive plastic shot which fractures and removes the embrittled paint. Used on small scale application.

Advantages

- Small units commercially available
- No liquid hazardous waste

Disadvantages

- Not applicable to large scale ops
- Epoxy and urethane coatings are more difficult to remove
- Being researched

Specific Example

Air Products and Chemicals offer a Cryogenic Coating Removal system (Cryostrip) which is a highly engineered stainless steel system.

Only five units have ever been sold (to General Motors) and the system is no longer being actively marketed. Its disadvantages are: high capital cost; batch only; only good for thick coatings (i.e., greater than three layers). NOT SUITABLE FOR AIR FORCE.

However, a company named Volumatic, Inc. is developing a continuous (or mobile batch) cryogenic CO_2 system that is claimed to have improved upon the typical drawbacks associated with CO_2 pellets, namely improved pellet feeder systems and nozzle design. Air Products' interest is the use of liquid nitrogen as an amendment to fracture the paint.

d. Wheat Starch Blasting

Description

- Crystallized wheat starch used as the blast media.
- Application: general stripping

Advantages

- Effective against wide variety of coatings and substrates
- Very little damage to substrates
- Media biodegradable

Disadvantages

- Recycle of media difficult
- Potential storage bacterial growth
- Concerns with spontaneous combustion

Specific Example

Boeing has approved use of wheat starch on all commercial aircraft. Northrop is considering use of wheat starch on the B-2 bomber.

e. Others

- Walnut shell
- Steel shot
- Grit blasting
- Pentek/steel tubes

2. Liquid Media Blast

a. Sodium bicarbonate blasting

Description

Sodium bicarbonate slurry used as blast medium. Extensive rinse required. Water carries the abrasive and prevents dusting. Used in general paint stripping.

Advantages

- Little impact substrate damage
- Media inexpensive
- Dedicated facility not required
- Very effective - bicarbonate is hard enough to cut paints but friable and soft enough to prevent damage of even soft metals such as aluminum or copper.
- No problem with fumes

Disadvantages

- Much wastewater generated
- Corrosion concerns
- Media not recyclable

Specific Example

The Navy is investigating the use of sodium bicarbonate for depainting and cleaning bilge areas.

Mike Haas from the San Antonio ALC describes the use of Sodium bicarbonate stripping systems on the video.

b. Ice/Water jet blasting

Description

Ice slurry used as blast medium. Used in general paint stripping applications.

Advantages

- Safe in confined environment
- Very little damage to substrates
- No precleaning required

- Dedicated facility not required

Disadvantages

- Being studied
- Application to high performance exterior coatings in question.

Specific Example

Tinker AFB is at the experimental stage with high pressure water. They are developing robots for water jet application, which they expect to test in the near future. However, according to Charleston AFB, this technology is not allowed by the Air Force since it results in delamination.

The Army is also testing Waterjet paint stripping.

3. Pulse Media

a. Xenon Flashlamp Stripping

Description

High-energy quartz lamps used to evaporate coating. Used in stripping except for surfaces susceptible to damage.

Advantages

- Very little waste generated
- Not harmful to electronics

Disadvantages

- Requires extensive training
- Need to control gases produced
- Questions with respect to surface damage, worker safety
- Not effective on light-colored coats

Specific Example

McDonnell Douglas Aerospace (St. Louis) in April 1993 introduced a coatings removal process that reduces toxic wastes by 99 percent. This system (the Flashjet system) was jointly developed with the Maxwell and Cold Jet Inc. companies in cooperation with Air Force (awaiting certification) and was field tested on F-15s at Warner Robbins ALC.

The Flashjet system softens paint with pulsed-light energy created by a xenon flash lamp; dry ice pellets simultaneously cool the surface and remove the softened paint, which is collected in a disposal system. The CO_2 pellet spray component of the system operates at reduced pressure to minimize surface damage by abrasion. The Naval Air Systems Command is also interested in this combination.

The company reports that paint stripping an aircraft with 8,000 ft^2 of painted surface using CH_2Cl_2 releases about 10,000 lbs of VOCs and generates about 70,000 galls of contaminated rinsewater. Waste disposal for these volumes can cost up to $20,000. Flashjet generates no new waste, and the paint can be disposed for as little as $250, according to the company.

The traditional stripping method includes washing and rinsing steps; Flashjet involves only stripping. Conventional methods would require 600 manhours to accomplish the same results that Flashjet can achieve in 70 manhours, and throughput time would be reduced from 48 to 24 hours, the company says.

b. Laser Paint Stripping

Description

Pulsed laser evaporates coating. Used for stripping except for surfaces susceptible to damage

Advantages

- Very little waste generated
- Easier control than flashlamp

Disadvantages

- Need to control gases produced
- Expensive (robotics)
- Questions with respect to surface damage, worker safety
- Potential harm to electronics

Specific Example
This technology is being investigated at Wright-Patterson AFB. Industrial lasers together with controls, sensors and robotic systems, are available to facilitate design of a customized system. This technology is also being investigated by the Navy for removal of shipboard coatings.

4. Infra-Red

a. Description

Concentrated infra-red light is used to instantaneously heat coating to the point of combustion. Coatings attain high temperature while temperature of substrate is not significantly affected. Coatings immediately reduced to ash and vacuumed into a built-in compliant HEPA containment system; substrate and its original anchor pattern left completely in tact.

b. Advantages

Production rate comparable to blasting but without using water or hazardous chemicals; containment structures not necessary; can be applied to remove coatings on/or around delicate equipment.

c. Disadvantages

d. Specific Example - none available

5. Enzymatic Biostripping

a. Description

Identification and production of microbial enzyme responsible for degrading paint, which would be applied to surface. Used in stripping and in treatment of stripping wastes.

b. Advantages

- Degradation of paint chip wastes
- Reduction of wastes generated
- Safe for worker
- Less damaging to substrate
- Potentially economical

c. Disadvantages

Early R&D stages

Still characterizing candidate enzymes. Plans are to use rDNA techniques to produce suitable enzymes on large scale, in cooperation with University of Maryland.

6. Other Methods

a. Description

Processes, generally non-aerospace related, including molten salt bath, burn-off, hot caustic strip baths. Used in the stripping of steel; generally only applicable to steel.

IV. CURRENT R&D TRENDS WITHIN THE MILITARY

A. HAZMIN Technologies under Development

1. Process Changes

a. Plastic media blasting to replace wet solvent stripping (Air Force, Army, Navy)
b. Fluidized bed paint striping for small parts (Army; example)
c. Extension of stripping solutions by dialysis and filtration (Army)
d. Cryogenic paint stripping (Navy)
e. Paint removal using a pulsed carbon dioxide laser (Navy)
f. Ultraviolet (UV) light based systems

2. Materials Substitution

a. Biodegradable paint strippers (Tinker AFB: Candidate biodegradable materials will be screened for performance as abrasive blast paint stripping media. Currently, PMB processes generate large quantities of solid waste, classified as hazardous because of constituent leachable heavy metals, although the major component is spent plastic media. Efforts to separate the heavy metals have been unsuccessful to date. Biodegradation of the spent plastic media is a treatment option that would decrease the mass of the waste by approximately 95 percent.

b. Alternate chemical paint stripper formulations (Army)

c. Development of sinkable/biodegradable plastic (Navy)

3. Recovery/Reuse

a. Recovery of treated plastic media blasting waste (Air Force; example)

b. Reuse of solvents after distillation/filtration (Air Force)

c. A Fluidized Bed Calciner Detoxification/Reprocessing system is being developed by the Navy recycling of contaminated abrasive blasting dust, such as aluminum oxide and garnet.

4. Volume Reduction of Hazardous Waste

Low Temperature Ashing of PMB Waste (Tyndall AFB). This is another effort to remove the plastic component of the hazardous contaminated spent plastic media in order to achieve a 95 percent volume reduction.

V. SUMMARY

In this class we have covered current and developmental depainting technologies, with an emphasis on reducing the amount of pollutants. We have looked at case studies with actual technologies being used at Air Force bases. And finally, we identified pollution prevention opportunities in paint stripping. You are now familiar with the techniques that the Air Force is currently using in paint removal along with upcoming technologies in development. Why did we even discuss CH_2Cl_2? Because we need to limit its use and find alternatives that are being used. We need to apply this and other identified solutions to your paint removal pollution problems.

BLOCK 11: ECONOMIC EVALUATION

1.0 Introduction

This Block describes cost estimation methods used in pollution prevention programs. The concept of externalized costs is discussed. Life-cycle cost estimation methods and identifying the benefits of pollution prevention measures in program or product cost estimates also is presented.

2.0 Objective

To review of methods for cost evaluation used in pollution prevention projects, and the benefits achieved by ensuring that pollution prevention decisions related to products are considered in an analysis.

1. Students will learn selected methods for economic evaluation, using standard measures of profitability;

2. Students will learn all the cost involved in waste management opportunity assessments;

3. Students will learn the basic economic goals for a source reduction project;

4. Students will identify the variety of operating costs considered in source reduction.

3.0 Key Concepts

OVERVIEW:

In the past, preparing financial justification for pollution prevention projects has often been limited to declaring that if funding were not provided, an environmental incident would lead to a lawsuit or citations.

Usually, because funds were fairly plentiful, these projects would get funded. In some cases, this approach may have led to projects with limited benefit (albeit a higher potential for generating lawsuits or citations) being funded, while other more beneficial projects may have been delayed.

Whenever funds would get tight, however, pollution prevention projects would usually take a backseat to other, better justified projects.

In today's funding situation, pollution prevention projects have to have the same level of justification if they are going to compete for the limited resources available to the Air Force.

We certainly can and should utilize factors such as regulatory requirements and the prevention of fines or citations as part of the justification, however, a more detailed financial justification will greatly increase the projects's chances of being funded.

To be able to prepare this detailed financial justification, an understanding of financial concepts and factors is necessary. Factors such as payback period, return on investment, and net present value are important concepts in preparing the financial justification for any project. These financial tools can demonstrate the importance of the pollution prevention investment on a life cycle or total cost basis; in terms of revenues, expenses, and profits.

The concept of life cycle costing, or Total Cost Accounting (TCA), analyzes the costs and benefits associated with a piece of equipment or a procedure over the entire time the equipment or procedure is to be used. This concept was first used by the Department of Defense in procuring large weapon systems.

Experience showed that the up-front purchase price was a poor measure of the total cost; costs such as those associated with maintainability, reliability, disposal/salvage value, and training/education have to be evaluated when making financial decisions. When justifying pollution prevention projects, these same factors should be evaluated as carefully as possible to arrive at a clear picture of the total cost/benefit of the proposed system. Generally, costs elements can be divided into two categories; capital costs and operating costs.

Economic Evaluation

The economic evaluation is carried out using standard measures of profitability, such as payback period, return on investment, and net present value. Each organization has its own economic criteria for selecting projects for implementation. In performing the economic evaluation, various costs and savings must be considered. As in any projects, the cost elements of a pollution prevention project can be broken down into capital costs and operating costs. The economic analysis described in this section represents a preliminary, rather than detailed, analysis.

For smaller facilities with only a few processes, the entire pollution prevention opportunity assessment procedure will tend to be much less formal. In this situation, several obvious options, such as installation of flow controls and good operating practices may be implemented with little or no economic evaluation. In these instances, no complicated analyses are necessary to demonstrate the advantages of adopting the selected options. A proper perspective must be maintained between the magnitude of savings that a potential option may offer, and the amount of manpower required to do the technical and economic feasibility analyses.

Capital Costs

Viewgraph 2 is a comprehensive list of capital cost items associated with a large plant upgrading project. These costs include not only the fixed capital costs for designing, purchasing, and installing equipment, but also costs for working capital, permitting, training, start-up, and financing charges.

With the increasing level of environmental regulations initial permitting costs are becoming a significant portion of capital costs for many recycling options (as well as treatment, storage, and disposal options). Many source reduction techniques have the advantage of not requiring environmental permitting in order to be implemented.

Operating Costs and Savings

The basic economic goal of any pollution prevention project is to reduce (or eliminate) waste disposal costs and to reduce input material costs. However, a variety of other operating costs (and savings) should also be considered. In making the economic evaluation, it is convenient to use incremental operating costs in comparing the existing system with the new system that incorporates the pollution prevention option. ("Incremental operating costs" represent the difference between the estimated operating costs associated with the pollution prevention option, and the actual operating costs of the existing system, without the option.) Viewgraph 3 describes incremental operating costs and savings and incremental revenues typically associated with pollution prevention projects.

Reducing or avoiding present and future operating costs associated with waste treatment, storage, and disposal are major elements of the pollution prevention project economic evaluation. Companies have tended to ignore these costs in the past because land disposal was relatively inexpensive. However, regulatory requirements imposed on generators and waste management have increased to the point where it is becoming a significant factor in a company's overall cost structure. In addition to external costs, there are significant internal costs, including the labor to store and ship out wastes, liability insurance costs, and onsite treatment costs.

For the purpose of evaluating a project to reduce waste quantities, some types of costs are larger and more easily quantified. These include:

- disposal fees
- transportation costs
- predisposal treatment costs
- raw materials costs
- operating and maintenance costs.

It is suggested that savings in these costs be taken into consideration first, because they have a greater effect on project economics and involve less effort to estimate reliably. The remaining elements are usually secondary in their direct impact and should be included on an as-needed basis in fine-tuning the analysis.

Everyone thinks of waste as just an environmental issue. That's natural, but mistaken. Waste is a huge economic issue. It is also the biggest opportunity North American manufacturers have ever had to increase their profits. By eliminating waste, any company will improve the quality of its products and the environment, and earn significant amounts of money.

The top industrial managers are beginning to recognize this. On June 11, 1991, The Wall Street Journal ran a front page article, "Chemical Firms Find that it Pays to Reduce Pollution at Source." The article discusses the savings that Dow, Du Pont, and Monsanto have made by cutting waste.

The Du Pont case makes the critical points. To quote: "Du Pont engineers argued that reducing the pollution would be too expensive. But when they took a second look last year, they found just the opposite was true. By adjusting the production process to use less of one raw material, they were able to slash the plant's waste by two-thirds. Yields went up and costs went down.
The savings: $1 million a year.... Edgar Woolard, Du Pont's chairman and chief executive officer, says the company now even sees waste reduction as a way to achieve a competitive advantage."

This article shows how to apply the lesson these managers have learned: Waste reduction pays. It demonstrates first that waste is a huge cost in most businesses. Then it presents good evidence that waste is not an inevitable cost of doing business. Any company can increase profits quickly and permanently by cutting waste. Third, it introduces a simple methodology for measuring the economic damage waste causes of waste in manufacturing processes.

The Cost of Waste

It is simple, in principle, to calculate how much waste costs an industrial company. All one has to do is add up four elements:

Raw material

First, there is the cost of the raw material in the waste. Manufacturers buy the raw material in every piece of scrap or gallon of effluent. They intend to use it to make salable product. When the raw material becomes waste, the manufacturer loses the material's value.

Labor

Nobody buys material just to throw it away. By the time it becomes waste, the factory will have worked on it. Thus, all waste contains labor. The value of that labor is also lost, as is the labor used to rework unsalable product.

Disposal

Disposal charges are clearly an expense that springs from waste. In most companies they are the only element of waste-related expense that is recognized explicitly. As landfills close, garbage disposal costs mount. When the waste is legally hazardous, the disposal charges are exorbitant.

Waste handling

This figure has two elements. First, the plant will use labor to collect and store its rubbish. It may also process its garbage, for example, by compacting solids, or distilling liquids. The expense of running these operations is a result of making waste. Secondly, disposal is tightly regulated. It imposes a costly administrative burden. This is particularly true when hazardous chemicals are involved.

Viewgraph 4 shows the result of combining these four elements into a cost of waste (analogous to the cost of quality) for two different businesses. Disposal and internal waste-handling charges are combined in both cases.

Viewgraph 4 leads inevitably to two conclusions. First, waste is expensive. It costs more than direct labor in most manufacturing operations. The excess expense caused by waste is very seldom less than half the direct labor cost. It is often several times as large. That means that if waste can be reduced (i.e., if it is not an inevitable cost of doing business), it is the biggest opportunity to increase profits in most North American plants.

The second conclusion is that waste costs money because the plant loses raw material. Labor is a small part of the total. Disposal and waste handling are trivial. This is even true in the chemical industry where disposal is costly because most of the wastes are hazardous. Viewgraph 5, which analyzes waste-related expense at eighteen North American chemical plants, confirms this point.

To save money on waste we have to avoid making it. Treating it afterwards is not the answer. That can only influence disposal, which is a tiny fragment of the total. Minimizing the cost of waste is a question of optimizing raw material utilization.

That lesson is also important for the environment. There are no good ways of disposing of waste, only bad or worse ones. The slogan "Reduce, Reuse, Recycle" recognizes that environmental truth. To recognize the economic truth, the slogan should be "Reduce, Reduce, Reduce."

Competing through Pollution Prevention

In the past, many managers regarded waste as a cost of doing business. They felt it was inevitable, or uncontrollable. Sometimes, like the Du Pont engineers, they argued that reducing the pollution would be too expensive.

The truth is exactly the opposite. The right process changes reduce material losses quickly and permanently. These changes are not normally expensive. They do not usually require significant capital investment. What they require is a change in attitude. That changes is a return to looking at the facts of the business on the factory floor, to include Air Force maintenance facilities.

The North American automotive coatings industry provides striking quantitative support for this argument. It is a good example because the industry is so homogeneous. The main players are three major chemical companies: Du Pont, PPG, and BASF. Each of the three has several plants. All the plants use essentially the same production processes and equipment. They buy from the same suppliers and sell to the same customers. Yet, Viewgraph 5 shows there is a startling difference in waste costs among plants. The lowest-waste plant spends $1.60 less on waste per gallon of product sold than the worst plant. This difference is within a few cents of the industry average for labor cost per gallon. That must be considered a significant competitive cost advantage.

Calculating Waste Costs

Viewgraph 7 shows the way most accounting systems divide up the cost of waste: (1) the value of the raw material in the waste, (2) the labor loss, (3) disposal charges, and (4) internal cost of waste handling. Our aim is to provide a quick way of calculating what waste actually costs a company. The methodology uses figures available from nearly all standard costing systems to calculate an overall cost of waste. This cost of waste is analogous to the cost of quality, but

simpler. It is designed to be a sober, conservative measure of the hard costs of wasting material. It is possible to determine the cost of waste in a typical plant in two or three days.

Valuing explicit and implied losses

The only part of the calculation that poses any difficulty is deriving the value of the part of the raw material losses that is built into the standard costs of the products. It is critical to get that number right, because it usually represents the largest component of the cost of waste. Nearly all the other figures--the variances, write-offs, labor, and disposal charges--are available directly from the cost accounting department. Thus, this section deals only with ways of valuing explicit and implied standard loss factors.

Virtually every costing system builds material loss allowances into product costs. These allowances are designed to reflect the historical level of material waste generated by manufacturing the company's products. Budgets and prices should be based on standards that include these allowances in order to reflect current reality. The fact that the losses are built into the standard, however, does not mean they are inevitable. If accounting budgets to use six pounds of raw material to make five pounds of product, the plant is budgeting to waste one pound. That pound is waste whether it is built into the standards or reported as a variance. Unfortunately, if it is built into the standards, it will become invisible to management, as though it cost nothing.

Most costing systems use explicit and implied cost allowances. Explicit loss allowances are stated directly on product cost sheets. They have names like manufacturing loss allowance, process loss, shrinkage factor, or scrap factor. For the most part, they are expressed as a percentage of the raw material actually used to make the product. When a product goes through several manufacturing steps (e.g., molding, trimming, painting, and finishing, the standard cost will often introduce explicit loss allowances at each step.

By definition, implied standard loss allowances are not stated openly on the cost sheet. They take the form of a standard cost that states that the product has more parts in it or weighs more than it actually does. Implied losses can only be determined by weighing or measuring the product and comparing reality with the costing.

The differences may be obvious (e.g., costing three bolts into an assembly that uses two), or they may be more difficult to detect. For example, in a rotary casting operation, the standard costings allowed 2.1 pounds of material per piece. The finished castings, after being ground to standard size, weighed just under one pound. The additional waste built into the standard was sent to a landfill as grinding dust or reject parts.

Viewgraph 8 shows how the costing system at the automotive trunk liner plant discussed earlier, applies explicit and implied loss allowances. Following this example, it becomes apparent how much the cost of waste is hidden by current accounting practices.

The top half of Viewgraph 8 shows how the accountants arrive at a standard usage of 2.48 pounds per plastic part. They have done so by weighing the blanks fed into the press and allowing a 2 percent, or .05 pound explicit loss allowance per part for defects or damage. As shown in the bottom half of the table, however, the actual weight of the plastic in the part is only 1.15 pounds. The rest of the plastic, 1.28 pounds per part (51.6 percent of the material input) is lost as edge trim or offal. This implied loss is built into the standard cost and will not show up in any financial reports. Thus, in most companies, the accountants themselves will be unaware of these losses.

To calculate the total value of the material losses built into the standards, it is necessary to multiply the total value of raw material throughput by the weighted average standard loss allowance percentages. In the trunk liner factory, all the parts had a 2 percent explicit loss allowance. Implied loss varied from part to part: The highest contained an implied loss allowance of 43.7 percent. Thus, the total standard loss allowance for an average part was 45.7 percent of the material input. Put another way, by performing at that standard, the plant was wasting 45.7 percent of material input.

This trunk liner plant is an extreme example, but it illustrates a universal finding. The cost of waste in most plants is between five to seven times higher than management or environmental professionals realize.

Viewgraph 9 illustrates the physical materials losses associated with a typical manufacturing process (or Air Logistics Centers). Systematic assessment and reduction of each of these material loss streams is essential for achieving effective pollution prevention and/or industrial processes.

The Economic Impact of Pollution Prevention

North America leads the world in per capita production of garbage. The continental cost of waste has never been measured, but it is possible to estimate its order of magnitude. Waste costs more than labor in most manufacturing operations. National statistics show that U.S. manufacturing has 18.2 million hourly paid employees. Their average hourly wage is over $12. Simple multiplication suggests a cost of waste in the $400 billion a year range. Active pollution prevention can halve that, saving every North American $800 a year, and at the same time, improve the environment.

The first step in cutting North America's continental cost of waste is absorbing three concepts stressed in this article. First, waste destroys profits. This is true for any manufacturer in any industry. Second, it can be reduced cheaply, quickly, and permanently. It is not an inevitable cost of doing business. Third, to save money on waste, we have to avoid making it. Treating it is not the answer, economically or environmentally. Minimizing the cost of waste is a question of optimizing raw material utilization.

Eliminating industrial pollution will be slow. It will have to be tackled process by process and plant by plant. One of the best ways for any manufacturer to start is to devote a few days to measuring the cost of waste in one plant. The result will be a surprisingly large opportunity to improve profits. The next step is physical waste measurement. Then the hard work starts. Take each waste stream, study its source, and "Reduce, Reduce, Reduce."

Key concepts and factors

a. **Life Cycle Costing:** Sometimes referred to as Total Cost Accounting, this method analyzes the costs and benefits associated with a piece of equipment or a procedure over the entire time the equipment or procedure is to be used. The concept originated in the federal government and was first applied in procuring weapons systems. Experience showed that the up-front purchase price was a poor measure of the total cost; costs such as those associated with maintainability, reliability, disposal/salvage value, and training/ education had to be given equal weight in making financial decisions. Similarly, in justifying pollution prevention, all benefits and costs must be spelled out in the most concrete terms possible over the life of each option.

b. **Present Worth:** The importance of present worth, or present value, lies in the fact that time is money. The preference between a dollar now or a dollar a year from now is driven by the fact that the dollar in-hand can earn interest. Mathematically, this relationship is as follows:

$$\text{Present Value} = \frac{\text{Future Value}}{(1+\text{interest rate})^{\text{Number of years}}} \qquad P = \frac{F}{(1+r)^{n}}$$

where P is the present worth or present value, F is the future value, r is the interest or discount rate, and n is the number of periods. In the above example, $1 in one year at 5% interest compounded annually would have a computed present value of:

$$P = \frac{\$1.00}{(1+.05)} = \$.95$$

Because money can "work," at 5% interest, there is no difference between $.95 now and $1.00 on one year because they both have the same value at the current time. Similarly, if the $1 was to be received in 3 years, the present value would be:

$$P = \frac{\$1.00}{(1+.05)} = \$.86$$

In considering either multiple payments or cash into and out of a firm, the present values are additive. For example, at 5% interest, the present value of receiving both $1 in one year and $1 in 3 years would be $.95 + $.86 = present value would be $.95 - $.86 = $.09. As a result, present worth calculations allow both costs and benefits which are expended or earned in the future to be expressed as a single lump sum at their current or present value.

Long-term Financial Indicators. To consistently provide corporate decision-makers with accurate and comparable project financial assessments for capital budgeting, the project assessment tools must meet at least two criteria: 1) they must consider all cash flows (positive and negative) over the life of the project; and 2) they must consider the time value of money (i.e. it must appropriately discount future cash flows. The Net Present Value (NPV), Internal Rate of Return, and Profitability Indicator (PI) methods meet both these criteria. Where projects are competing against each other for limited resources the NPV method is preferred because there are certain conditions under which the IRR or PI methods fail to identify the most advantageous project. The payback method, commonly used by small companies, does not meet either of these criteria. NPV, IRR, PI, and payback are introduced here in their simplest fashion.

Net Present Value (NPV): Under the NPV method, the present value of each cash flow, both inflows and outflows, is calculated, and discounted at the project's cost of capital. The sum of the discounted cash flows is the project's NPV. A positive NPV means a project is worth pursuing; a negative NPV indicates it should be rejected. If the availability of capital is constrained (as it usually is) or several projects are competing with one another, other things being equal, the project or combination of projects with the highest positive NPV should be chosen. The NPV method, particularly as applied to long-term projects with significant cash flows in later years, is very sensitive to the level of the discount rate. Thus, for a project with most of its cash flows in the early years, its NPV will not be lowered much by increasing the discount rate. On the other hand, the NPV of a project whose cash flows come later will be substantially lowered, rendering the project a much less attractive investment opportunity.

Internal Rate of Return (IRR): The IRR method calculates the discount rate that equates the present value of a project's expected cash inflows to the present value of the project's expected costs. Thus, the basic formula to calculate the IRR is the same as that for the NPV; for the IRR, the NPV is set to zero and the discount rate is calculated; for the NPV, the discount rate is known and the NPV is calculated. A project is worth pursuing when the calculated IRR is greater than the cost of capital to finance the project. Where several projects are vying for limited resources, all else being equal, the project with the highest IRR should be pursued.

Profitability Index (PI): The profitability index is also known as the **benefit/cost ratio.** The PI is simply the present value of benefits (cash inflows) divided by the present value of costs (cash outflows), and shows the relative profitability of a project or present value benefits per dollar of costs. Projects with profitability indices greater than 1.0 should be pursued, and the higher the PI, the more attractive the project.

Payback: Payback is the simplest of the techniques for evaluating capital project investments. It provides a "quick-and-dirty" or "back-of-the-envelope" appraisal. While the payback calculation may suffice for a preliminary assessment, it should not be relied upon as the sole method for project evaluation. The payback period is the expected number of years required to recover the original project investment. The payback period can be calculated before or after taxes, and serves as a type of "breakeven" calculation in that if cash flows come in at the expected rate until the payback year, then the project will break even from a dollar standpoint. However, the regular payback does not account for the cost of capital, meaning that the cost of the debt and equity used in the investment is not reflected in the cash flows or the calculation. Another major drawback of the payback method is that it does not take account of cash flows beyond the payback year. The payback period does, however, provide an estimate of how long funds will be tied up in a project and is therefore often used as an indicator of project liquidity.

Cost Allocation. A firm's cost accounting system is used to track and allocate production costs to a product or process line, principally for budgeting (i.e. operational budgeting) and pricing. When costs for waste management, regulatory compliance, and pollution control are properly allocated to processes or product lines, the cost accounting system provides a rich source of data for TCA.

For purposes of investment analysis, the ideal cost accounting system has two primary features. First, the system should allocate all costs to the processes that are responsible for their creation. This is a perennial challenge to financial officers and cost accountants who decide on the placement of costs into either overhead or product or process accounts. Waste disposal costs, for example, are often placed in overhead accounts, while a process or product allocation would assign such costs based on some activity or component of the manufacturing process.

Second, it is not enough to simply allocate costs to appropriate processes. Costs should be allocated in a manner that is reflective of the way in that costs are actually incurred. For example, waste disposal costs in some companies are allocated across operating centers--administrative, research and development, and manufacturing--on the basis of floor space rather than on the quantity and type of waste generated by each. This impedes a rigorous estimation of the financial benefits of reduced waste generation. Thus, effective cost accounting is critical to directing management attention to the sources of waste generation and the benefits of changing current waste management practices.

TCA METHODS

What features should a TCA method have to make it useful and useable to businesses? Since TCA methods have not yet received widespread application, no definitive assessment is possible, however, reported into the budgeting and project analysis methods of a range of firms in the Northeast, has revealed three highly desirable features.

First, a desirable system is one the encourages and helps the user to include a complete set of costs and savings, yet provides the **flexibility** to tailor the level of the analysis to the needs of the firm, project type, and size.

Second, the **simpler the method, and the less time it takes to learn and use,** the better. Environmental managers, project engineers and others responsible for financial analysis of pollution prevention projects usually have little extra time to learn or use complicated tools. Many, even in large firms, do not have a sophisticated understanding of computers or financial terminology. A system that requires only rudimentary computer skills and basic knowledge of financial language and calculations will find greatest receptivity.

Finally, to allow users maximum flexibility to conduct the analysis manually or with the use of a computer, **the availability of both paper worksheets and software** is desirable. While computerized tools clearly introduce flexibility and speed, they should not stand in the way of adoption by those who prefer less automated methods of project evaluation.

Several TCA approaches have been developed to facilitate analysis of pollution prevention investments. Three of the most prominent among these are:

- **Financial Analysis of Waste Management Alternatives,** developed by General Electric Corporation ("GE Method");
- **Pollution Prevention Benefits Manual,** developed for the U.S. Environmental Protection Agency ("EPA Method");
- **PRECOSIS,** developed by George Beetle Company.

Each of these methods contain some, but not all, of the features we have described. None have achieved widespread acceptance in the business community, despite their availability for as long as four years. This attests to a number of barriers to corporate acceptance, ranging from excessive complexity, intensive data demands, regulatory impediments, to management inertia. Nonetheless, they serve a valuable illustrations of progress to date and as points of reference for formulating additional methods for use in the industrial community. To round out our assessment, we also briefly describe two additional approaches:

- The Economic Feasibility section and Worksheets for Economic Evaluation in the U.S. EPA, **Waste Minimization Opportunity Assessment Manual;**
- Part of Waste Advantage, Inc.'s report titled, **Industrial Waste Prevention, Guide to developing an Effective Waste Minimization Program.**

The General Electric Method (GE)

Prepared for:	General Electric, Corporate Environmental Programs Richard W. MacLean, Manager
Prepared by:	General Electric and ICF Incorporated
Publication date:	1987
Contents:	Workbook, Worksheets and Financial Calculation Software developed with Lotus 1-2-3, version 2.01.

Description. Viewgraph 10 illustrates the GE method. The GE workbook and software are tools for identifying and ranking waste minimization investment options. The user quantifies **direct cost** (out-of-pocket cash costs routinely associated with waste management and disposal) and **future liability costs** (including potential environmental liabilities for remedial action costs, and related costs for personal injury and property damage) of a current waste management practice versus one or several alternative waste minimization options. To evaluate the profitability of waste minimization investments the user follows three steps outlined in Viewgraph 10.

The Workbook employs a system of waste-flow diagrams and detailed checklists to help the user identify (Step 1) and estimate (Step 2) the direct capital and operating costs (Step 2) associated with generation and on- and off-site management of waste streams targeted for reduction. A procedure is presented for estimating the magnitude and timing of future liability costs associated with current and location of treatment, storage and disposal facilities (TSDF) utilized, and the quantity and nature of the waste generated. The user first develops a score for the TSDF based on the technology it employs and the location of the facility (i.e. surrounding population density, proximity to water supply, etc.). This score is then used to adjust--up or down--a per-ton cost estimate for corrective actions and claims developed for a base-case, generic hazardous waste landfill. Included in this estimate are the costs of: surface sealing, fluid removal and treatment, personal injury, real property claims, economic losses and natural resource damage claims.

The GE workbook provides step-by-step instructions for entering both **direct** and **future liability** cost data and relevant financial parameters into the financial software package or paper worksheets provided in the workbook (Step 3). The software calculates streams of after-tax incremental cash flow of the investment, the net present value (NPV) for the current and alternative practice, and the following financial indicators: a) break-even point, b) return on investment (ROI), and c) discounted cash flow rate of return. The workbook offers recommendations for using the financial indices to identify and rank waste minimization projects.

Pollution Prevention Benefits Manual (EPA Method)

Prepared for:	Office of Solid Waste/Office of Policy, Planning and Evaluation, U.S. Environmental Protection Agency,
Prepared by:	ICF Incorporated
Printing date:	October 1990
Contents:	Manual and Worksheets

Description. A schematic of the EPA Methodology is provided in Viewgraph 11. The EPA Manual is designed to assist in the cost comparison of one or more pollution prevention (PP) alternatives to a current industrial practice. The method sets up a hierarchy of costs and follows:

Tier 0 - Usual Costs:	e.g. equipment, labor, and materials
Tier 1 - Hidden Costs:	e.g. compliance, and permits
Tier 2 - Liability Costs:	e.g. penalties/fines and future liabilities
Tier 3 - Less Tangible Costs:	e.g. consumer responses and employee relations

The hierarchy progresses from the most conventional and certain costs in Tier 0 to the most difficult to estimate and least certain costs in Tier 3. At each tier, the user first analyzes all costs associated with the current and alternative PP project, and then calculates key financial indicators of the economic viability of the PP project. Viewgraph 11 illustrates the sequential nature of the method. Financial calculations for each tier are added a tier at a time, until the result concludes that the PP alternative meets the investment criteria (i.e. hurdle rate) of the firm, or all tiers (0 through 3) have been completed. For example, if the results of the Tier 0 financial calculation indicate that the alternative strategy meets the firm's investment criteria, the user may choose not to continue to include Tier 1-3 costs. If, however, the result falls short of the investment criteria, then the user may proceed to calculate and add the Tier 1 results to the Tier 0 results, and so on. Even if the Tier 0 or 1 calculation meets the criteria of the firm, a user may want to proceed to estimate Tier 2 and 3 costs to fully analyze the financial implications of the alternative practice.

The Manual provides a Regulatory Status Questionnaire, a summary of relevant regulatory programs and cost equations to assist the user in estimating Tier 1 regulatory costs for several compliance activities, including labeling, notification, recordkeeping, and monitoring. The Manual contains numerous cost equations for the estimation of the potential future liability costs such as: ground water removal and treatment, surface sealing, personal injury, and natural resource damage. In addition, the manual provides guidance for calculating three financial indicators: annualized savings, internal rate of return, and net present value. The manual does not come with software, however it does contain worksheets that aid in organizing ad presenting results from the cost calculations.

Data Requirements. The following is a summary of the data requirements for each Tier included in the manual. While this list is exhaustive, one should keep in mind that a) not all Tiers are necessary to analyze all projects, and b) not all costs within each Tier need to be quantified if data are not available.

Tier 0: Usual Costs

- Depreciable Capital Costs
  - equipment
  - material
  - utility connections
  - site preparation
  - installation
  - engineering and procurement

- Expenses
  - start-up costs
  - permitting costs
  - salvage value
  - training costs
  - initial chemicals
  - working capital
  - disposal costs
  - raw material costs
  - utilities costs
  - catalysts and chemicals
  - operating and materials (O&M) labor costs
  - operating and materials supplies costs
  - insurance costs

- Operating Revenues
  - from sale of primary products
  - from sale of marketable by-products

Tier 1: Hidden Costs

- Facility's regulatory status under RCRA. CERCLA, SARA Title III, Clean Air Act, OSHA, and relevant State regulatory programs

- Technology-forcing regulatory requirements and the costs associated with them

- Cost components for regulatory activities such as loaded wage rates, frequency of activity, and time required to complete activity, for the following regulatory activities:
  - notification
  - reporting
  - monitoring/testing
  - recordkeeping
  - planning/studies/modeling
  - training
  - inspections
  - manifesting
  - labeling
  - preparedness/protective equipment (maintenance)
  - closure/post closure assurance medical surveillance
  - insurance and special taxes

Tier 2: Liability Costs

The Manual provides cost equations to assist in the calculation of the following future liability costs:

- Soil and waste removal and treatment
- Ground-water removal and treatment
- Surface sealing
- Personal injury
- Economic loss
- Real property damage, and

- Natural resource damage.

Each equation consists of several variables, for which the Manual provides suggested values. To illustrate, the equation for real property damage stemming from a hazardous material storage tank or disposal facility is:

Cost = a x b x c (in thousands of dollars), where:

a = Property devaluation factor
0.15 to 0.30

b = land value ($000/acre)

c = area of the off-site plume
= $[0.33 D^2 + (D \times W) - 0.5 W^2]/4047$

Where

D = distance to nearest drinking water well (meters)
150 m to 3200 m

W = width of ground-water plume at facility boundary (meters)

Storage Tanks: W = 3 to 100 meters

Disposal Facilities: @ = 500 to 700 meters

A similar equation and set of suggested variable values is provided to predict the expected year in which liabilities may be incurred. While the Manual provides a range of suggested values, the user must either choose from the range or use values based on actual information about a facility, the hydrogeologic characteristics of the facility site, distance to nearest drinking water well, and so forth. Since more than one company may be liable for a particular claim, the user must estimate his or her company's share of the potential liability costs.

Tier 3: Intangible Costs

The user supplies relevant information to estimate less tangible benefits of pollution prevention resulting from enhanced consumer acceptance, employee/union relations, and corporate image. The Manual recommends using the judgement of the analyst and provide some guidance on how to identify and estimate these benefits.

PRECOSIS

Prepared for:	U.S. Environmental Protection Agency, Center for Environmental Research Information, Cincinnati, Ohio
Prepared by:	George Beetle, George Beetle Company
Publication date:	1989
Contents:	Manual and Software

PRECOSIS was designed to support the financial analysis of waste reduction projects. The software is a menu-driven program consisting of ten data input tables and two output reports containing financial calculations. The programs can be used on any IBM-compatible microcomputer having 512 kilobytes or more of base memory.

Cost data re-grouped into three categories:

- **resource effects** - costs of labor, material, and facilities;
- **revenue or value effects** - changes in output quantity and quality, and secondary products/services; and
- **waste management effects** - includes storage, handling, disposal, compliance, insurance, and litigation.

The financial assessment of alternative waste reduction strategies is conducted in four steps, as illustrated in **Viewgraph 12**. First, data describing the baseline (or current) process are entered (Step 1). The user enters cost data for labor, materials, facilities, and waste management in unit cost format (e.g. cost per ton of a feedstock material, or cost per gallon for waste disposal), and then specifies the number of units needed for the current process (e.g. pounds of feedstock used per year or number of gallons of waste disposed per year). Revenue data are handled in a similar fashion. Using these costs and several financial parameters entered by the user, the system calculates the total cost of the current system.

To calculate costs associated with the alternative process, the user must enter an expected increase or decrease (called "effects") in the number of units of resources used, waste generated, and product produced as a result of the process change (Step 2). For example, if 500 units of waste is generated by the current system, and 50 units by the alternative system, then the expected decrease in the units of waste is 450.

The software calculates net present value, estimated payback years, internal return on investment, and numerous other financial indicators to evaluate the profitability of the alternative process (Step 3).

Other TCA Methods

In additional to GE, EPA and PRECOSIS, two additional cost analysis tools are available for industry and technical assistance providers. The first is a series of worksheets contained in the U.S. EPA's *Waste Minimization Opportunity Assessment Manual*. This cost analysis framework consists of a series of data collection sheets and a profitability worksheet for calculating several financial indicators.

The data collection sheets contain the following entries:

1. Capital costs, including
   a. purchased process equipment,
   b. materials,
   c. utility connections,
   d. site preparation,
   e. estimated installation,
   f. engineering and procurement,
   g. start-up,
   h. training,
   i. permitting,
   j. initial catalysts and chemicals,
   k. working capital, and
   l. equipment salvage value.

2. Incremental operating costs and revenue, including
   a. waste disposal,
   b. raw material consumption,
   c.ancillary catalysts and chemicals,
   d.labor costs,
   e. maintenance and supplies, and
   f. insurance and liability,
   g. incremental revenues from increased/decreased production,
   h. incremental revenues from marketable by-products

The profitability worksheet assists the user in calculating:

a. cash flows of the investment,
b. payback period,
c. annual cash flow,
d. present value cash flow, and
e. net present value.

This cost analysis tool is rather simple yet comprehensive, and does not come with computer software.

The second is a method developed by Waste Advantage, Inc. as part of their report titled *Industrial Waste Prevention, Guide to Developing an Effective Waste Minimization Program.* This method assists the user in developing what is called a "waste generation cost". The waste generation cost is the waste disposal cost **plus** all costs associated with creating the waste. A waste generation cost is developed for each waste stream on a per year basis.

The system categorizes these costs as follows:

1. Treatment, storage, and disposal facility costs,
2. Waste transportation costs,
3. Wasted raw material costs,
4. Labor costs,
5. Other costs, including compliance, consulting fees, drums, and public image, and
6. Future waste disposal liability costs.

For each of the six cost categories above, the method provides a detailed list of the cost-bearing activities that should be included in the waste generation cost calculation.

The per-gallon waste generation cost is calculated by dividing the annual cost by the number of gallons generated in a year. The payback period of a waste minimization investment is:

$$\text{payback period} = \frac{\text{capital investment}}{(\$/\text{gal waste generation cost}) \times (\text{gallon/year reduced})}$$

The method includes one data collection sheet, a cost worksheet, and several useful sample analyses. The calculation of payback is illustrated in one of the examples. No other financial indicators are addressed.

If waste reduction is the focus of a pollution prevention project, this method can be used to calculate a comprehensive unit cost for waste generation. This unit cost can then be used to further calculate the payback period for one or several waste reduction projects. The methods presented in the Hazardous Waste Opportunity Assessment Manual and the Waste Advantage Guide are useful, simple tools that can serve to assist in pollution prevention project cost data collection and profitability analysis.

DEFINING THE PROJECT'S COST

The first step in determining the cost of a project is to establish a baseline for the analysis. The "do-nothing" or "status quo" alternative is generally used as a baseline. Then any changes in material use, utility expense, etc., for other options being considered are measured as either more or less expensive than the baseline.

Cost Categories: using the EPA method described above:

Tier 0: Usual costs such as direct labor, materials, equipment, etc.

Tier 1: Hidden costs such as monitoring expenses, reporting and record keeping and permit requirements.

Tier 2: Future liability costs such as remedial actions, personal injury under Occupation, Safety, and Health Act (OSHA), property

THE STARTING POINT - BASELINE COSTS

To illustrate the concept of the "do-nothing' or "status quo" option, an example of a small electronics firm will be used to illustrate the computation of a baseline cost. Presently, the firm cleans metal parts with a chlorinated solvent. Because the solvent is hazardous, the wastewater from rinsing the parts must be labeled as hazardous waste. The company is considering ways to reduce the volume of hazardous waste generated.

To establish the baseline, the current cost of doing business must first be determined. Once the present costs are known, all potential alternatives such as substituting a non-hazardous solvent for the current hazardous material would then be related to this baseline cost.

How to Compute the Baseline Costs

The simplest way to establish a baseline cost is to add up the relevant input and output materials for the process and then compute their appropriate dollar value. This is started by first balancing the material entering and leaving the operation which contributes to the waste. Viewgraph 13 shows this for a typical tank-line that generates the hazardous waste.

Annual Material Balance for the Hazardous Solvent

The next step is to ensure the material balance makes sense; i.e., the volume of solvent purchased must be accounted for in the losses, product, inventory, and/or waste. In the example, the solvent purchased is equal to that lost to evaporation, plus that lost in the waste rinsewater. Once accomplished, determining the baseline cost becomes a simple matter of pricing each input and output and multiplying their volumes by the appropriate unit. The baseline costs for this example are shown in Viewgraph 13. Although the next step would be to examine expected business changes such as business expansions, new accounts, rising prices, etc., for simplicity, the tabulated costs and volumes will be assumed constant. This means that the current annual costs will be the same in the out-years except for one very important aspect, the time value of money.

How to Account for the Effects of Interest

Due to the assumptions made regarding constant cost, the $17,885 annual cost shown in Viewgraph 13 will be repeated each year. The present value calculations shown earlier enable this annual expenditure to be expressed as a single sum which includes the effects in interest. The first year's cost, assuming the bills were paid at the end of the end of the year, would be the amount of money that would have to be banked starting today, to pay a $17,885 bill in one year. Computational, using a 10% interest rate, the computation is as follows:

$$P = \frac{\$17{,}885}{(1+.10)} = \$16{,}260$$

This means that if $16,260 was banked at 10% interest, it would provide enough monies to pay the $17,885 bill at the end of the year. Similarly, the second, third, fourth, etc., years expenditures can also be expressed in present value. This is done in Viewgraph 14. The bottom line to the analysis is that the total cost of the cleaning system over the next 10 years, given a 10% interest rate, is $109,896 in present value terms. In other words, $100,000 invested today at 10% interest would be sufficient to pay the entire material and disposal costs for the circuit board cleaning operation for the next 10 years. Hence, any changes to the operation of the firm can now be compared to this $100,00 baseline. Any changes which would result in a lower 10 year cost would be a benefit in that it would save money; any option with a higher cost will be more expensive and should not be adopted rom a financial or economic standpoint.

SAMPLE CALCULATIONS

This section provides a step-by-step outline of the process of analyzing a pollution prevention project. The hypothetical firm under review takes in used parts, cleans them in a dip tank using a hazardous solvent, and applies a new finish. The financial analysis will be between the current solvent cleaning operation and two pollution prevention alternatives: a solvent recycle system and non-hazardous material substitution.

How to Establish the Baseline

As indicated before, the first step is to define the baseline cost of the process. Once accomplished, the financial effects of any change to business as usual can be judged as either equal to, more expensive, or cheaper than the baseline case. To do this, the expenses resulting from the baseline, the recycle system and the non-hazardous solvent must be computed and compared. Viewgraph 15 shows the material balance for the current system.

Baseline Material Balance

With the mass balance complete, annual costs can be assigned for the process. The resulting cash flow would be as shown in the table of Viewgraph 15.

Note that none of the other expenses previously discuss above need to be addressed at this point as they will be computed, as applicable, as changes from this baseline.

To express these annual costs in present value terms, a time reference must be selected so that each option can be considered over the same length of time. Since the recycle equipment has an expected life of 10 years, the baseline and both options will be examined over this time period.

For the purpose of illustration, the firm's discount rate (the firm's internal interest or "hurdle" rate) shall be taken as 15% and the inflation rate is assumed at a constant 5% per year. Since the discount rate and inflation work in opposite directions (i.e. interest makes your money more valuable over time and inflation makes it less valuable over time), they can be combined. However, for simplicity, they shall be treated separately. All present value computations shall be made using 15% interest and all expenses shall be increased at an inflationary rate of 5% per year.

To account for prices which rise faster than inflation, annual real price increases (in excess of inflation) of 1% of the cost of solvent and 4% of the cost of disposal shall be assumed. In these cases, the cost of solvent shall increase 6% per year (5% inflation + 1% real price increase) and waste disposal shall increase 9% per year. Given these assumptions, the baseline expenses for the next decade are as shown in Viewgraph 16.

In many cases firms simplify the calculations by assuming costs will be constant over the life of the project. If this is the case, then all outyear costs would be the same as was done with the earlier example in Viewgraph 13.
The intermediate step in the financial analysis will be to compare the annual costs of the two pollution prevention options with the annual costs of the baseline process. (This will be illustrated in Table 9). Then the present value of the annual cost savings (or cost increase) of the options will be simultaneously at the end of the analysis.

The final step will be to sum the present values from each year to obtain the net present value. The net present value represents the quantifiable worth of the project.

Examining Pollution Prevention Option 1 - Recycle

As before, the first step is to establish the mass balance diagram for this option. This is shown in Viewgraph 17.

Material Balance for the Recycle System

As is the case with many recycle options, a salable by- product is generated (the recycled solvent), but instead of offering the solvent for sale, the firm is using it as an input to offset the cost of new solvent so there is no revenue impact. Further, since the actual cleaning operation has not changed, there should be no change in production rate as a result of this option. As a result, there are no revenue impacts to consider.

This material balance in Viewgraph 17 can be readily converted to a cash flow. As discussed earlier, the recovery equipment has a life of 10 years. Further, there is no salvage value; the solvent must be chemically treated at the end of year 5 to retain it's effectiveness at a cost of $1000; and no additional permits, such as RCRA treatment permits or air permits, are required to operate or install the equipment. Given these assumptions, the annual costs are as shown in Viewgraph 18. Cost consideration include the following:

Insurance: The recycle operation involves a drum evaporator which could significantly increase insurance expense. However, for simplicity, it is assumed there in no increase in insurance expense.

Depreciation: Straight line deprecation shall be used with the procurement costs being expended at 10% each year for 10 years.

Interest: The firm borrowed the capital costs, will make annual payments for 3 years, and must pay 12% interest annually. Note: the principle ($66,500) will be repaid in three equal installments. The interest expense is calculated for each year based upon the current balance. (The actual monies borrowed, or repaid, are neither revenues nor expenses and do not appear in the financial analysis)

Labor: The equipment requires 1 hour of maintenance per day. This expense (@ $20/hr) has been included in the operations expenses listed above. For simplicity, the wage rate will be assumed constant except for cost of living increases due to inflation.

Training: The training was supplied by the recycle equipment supplier with training on site so there are no direct costs. Three operators must spend 2 hours each learning the operations. Their wage cost will also be taken as $20/hour.

Floor Space Considerations: The equipment is relatively compact, will be installed integral to the process, and will carry a zero floor space expense.

As done with the baseline, annual costs for the recycling option must also be spread over time as they will actually occur. Given our assumptions the costs, by year, for the 10 year life are shown in Viewgraph 19.

Examining Pollution Prevention Option 2 - Material Substitution

This option consists of replacing the hazardous solvent used for cleaning in the baseline case with a non-hazardous cleaner which is used in the same manner. The firm has been fortunate to find a cleaning solution which is disposable in the sewer and does not require disposal as a hazardous waste. The cost of sewering the 3950 gallons is assumed to be negligible.

In pollution prevention projects which involves substituting a non-hazardous material for a hazardous material, part of the analysis must consider how well the new product or process works in relation to the current practice. In this example, it is assumed no operational changes are required so production levels can be maintained. However, the cost of the cleaner is nearly 25-percent higher: $4.60/gal. The first year costs for implementing this option are shown in Viewgraph 20. Cost consideration are as follows:

Insurance: Since the material substitution operation involves less risk to the employees, there could be an insurance reduction; however, because insurance cost is very site/circumstance specific, and to not bias the analysis, it will again be assumed to be a constant cost.

Depreciation: Since there is no capital expenditure, there is no equipment to depreciate.

Interest: The company has the cash reserve to absorb the additional cleaner cost without borrowing any additional capital. Hence, there is no interest expense.

Labor: There is no additional equipment maintenance requirement and the wage is again constant except for cost of living increases due to inflation.

Training: As before, we will assume the training needed to use the new cleaner was supplied by the vender and 3 operators spent 2 hours learning how to handle, test, and maintain the cleaner. Their wage rate will be taken as $20/hour (from the previous example).

With the same assumptions regarding cost increases, the annual costs for switching to the non-hazardous cleaner, over the ten year period, are shown in Viewgraph 21.

Making the Financial Comparison:

With all annual costs computed, the final comparisons can be made. Viewgraph 22 shows the annual baseline costs (from Viewgraph 16) in the first columns; columns 2 and 3 show the annual costs for recycle (from Viewgraph 19) and the increase or decrease from the baseline; and finally, columns 4 and 5 show the annual costs for material substitution (from Viewgraph 21) and their associated change from the baseline.

If an option's annual costs are less than the baseline, the difference is considered a benefit. Conversely, if the option's annual costs are higher than the baseline (indicated by parenthesis), the difference is considered a cost. So that the two options can be compared, the final steps are to bring each option's costs and benefits back to present value, compute the net difference, and make the financial decision. These calculations are shown in . The present value calculation

uses the formula presented earlier with the interest rate set a 15. Recall that 15% was set as the example firm's "hurdle" rate the acceptable internal interest rate)

Making the Final Decision

In this example, both options display a positive effect on profitability. The two proposals each generate a net benefit compared to the baseline, status quo, option. Likewise, the proposals also meet the firm's internal hurdle rate (15%), because their present values are positive when calculated using a 15% discount rate.

The final task is to select between the two options. In that they have the same present worth of net benefits, they are equivalent under the financial criteria. However, as previously discussed, then projects appear financially equivalent, consideration of other tier costs can swing favor toward an option. In the above analysis, only tier 0 costs were included. If one considers the labor savings due to not having to manifest waste shipments, label drums, and so on., because the material substitution option eliminates hazardous waste generation, there is a substantial savings. Additionally, the elimination of hazardous waste limits the potential intangible tier 2 and 3 costs for remedial actions, lawsuits, etc. Given these considerations, and the fact that material substitution was higher on the pollution prevention hierarchy, the material substitution option is clearly the most beneficial option.

SUMMARY

This lecture has introduced you to some of the concepts of economic evaluation and some of the costs associated with economic evaluation in order for you to better understand how to justify pollution prevention projects. The economic evaluation concepts learned here today were intended to help you prioritize source reduction projects at your facility. By understanding all the variables in an economic evaluation, you can better prioritize projects. Now that you understand the economic evaluation concepts, and have actually used them while using SWAMI, you can go back to your installations and better prioritize projects.

BLOCK 12: AIR FORCE'S HAZARDOUS MATERIAL PHARMACY SYSTEM

1.0 Introduction

Block 12 describes the Air Force's Hazardous Material Pharmacy System and how the System is used to support pollution prevention programs in the Air Force. Block 12 is designed to provides students a working understanding of the system. The latest revisions to the System also are covered.

2.0 Objective

To explain the AFCEE Hazardous Material Pharmacy System. To provide a working understanding of the system.

1. Students will understand the analogous reference to the control over prescription drugs in the hazardous material pharmacy concept.

2. Students will understand the benefits of the hazardous material pharmacy concept.

3. Students will learn how the concept has been implemented at several prototype sites.

4. Students will learn how the benefits of the concept were measured at the prototype sites.

5. Students will learn how to implement a hazardous material pharmacy concept through the use of examples at the prototype sites.

3.0 Key Concepts

One solution to this problem has been to establish a single point for requisitioning receipt, repackaging and issue of hazardous material. This concept/mode of operations is analogous to the control over prescription drugs and is hereinafter referred to as the hazardous material pharmacy.

A description of the AFCEE Hazardous Material Pharmacy concept is provided in the attached document: Hazardous Material Pharmacy: Commanders' "How to Guide."

SUMMARY

The Air Force Center for Environmental Excellence recognizes that the success of organization like those used for the prototype can be realized at bases throughout the Air Force. The benefits of the hazardous material pharmacy concept are tremendous. At Pt. Mugu NAWS, hazardous material purchases were reduced from $132K to $55K during the first year of operation with only one directorate participating in the program. Purchases were further reduced in the second year to $43K despite the fact that during this period the program was expanding to incorporate the rest of the base at the rate of one organization per month. This lecture has provided an overview of the concept for the hazardous material pharmacy, and has provided guidance to implement this concept at your base.

BLOCK 13: MANAGEMENT OF MUNICIPAL SOLID WASTES

1.0 Introduction

Block 13 reviews Federal, Department of Defense, and Air Force MSW policy and directives. Air Force policy and directives emphasize an integrated approach that includes source reduction, collection, recycling, composting, incineration, treatment, and landfilling techniques. All aspects of municipal solid-waste are reviewed including source reduction and its benefits, collection methods, benefits of composting and recycling, and various disposal methods. Current waste treatment processes and how they can be used to reduce waste are described.

2.0 Objective

To review waste handling and processing techniques associated with an integrated approach to management of MSW and to review federal regulations, Air Force MSW policy, and current and future trends in state and federal regulation of MSW.

1. Students will know the definition of MSW and become familiar with federal regulations, Air Force policy, and future trends in regulations pertaining to management of MSW through a brief overview of those applicable regulations and policy statements.

2. Students will learn all aspects of the Integrated Solid Waste Management (ISWM) hierarchy and waste management techniques used to implement these components:

    - Source reduction
    - Recycling
    - Waste Transformation
    - Landfilling

3. Students will learn all aspects of municipal solid waste that need to be integrated for effective and efficient management of the waste by reviewing:

    - source reduction and its benefits
    - collection methods
    - benefits of composting and recycling
    - various means of disposal

4. Students will understand responsibilities and roles at the base level.

5. Students will understand the related concepts of hazardous waste and municipal solid waste management.

6. Students will learn current waste treatment processes, and how they can be used to reduce waste.

3.0 Key Concepts

I. INTRODUCTION

A. Air Force Pollution Prevention Directive

According to the (new AFD 19-4) Environmental Protection, Pollution Prevention Program: "The purpose of this policy is to reduce the use of hazardous and toxic materials and the generation of wastes through source reduction and environmentally sound recycling.

Section C: Policy Objectives:

13. Municipal Solid Waste (MSW) Management. The Air Force shall measure MSW disposal reductions, and the amounts of MSW recycled, composted, and treated by weight. Every installation shall operate or participate in a recycling program and composting program conforming with regional solid waste management plans."

B. From the Air Force Installation Pollution Prevention Program Manual:

"The Air Force Municipal Solid Waste (MSW) policy is contained in AFR 19-17, and is based on the use of an integrated approach that includes source reduction, collection, recycling, composting, incineration, treatment, and landfilling techniques and programs. Regional civilian MSW management facilities should be used whenever possible and bases should participate in regional planning efforts." (p.5-1)

C. Federal Solid Waste Policy

- Long history, in terms of environmental consciousness, of federal concern regarding the treatment and disposal of solid, nonhazardous waste:

- The Solid Waste Disposal Act of 1965 embodied the effort by Congress to:

  1. "Promote the demonstration, construction, and application of solid waste management and resource recovery systems which preserve and enhance the quality of air, water and land."

  2. Encourage research and development in the area of solid waste management, including recycling.
  3. Raise awareness in the states and localities of solid waste management, including recycling.

  4. Establish guidelines governing the treatment and disposal of solid waste. (Tchobanglous, p.40)

D. Discuss the recent (past few years) proposal by the states to set the goal of 25 percent reduction in the volume of MSW sent for disposal. Goal to be attained by 1995 or so. EPA may have encouraged goal by withholding funding if MSW reduction goal not achieved.

II. REGULATIONS AND POLICY OF MSW

The generation and disposal of nonhazardous, or municipal, solid waste is an area of concern which is addressed under pollution prevention programs by the Air Force and the federal government.

A. Air Force Pollution Prevention Policy Objective

The Air Force shall measure MSW disposal reductions, and the amounts of MSW recycled, composted, and treated by weight. Every installation shall operate or participate in a recycling program and composting program conforming with regional solid waste management plans."

B. From the Air Force Installation Pollution Prevention Program Manual

"The Air Force Municipal Solid Waste (MSW) policy......is based on the use of an integrated approach that includes source reduction, collection, recycling, composting, incineration, treatment, and landfilling techniques and programs. Regional civilian MSW management facilities should be used whenever possible and bases should participate in regional planning efforts."

C. Federal Solid Waste Policy:

<u>The Solid Waste Disposal Act of 1965</u>

The intent of the Solid Waste Disposal Act of 1965 was to:

1. "Promote the demonstration, construction, and application of solid waste management and resource recovery systems which preserve and enhance the quality of air, water and land."

2. Encourage research and development in the area of solid waste management, including recycling.

3. Raise awareness in the states and localities of solid waste management, including recycling.

4. Establish guidelines governing the treatment and disposal of solid waste. (Tchobanglous, 1993)

Resource Conservation and Recovery Act, 1976

The Resource Conservation and Recovery Act (RCRA) had a profound effect on solid waste management. It established a set of guidelines for solid waste management, including solid waste storage, treatment, and disposal. EPA separated hazardous waste from municipal solid waste.

D. Current and Future Trends in State and Federal Solid Waste Legislation

Traditionally, federal legislation and associated regulations have encouraged the implementation of solid waste management programs on a state government level. As a result, each state has developed its own solid waste management program. Many states have solid waste management programs that provide strong direction to the selection and implementation of solid waste management facilities. California and New Jersey were among the first states to implement strong solid waste management programs. In California, waste diversion goals are mandated to reduce the quantity of wastes going to landfills by 25 percent in 1995 and 50 percent in the year 2000. In New Jersey, the legislature adopted mandatory recycling in 1987. Under this program, all counties were required to achieve 25 percent recycling within two years. The state also collects taxes to facilitate development of resource recovery facilities.

In the majority of states, the land disposal units have changed from dumps into waste management units that are defined by engineering properties and scientific data mandated in construction and operating permits.

An integrated solid waste management hierarchy adopted b the U.S. EPA is composed of the following elements (in descending order of importance):

- Source reduction
- Recycling
- Waste transformation
- Landfilling

This hierarchy has been adopted by many states; however, the hierarchy is difficult to impose on local governments within states. Source reduction and recycling are difficult to implement in local governments because local tax moneys spent on these programs do no often provide visible benefits to community residents.

Because of these and other difficulties in implementation of source reduction, the U.S. EPA has outlined some options for actions to stimulate source reduction of solid wastes (U.S. EPA, 1988). The actions requiring legislation or new regulations at the federal level include:

1. Product constituent regulation. This source reduction option would target constituents that are known to be in the waste stream and are known to be toxic. A range of regulatory actions could be used, including product bans, cautionary labeling and approval labeling.

2. New product approval process. Manufacturers who introduce a new product or package would be required by the government to test or otherwise demonstrate the impacts of the products on the waste stream.

3. Procurement restrictions. Governments control the procurement of large quantities of goods. Control over acquisition of large quantities makes government institutions reasonable candidates for regulations fostering procurement of goods that result in a waste having lower toxicity and less volume. The action would be to change purchasing regulations that deal only with the performance of the goods in service.

- Plastics
- Glass
- Ferrous Metal
- Nonferrous metal
- Construction and Demolition Waste
- Waste Oil
- Used Tires

This diagram shows markets and typical uses for materials recovered from solid waste.

Aluminum Cans

Aluminum cans constitute less that 1 percent of the MSW generated annually in the U.S. Aluminum cans are accepted in curbside pick-up programs, at buy-back locations, at recycling collection centers, and by scrap metal dealers.

Paper and Cardboard

On a weight basis paper constitutes the largest component of municipal solid waste. The principal types of paper now recycled are newspaper, corrugated cardboard, high-grade paper, and mixed paper. High-grade paper includes computer paper, white and colored ledger paper, and reproduction paper. Mixed paper includes noncorrugated boxes, magazines, and carbon paper.

Paper manufacturers acquire post-consumer waste paper by direct purchase or through independent brokers. Paper buyers usually require delivery to their premises although some will make pickups if quantities are sufficient.

The market for waste paper is strongly affected by the general economy, because a large portion of low-grade paper is used to make building products and containers for consumer goods.

Plastics

Although plastic materials comprise only seven percent of MSW by weight, they comprise a much larger percentage on a volume basis.

Most plastic container manufacturers now code their products with a number from 1 to 7, representing the most commonly produced resins, to facilitate separation and recycling. Buyers require that post-consumer plastic to be well sorted into resin type, reasonable free of foreign material, free of excess moisture and baled to within a specified range of size and weight. Collection centers or brokers can perform the process of resin separation and baling.

Because of the decreasing availability of landfill sites and the increasing amount of plastic in MSW, local, state, and federal officials are exploring limits on plastic materials entering the waste stream. Plastics are already the target of some state laws.

The current barriers to recycling of glass include technical and market barriers. Technical barriers include the task of an established sorting and collection system for plastics and the difficulty in separating plastics. Compared to the recycling infrastructure for paper, glass, and aluminum, plastics are far behind.

Glass

Glass constitutes approximately 8 percent by weight of MSW. Almost all recycled glass is used to produce new glass containers and bottles. Nationwide, new containers include approximately 30 percent of post-consumer glass and recycled cullet (crushed glass from manufacturing operations. A minor amount of glass is used to make glass wool or fiberglass insulation, paving material, and building products such as brick, ceramic and terrazzo tile and lightweight foamed concrete.

The economics of recycling primarily depend on the costs of alternative disposal methods, the markets for recovered products, and the costs associated with running the recycling program. The economics of glass recycling must be reviewed in terms of "avoided costs" - - the costs that are saved by no landfilling the glass fraction of MSW. Removing post-consumer glass from the waste stream

- Separation and collection of waste materials

- The preparation of these materials for reuse, reprocessing, and remanufacture

- The reuse, reprocessing, and remanufacture of these materials

1. Separation and collection of waste materials

Source separation of wastes is an effective way to improve the performance of all following facilities in the integrated waste management systems. This diagram shows some typical waste diversion opportunities. Source separation has three primary benefits:

- Improved effectiveness of recycling
- Improved quality of the recovered materials
- Decreased cost of landfills

<u>Pretreatment for Source Separation and Resource Recovery</u>

1. Size Reduction Methods: some separation processes and many recovery processes, for efficient operation, require that the influent stream consist of pieces with a uniform size.

   a. shredding
   b. grinders
   c. chippers
   d. jaw crushers
   e. rasp mills
   f. hammer mills
   g. hydropulpers

2. Separation Methods: once various types of materials have been mixed, often necessary to separate the stream into the individual components in order to reprocess the material for reuse. Separation of various types of waste is not 100 percent efficient.

   a. hand sorting - at source or central facility
   b. density - air classifiers, inertial separation, flotation (use of differential specific gravities)
   c. screening
   d. magnetic
   e. optical

2. Reuse

- Waste directly applied for either the original purpose or a different purpose with minimal treatment in between processes. Includes washing:

  - beverage bottles for refilling

  - buy materials in large, durable containers which can be rinsed or directly used for storageand transport of other materials.

- Where possible, reuse is the preferred method of resource recovery, since it does not include any reprocessing. Reprocessing often requires inputs besides the recovered material, such as energy.

3. Recycling/Reuse of Various Materials

Typical materials that are candidates for recycling include:

- Aluminum cans
- Paper and cardboard

The third rank in the Integrated Solid Waste Management hierarchy is waste transformation. Waste transformation involves the physical, chemical, or biological alteration of wastes. Waste transformation is used to:

- Improve the efficiency of solid waste management operations and systems
- Recover reusable and recyclable materials
- Recover conversion products and energy in the form of heat and combustible biogas

For the purposes of this discussion, waste transformation will include combustion, gasification, pyrolysis, mechanical volume reduction, and composting.

1. Thermal Conversion Technologies (Combustion, Gasification, and Pyrolysis):

Combustion is the thermal processing of solid waste by chemical oxidation with stoichiometric or excess amounts of air.

Although the method is typically treated as a final disposal option, incineration can be considered a method to reduce the waste volume and to recover the heat content of the materials. Volume reduction ranges from 80 percent to above 90 percent, depending on the components of the waste and the temperature of combustion.

Two types of combustors include mass-fired and refuse-derived fuel.

MSW (mass-fired). Minimal processing is given to solid waste before it is placed in the hopper used to feed the combustor. Energy is recovered as hot water or steam.

Refuse-Derived fuel. RDF is produced from the organic fraction of MSW to consistently meet specifications for energy content, moisture, and ash content. Energy is recovered in solid fuel pellets.

Mass-fired combustors are the predominant type in the U.S. Because of the higher energy content of RDF compared with unprocessed MSW, RDF combustion systems can be physically smaller than comparable rated mass-fired systems; however, the need for front-end processing can add to the space needed to the RDF. An RDF-fired system can be controlled more effectively than a mass-fired system because of the more homogeneous nature of RDF, allowing for better combustion control and better performance of air pollution control devices.

Issues in the Implementation of Combustion Facilities:

1) Siting. To minimize the impact of the operation of combustion facilities, they should be sited in more remote locations where adequate buffer zones surrounding the facility can be maintained.

2) Air Emissions. Proper design of control systems for air emissions is of critical importance in the design of combustion systems. In some cases, the cost and complexity of the environmental control system is equal to or greater than the cost of the combustion facilities. Particulates, nitrous oxides, sulfur compounds and incomplete combustion products from plastics, paper, etc., necessitate the use of air pollution controls. Incomplete combustion products can be reduced by raising the temperature of combustion or increasing the retention time of the waste in the combustion chamber; however, increasing the temperature can increase the amount of nitrous oxide emissions. Nitrous oxides result when there is oxygen in excess of the combustion requirements. Control of the air flow to induce a reducing atmosphere in the combustion chamber will significantly reduce nitrous oxide emissions.

3) Disposal of Residues. Solid residues produced by combustion facilities include bottom ash, fly ash, and scrubber product. Management of these residuals is an integral part of the design and operation of a facility. Typically bottom ash is disposed of by landfilling. Because ash from facilities can leach hazardous wastes, many states require that disposal

decreases the weight of the MSW. Most tipping fees at U.S. landfills are figured by weight, so high glass content can have an impact on total disposal costs (EPA, 1988).

Ferrous Metal

The types of ferrous metal that may be used for recycling or reuse include:

- Steel cans
- Appliances, Automobiles, and Miscellaneous Scrap
- Shredded and Compacted Scrap

Steel cans (or tin cans) are recovered from the consumer waste stream through curbside collection programs and at collection centers. In general, the market price for steel cans is too low to provide a financial incentive to recycle to most consumers. However, despite the marginal economics, steel can recycling programs are expected to increase as a result of landfill-diversion legislation.

Appliances, automobiles, and miscellaneous steel scrap are usually processed by scrap dealers and auto dismantlers.

The demand for steel scrap is related to the general economy and to the demand for new autos, machine tools, and heavy construction equipment. Although historically, the demand has been cyclical, it now appears to be stable owing to improved competitiveness of the steel industry in the U.S. and the increased number of mini-mills to process scrap.

Nonferrous Metals

Nonferrous metals compose approximately 4 percent of MSW. Recyclable materials ar recovered from common household items (ladders, tools, hardwares); from construction and demolition projects (copper wire, paper and plumbing supplies, light fixtures, aluminum siding); and large consumer, commercial, and industrial products (appliances, automobiles, aircraft, machinery).

Scrap metal dealers buy materials from suppliers, the public, repair shops, and construction and demolition firms, and sell to brokers or industrial buyers.

Construction and Demolition (C/D) Wastes

Typically, C/D wastes are comprised of about 40 to 50 percent rubbish (concrete, asphalt, bricks, blocks, and dirt), 20 to 30 percent wood and related products (pallets, stumps, branches, forming and framing lumber, and shingles), and 20 to 30 percent miscellaneous wastes (painted lumber, metals, plaster, glass, plumbing and heating parts, and electrical parts). Although a relatively small percentage of C/D wastes are now recovered, significantly greater amounts will probably be recycled in the future as a result of higher tipping fees, mandatory landfill diversion legislation, and the success of entrepreneurs in processing mixed wastes. There are no industry-wide specifications for C/D wastes. Specifications are negotiated individually with buyers of the separated materials.

Used Tires

Tire dealers, auto dismantlers, and landfill operators pay independent contractors to pick up used tires. Whole tires are no longer buried at most landfills because they occupy a large volume and tend to rise to the surface. The principal reuse opportunities for rubber tires are for retreading and remanufacturing, tire-derived fuel, and rubber modified asphalt.

Most landfills are unwilling to accept tires because they are difficult to handle and take up a lot of space. Tire piles represent a serious environmental concern because of the potential for fires, and their associated emissions. Major tire fires have occurred in several locations in the U.S.

C. Waste Transformation

Composting is the use of biological processes to degrade organic fraction into CO_2, H_2O, humus; applicable primarily to the yard clippings and food waste components. The resulting compost has the following uses:

- Fertilizer - potential resale
- Land application - forests, no resale
- Landfill - is a reduced volume and a stable material (least preferred)

Issues in the Implementation of Composting

1) Proper Process Design and Operation

The following design requirements must be considered for composting:

a) Land requirements - required retention time

b) Ratio of C:N:P to permit optimum biodegradation - may need to add appropriate nutrients, combine food wastes with sewage treatment sludge

c) Bulking the food waste, air flow to permit aerobic degradation - mechanical vs. passive windrows

d) Lining of the composting area and runoff/leachate collection and treatment system to prevent discharge to the surroundings

2) Facility Siting and Production of Odors

Facility siting issues are primarily related to the production and movement of odors. Factors in controlling odors include attention to local microclimates, the distance to odor receptors, and the use of adequate buffer zones. Causes of odors in composting operations include low carbon to nitrogen ratios, poor temperature control, excessive moisture, and poor mixing.

3) Product Quality

Product quality for compost material can be defined in terms of the nutrient content, organic content, pH, texture, presence of foreign matter, and many other factors. The issue of pathogenic organisms, which can arise from compost piles, is of public health concern and must be controlled for adequate product quality.

Theoretically, this method offers many possibilities. The composting of municipal wastewater sludge is a proven, effective method of sludge treatment. The composted sludge can either be sold as fertilizer or applied to forest lands. Composting of hazardous organics, such as chlorinated phenols, is receiving attention as an innovative technology. Small, backyard composting has been popular for a while. The implementability of the method is uncertain. The potential, particularly if lawn clippings and food wastes are directly composted without contacting other materials (potential for cross-contamination), appears to be high.

4) Landfill Disposal

A sanitary landfill is an engineered structure for the long-term storage/disposal of municipal waste. Currently, the structure is designed to prevent the infiltration of surface and subsurface waters into the waste containment area, to prevent leachate generated by the waste from contaminating the environment, in particular the groundwater, and, after closure, to minimize the accumulation of explosive gases.

Design Criteria

1. The new landfill must be lined with one layer of synthetic, impermeable materials and also a layer of low permeability soil.

occurs only in lined MSW landfills or double-lined monofills devoted to the disposal of ash. In many states, the use of ash as a fill for cement production can be implemented.

4) Liquid Emissions. Liquid emissions from combustion facilities can arise from the following:

- Wastewater from the ash removal facility
- Effluent from wet scrubbers
- Wastewater from pump seals, cleaning
- Cooler tower blowdown
- Wastewater from treatment systems for boiler water

5) Economics. The economics of a combustion system can be evaluated using life cycle costing, which accounts for operating and maintenance costs over the lifetime of the system.

6) Heat value. Heat value is typically measured in Btu/lb, of the waste stream. Unseparated MSW waste will contain a high moisture content, primarily from the food waste and lawn/garden trimmings. Glass and metallic components increase the volume of ash residue and have negligible heat value. If the heat value of the total waste stream is less than the combustion requirements to permit a self-sustaining thermal reaction, then auxiliary fuel is required.

Gasification

Another type of combustion, gasification, is the general term used to describe the process of partial combustion in which a fuel is deliberately combusted with less that stoichiometric air. This process has only recently been applied to the processing of solid waste. Gasification is not widely used for solid waste treatment; however, due to lower air emissions, as compared to excess-air combustion systems, they may be used more frequently in the future.

Pyrolysis

Pyrolysis is the thermal processing of waste in the complete absence of oxygen to produce gaseous, liquid and solid fuels. Pyrolysis systems use an external source of heat to drive the endothermic reactions. The three major component fractions that result from pyrolysis include:

- Gas stream, containing primarily hydrogen, methane, carbon monoxide and carbon dioxide

- Liquid fraction, consisting of a tar or oil stream continuing acetic acid acetone, methanol and complex oxygenated hydrocarbons

- A char, consisting of almost pure carbon

Only one full-scale MSW pyrolysis system was built in the U.S., constructed in El Cajon, California. The system did not achieve purity specifications for aluminum and glass and failed to produce a saleable pyrolysis oil. Also known as destructive distillation.

2. Mechanical Volume Reduction

Volume reduction is one means by which the capacity lives of landfills are extended. These methods include:

Mechanical Volume Reduction, also known as compaction: apply pressure to force a given quantity of waste to occupy a smaller volume. High pressure and low pressure compactors. Compaction ratios achieved depend on the type of waste, range from 2:1 to 8:1. Baling is a very high pressure compaction method, typically performed at landfills before emplacement of waste.

3. Composting (recycling of organic nutrients)

2. Between the waste and the bottom/side liner, there is a highly permeable gravel layer to promote the flow of leachate into the leachate collection system. The leachate is pumped to the surface for appropriate treatment and disposal.

3. The landfill is covered with impermeable materials and capped in such a manner as to inhibit the infiltration of rainfall and other surface waters. The cap is sloped and vegetated to promote the runoff of precipitation and to minimize erosion. Between the topsoil and the cap liner is a layer of gravel or permeable media to promote the lateral drainage of infiltrated water.

4. Incorporation of a gas collection and venting system to control the accumulation of gases, such as methane, carbon dioxide and hydrogen sulfide, formed by biological activity after landfill closure.

5. Current designs inhibit the development of conditions which would promote the biological degradation of the MSW. The landfill is designed such that the internal atmosphere is too dry for biological activity. The design life of the landfills is 50 years. What will happen to the waste after those 50 years have passed is uncertain. Although called disposal, landfilling delays the need to address the ultimate fate of the "waste" materials.

Landfills require much area. With the current public attitude towards landfills, characterized by the Not In My Back Yard (NIMBY) syndrome, these waste disposal structures are difficult to site. Placing potentially usable materials in an underground storage vault constitutes an inefficient use of land and material resources.

IV. SUMMARY

The components and complexity of integrated solid waste management cannot be covered in this brief lecture. An understanding of options for MSW management and the need for an integrated program is the first step towards incorporating ISWM into your pollution prevention program. Thank you for your attention. I hope this brief overview of MSW management will impress you with the importance of integrated solid waste management.

contaminants. This cleaning action continues until the work reaches the vapor temperature. The amount of solvent vapor condensation on a part's surface depends on its weight and specific heat.

Cold-dipping Cleaners. Cold-dipping cleaners are widely used for removing oils, greases, and dirt from metal parts and equipment. Common solvents used for this type of cleaning include Stoddard Solvent (SS), PD-680 (Type III), naphtha, mineral spirits, and terpene-based solvents. The solvent is applied either by brushing, spraying, or dipping the item to be cleaned in a solvent dip tank. The components of these solvents are mainly alkane isomers between C_6 and C_{16}. They contain approximately 2 percent toluene and a maximum of 0.5 percent benzene. The toxic hazard rating for mineral spirits is considered to be slight to moderate.

Paint Thinners. Three major applications of paint thinners are to: 1) thin paint and coatings before application, 2) clean surfaces prior to painting and, 3) clean paint application equipment. Paint thinner compounds include toluene, xylene, methyl ethyl ketone, and alcohols.

Paint Strippers and Carbon Removers. Paint stripping operations are often carried out at corrosion control facilities for vehicles and aerospace ground equipment (AGE). Vehicles, AGE, and parts removed from vehicles, AGE, and aircraft are paint-stripped. Spot stripping of aircraft is occasionally performed. Complete repainting of aircraft is limited to DoD installations with large enough stripping and painting facilities to accommodate aircraft. Paint strippers and carbon removers consist mainly of methylene chloride mixed with additives such as phenol, ethanol, petronate HL, water, toluene, paraffin, sodium chromate, and methyl cellulose.

Precision Cleaners. Precision cleaning operations include the maintenance of fragile, sensitive navigational and electronic equipment. Typical precision cleaning solvents are ketones and esters, which are used for cleaning surfaces prior to painting. Freons are used 1) to clean electrical parts and appliances that require a solvent with high solvency power and rapid evaporation rate, and 2) for leak detection.

II. SOLVENT CONTAMINANTS

Department of Defense (DoD) installations use large amounts of solvent each year in cleaning operations. Types of contaminants that require solvent cleaning are generally heterogeneous mixtures of substances having different physical and chemical characteristics. Contaminants can by grouped into three areas:

1) Hydrocarbon oils, such as lubricating oils and greases, transmission oil, fuel oil, asphalt, and tar.

2) Paints and varnishes.

3) Soily material, such as clay and silt, cement, soot, and lampblack.

The first two categories are inert organic material (liquids and semiliquids), while the third category consists mainly of insoluble inorganic materials.

Mechanisms by which contaminants adhere to metal parts can be classified generically as: mechanical entrapment onto/into the part; bonding to the part by cohesion or wetting; and bonding by chemical or adsorptional combination with the part material.

Mechanical entrapment is limited to solid soil or contaminants on the rough protuberances of a part or in crevices of the part structure.

In cohesion or wetting, the contaminant, if in liquid form, is held by wetting of the part surface; in the case of a liquid/solid mixture, the liquid acts as an adhesive between the solid particles and the part material by metal wetting. The attachment can be broken by 1) an increase in the free energy of the liquid contaminant/part interface, 2) substitution of a new interface that has lower free energy (by adding surfactants), or 3) imparting of mechanical energy to the contaminant/part interface as by brushing or wiping action.

Chemical or adsorptional combination of contaminants with the part material occurs when a part has been exposed to strong acids or alkalis. This situation is not generally observed in routine cleaning operations.

BLOCK 14: BASICS OF SOLVENTS

1.0 Introduction

Block 14 introduces solvents and how they are used at DoD facilities. The classification and use of solvents in the DoD environment is reviewed. Hazardous waste production associated with activities at DoD installations is also covered. Physical/chemical and toxicological properties associated with commonly used solvents are presented as well as specific pollution prevention strategies for recycling/reuse and substitutions of solvents.

2.0 Objective

To explain what solvents are and how they are used. To discuss the applicability of replacements, including pros and cons. To discuss reuse philosophies like in-process recycling and countercurrent flow. Note: Includes computer-based instruction.

1. Students will know and understand the purposes and major types of solvents by surveying the materials used in DoD activities.

2. Students will know and understand the potential impacts of solvents used in DoD activities by reviewing the major classes of materials present and their properties.

3. Students will know and understand the basic strategies for pollution prevention associated with solvent recycling and reuse.

4. Students will know and understand the basic strategies for pollution prevention associated with solvents by reviewing material substitutions possible, and the new technologies and process substitutions available for solvent-related activities.

5. Students will know and understand the pollution prevention potential associated with solvents by viewing statistics on the quantities of solvents used in DoD activities.

3.0 Key Concepts

I. USE OF SOLVENTS AT DOD INSTALLATIONS

Solvents used at DOD installations can be classified into five groups. These groups are based on the chemical makeup and function of solvents and includes: 1) vapor degreasers, 2) cold-dipping cleaners, 3) paint thinners, 4) paint strippers and carbon removers, and 5) precision cleaners.

Actions of solvents that characterize their ability to effect cleaning include wetting and spreading on both part and contaminant surfaces, lowering the surface free energy of contaminant surfaces, speeding movement of solid and liquid particles, and solubilization. The degree of solubility of a contaminant (solute) in a solvent is known as the "solvent power" of the solvent.

Desirable characteristics of solvents include the following:

- Dissolve oils, grease, and other contaminants.
- A high vapor density relative to air and a low vapor pressure to minimize solvent losses.
- Chemically stable under conditions of use.
- Essentially noncorrosive to common construction materials.
- A boiling point and latent heat of vaporization low enough to permit the solvent to be separated easily from oil, grease, and other contaminants by simple distillation.
- Form azeotropes with liquid contaminants or with other solvents.
- Nonexplosive and nonflammable under the operating conditions.

<u>Vapor Degreasers</u>. Vapor degreasers are used primarily for removing oils and greases that are soluble in the degreasing solvent. Vapor degreasing solvents are mostly chlorinated compounds such as 1,1,1-trichloroethane, trichlorethylene, tetrachloroethylene (perchloroethylene) and methylene chloride. Material to be cleaned is immersed in the vapor zone of a degreaser. Since the material is introduced at ambient temperature, the solvent vapor condenses on the cooler exposed surface of the part and dissolves the

Chemical and Physical Properties

Boiling Point: 39.75 C at 760 mm Hg
Melting Point: -95.1 C
Molecular Weight: 84.94

Log Octanol/Water Partition Coefficient: 1.25
Water Solubility: 13,000 mg/L at 25 C
Vapor Pressure: 434.9 mm Hg at 25 C
Henry's Law Constant: 2.68 x 10-3 atm-m^3/mol

Natural Sources: None.

Artificial Sources: Air emissions from its use as an aerosol propellant, paint remover, metal degreaser, and a urethane foam blowing agent.

Human Health Exposure Potential

Probable Routes of Human Exposure: Human exposure will result primarily from ambient air, particularly in the vicinity of areas of usage. Another source of exposure is from drinking water originating from contaminated ground water sources.

Occupational Exposures: NIOSH (NOES Survey 1981-1983) has estimated that 1,147,425 workers are exposed to methylene chloride in the United States.

Body Burdens: Detected in all 8 samples of human milk from 4 urban areas.

Terrestrial Fate: If released to land, methylene chloride is expected to evaporate from near-surface soil into the atmosphere because of its high vapor pressure. From a reported log K_{om} of 1.44, a log K_{oc} of 1.68 has been calculated. Based on this value, methylene chloride is expected to be very mobile in soil. It is reported to adsorb strongly to peat moss, less strongly to clay, only slightly to dolomite limestone, and not at all to sand. Its presence in groundwater at high concentrations levels indicates its potential for leaching. Hydrolysis in soil is not an important fate process.

Aquatic Fate: Methylene chloride is expected to evaporate from surface water in several hours, depending on wind and mixing conditions. Biodegradation, hydrolysis, adsorption to sediment and bioconcentration in aquatic organisms are not important fate processes. A BCF of 5 can be calculated from its log K_{ow}.

Atmospheric Fate: Released to the atmosphere, degradation via reaction with photochemically produced hydroxyl radicals (half-life of several months) is the major fate process for methylene chloride. It is not subject to direct photolysis. It may be subject to removal in rain since it has been detected in rainwater.

B. Methyl Ethyl Ketone (MEK)

Substance Identification

Synonyms: 2-Butanone
CAS Registry Number: 78-93-3
Molecular Formula: C_4H_8O

Chemical and Physical Properties

Boiling Point: 79.6 C
Melting Point: -86.35 C
Molecular Weight: 72.10

Log Octanol/Water Partition Coefficient: 0.29
Water Solubility: 239,000 mg/L
Vapor Pressure: 90.6 mm Hg at 25 C

Natural Sources: Volcanos, forest fires, products of biological degradation, natural component of food.

Effective cleaning operations can be divided into three steps:

1) Separation of contaminants from part material.

2) Dispersion and solubilization of contaminants in the solvent.

3) Stabilization of the dispersed contaminants.

III. SPENT SOLVENTS

Most solvents at one time or another were considered to provide one-time use; when they become contaminated, they are discarded. In these cases, disposal methods are mainly destructive, i.e., waste solvents are incinerated, evaporated, or dumped. Now, military facilities are initiating programs for reclaiming used solvents. Because solvents usually do not break down chemically during cleaning operations, reclamation is technically feasible. The role of solvents in cleaning is limited mainly to physical solubilization of waxes, greases, oils, and other contaminants.

A major factor in the use of solvents is determining a solvent as spent (i.e., contaminated to the point that it is no longer effective for its intended purpose). Discarding a solvent before it is spent fails to maximize the material's life from an economic standpoint, while using it too long may result in use of an ineffective cleaner.

Surveying physicochemical and electrical properties is one method for monitoring solvent quality. These properties include the following:

1. *Kauri-Butanol Value* (KBV), used for evaluating the relative power of solvents, gives an index for ranking solvents on their ability to dissolve other material.

2. *Viscosity*, the internal friction or resistance to flow, is used to characterize oils and solvents. This property depends on the intermolecular attractive forces within the fluid.

3. *Specific gravity* is the ratio of the density of a liquid to that of water at the same temperature. Density is a fundamental physical property of a substance denoting the mass of a substance per unit volume.

4. *Refractive index*, the ratio of the velocity of light in a vacuum to the velocity of light in the liquid, is used to identify substances and determine their purity.

5. *Visible light absorbance* is the transmission of visible radiation between 450 and 600 nm.

6. *Electrical conductivity*, the ability of a solution of carry an electric current, will increase or decrease during the course of solvent usage depending on the impurities being accumulated.

7. *Acid Acceptance Value (AAV)* measures the acid acceptance inhibitor level present in solvents.

In the case of chlorinated solvents, determination of a solvent's inhibitor level is critical to determining solvent quality. Inhibitors are present in chlorinated solvents to prevent solvent breakdown, the solvent's becoming an acid, and solvent-part reaction. Three basic types of inhibitors added to chlorinated solvents are: 1) antioxidants, 2) acid acceptors, and 3) metal reaction stabilizers. The combination of inhibitors added to the solvent depends on the characteristics of the solvent and the cleaning operation.

IV. PHYSICAL/CHEMICAL AND TOXICOLOGICAL PROPERTIES ASSOCIATED WITH COMMONLY USED SOLVENTS

A. Methylene Chloride

Substance Identification

Synonyms: Dichloromethane
CAS Registry Number: 75-09-2
Molecular Formula: $CH_{12}Cl_2$

Occupational Exposures: NIOSH (NOES Survey 1981-83) has statistically estimated that 392,805 workers are exposed to 1,1,1-trichloroethane in the United States.

Body Burdens: Detected in all eight samples of human milk from four urban areas.

Environmental Fate/Exposure Potential

Terrestrial Fate: Evaporates fairly rapidly into the atmosphere because of its high vapor pressure. Passes rapidly through soil into ground water. No, or very slow, degradation in soils. 1,1,1-trichloroethane has little tendency to bioconcentrate.

Aquatic Fate: Primary loss will be by evaporation into the atmosphere. Half-life will range from hours to a few weeks depending on wind and mixing conditions. Biodegradation and adsorption onto particulate matter will be insignificant relative to volatilization.

Atmospheric Fate: 1,1,1-Trichloroethane is fairly stable in the atmosphere and is transported long distances, being found even at the South Pole.

V. POLLUTION PREVENTION STRATEGIES ASSOCIATED WITH SOLVENT USE

Waste minimization contributes to protection of human health and the environment by reducing risks to potential exposed people and environmental impacts from the release of pollutants. Also, an aggressive waste minimization program helps to reduce costs and to enhance DoD credibility regarding adherence to environmental protection.

Waste minimization in an industrial operation is a multifaceted process. It encompasses a variety of techniques that can be implemented to reduce the generation of waste at its source or to reduce the quantity of waste to be disposed of. Waste minimization options associated with the use of solvents include: 1) process modification, 2) material substitution, 3) on-site solvent recycling, and 4) off-site solvent recycling.

A. Process Modification

To curb solvent consumption during cleaning, good operating practices are essential. Listed below are some of waste minimizing practices for use during removal of grease, oil, and dirt from metal.

- Preclean parts with squeegees or rags to remove as much dirt and grease as possible. This will extend the solvent life before it becomes dirty and needs replacement.

- Keep tanks covered except when in use to reduce vapor loss.

- Use a course spray or solid stream of solvent instead of fine spray to reduce volatilization.

- Maintain parts-cleaning equipment to reduce the incidence of spill or leaks.

- Lower and raise parts slowly and smoothly to reduce vapor release and liquid removal.

- Provide drip racks or other drainage to allow solvents to drip off parts before moving.

- Place wipe rags in a closed container and reuse them whenever possible.

- Avoid mixing hazardous wastes with nonhazardous wastes; mixing increases the volume of hazardous waste that requires disposal.

- Use multistage countercurrent cleaning; use two or more consecutive solvent rinse tanks or sinks. The first-stage tank becomes the "dirty" sink and serves to remove gross contamination, whereas the later-stage sinks or tanks stay clean longer because they remove only residual oil and grease.

- Implementation of proper stripping equipment cleaning techniques. Stripping efficiency is higher when the equipment is cleaned regularly.

Artificial Sources: Emissions from its use as a solvent for lacquers, adhesives, rubber cement, printing inks, paint removers and cleaning solution, catalyst, carrier, and wastewater from these uses.

Human Health Exposure Potential

Probable Routes of Human Exposure: The major routes of exposure to MEK are from ingestion of contaminated drinking water and food, and inhalation of contaminated air near sources of emissions and during air pollution episodes. Exposure via water and food ingestion is most likely scattered and slight.

Occupational Exposures: Occupational surveillance <25 ppm. NIOSH (NOES Survey 1981-83) has statistically estimated that 1,221,857 workers are exposed to MEK in the United States.

Body Burdens: Detected in 5 of 8 samples of human milk from 4 U.S. urban areas.

Environmental Fate/Exposure Potential

Terrestrial Fate: When released to soil, MEK is expected to evaporate into the atmosphere from near-surface soil. Based on an estimated K_{oc} value of 34 (based on the log K_{ow}), MEK is expected to have a high mobility in soil and may leach into groundwater. Hydrolysis from is not an important fate process. Biodegradation in soil and groundwater is expected to be slow.

Aquatic Fate: When released into water, MEK is expected to evaporate into the atmosphere; the half-life has been estimated to be 3 and 12 days in rivers and lakes, respectively. Biodegradation in both fresh and salt water is expected to be slow. MEK may be subject to direct photolysis. Hydrolysis, photooxidation, adsorption to sediment, and bioconcentration in aquatic organisms are not significant fate processes. A BCF of 1.0 has been estimated using the log K_{ow}.

Atmospheric Fate: Once in the atmosphere, MEK is expected to exist primarily in the gas phase. Degradation via reaction with photochemically produced hydroxyl radicals (half-life 2.3 days) is the major fate process. Acetaldehyde is the end product of this reaction. Direct photolysis may occur. MEK may be subject to removal in rain since it has been detected in rainwater.

C. 1,1,1-Trichloroethane

Substance Identification

Synonyms: Methyl chloroform
CAS Registry Number: 71-55-6
Molecular Formula: $C_2H_3Cl_3$

Chemical and Physical Properties

Boiling Point: 74.1 C at 760 mm Hg
Melting Point: -30.4 C
Molecular Weight: 133.42

Log Octanol/Water Partition Coefficient: 2.49
Water Solubility: 347 mg/L at 25 C
Vapor Pressure: 123.7 mm Hg at 25 C
Henry's Law Constant: 8×10^{-3} atm-m^3/mol

Natural Sources: None.

Artificial Sources: Wastewater and stack and fugitive emissions from production. Volatilization losses from its use in the cold cleaning of metals, in vapor degreasing, and as a solvent and aerosol, etc.

Human Health Exposure Potential

Probable Routes of Human Exposure: Humans may be exposed to 1,1,1-trichloroethane dermally and by inhalation of air at occupational sites.

D. Off-Site Recycling

Contracts with solvent service companies which treat and recycle solvent waste off-site are available for installations when on-site solvent recycling is not feasible. Under these contracts, an off-site recycler provides the solvent as well as the cleaning equipment; the recycler changes the solvent on a regular schedule and transports the waste to a recycling center, where the solvent is reclaimed. The solvent user, in effect, leases the solvent and equipment, and as generator of the waste, is responsible for the safe disposal of the wastes or residuals associated with recycling.

The two basic types of off-site solvent recycling services available are custom toll recycling and open market recycling. In custom toll recycling, the generator's spent solvents are kept segregated, batch-processed separately to the generator's specification, and then returned for reuse. The minimum batch size is generally 1,000 to 2,000 gallons. In open market recycling, the spent solvents are co-mingled with like or similar wastes from many generators and processed to specification for resale and reuse in the marketplace as refined solvent.

VI. SOLVENT USE ALTERNATIVES/TECHNOLOGIES

A. Terpene-Based Cleaners

Unlike many of the solvents currently in use (e.g., Stoddard solvent, MEK, 1,1,1-trichloroethane), terpene-based solvents, which are derived from citrus plants and pine trees, are completely water-soluble and in most instances require a clear water rinse. The cleaning procedures are similar to those needed for an alkaline soap. The products are free rinsing, and their evaporation rates are comparable to water. After cleaning bare metals, corrosion protection will be required to prevent flash corrosion.

Terpene-based cleaners are available commercially in concentrated form or as water solutions with surfactants, emulsifiers, rust inhibitors, and other additives. The volatile organic compound (VOC) content of undiluted cleaners averages about 50 percent, though the exact amount may vary depending on the composition. Terpene-based cleaners are not listed as ozone layer depleting substances.

Terpene-based cleaners are used in dilutions with water ranging from one part cleaner-two parts water for heavy-duty cleaning to cleaner-water ratio of 1:20 for light-duty cleaning. Used product with small amounts of oil and dirt can be drained directly into the sanitary sewer. Used terpene-based cleaners containing large or significant amounts of oil and dirt can be discharged to oil/water separators, where dilution with water will result in oil and grease separation.

Terpene-based cleaners have tested favorably as substitutes for halogenated solvents in the removal of heavy grease, oily deposits, and carbonized oils. Reported disadvantages of terpene-based cleaners include inability to separate long-chain aliphatic oils for recycling of the cleaning solution either in concentrated form and in aqueous emulsions. Ultrafiltration to remove oil is not viable for recycling and is only useful for treating dilute emulsions prior to wastewater treatment. Recovery by distillation is impractical since terpenes boil around 340 F, which means that many light oils would be carried over the boiling point of the solvent. Also, terpene-based cleaners cost more than traditional chlorinated and hedrocarbon solvents.

B. Counter-Current Rinse Systems

Most hazardous waste comes from wastewater generated by the rinsing operations that follow cleaning, plating, and stripping operations. The savings associated with reducing rinse water use are primarily from reduced water, sewer, and sludge disposal fees. Multiple rinse tanks can be used to significantly reduce the volume of rinse water used. A multistage counter-current rinse system uses up to 90 percent less rinse water than a conventional single-stage rinse system. In a multistage counter-current rinse system, workpiece flow moves in a direction opposite to the rinse water flow. Water exiting the first tank (the last tank in which the workpiece is immersed) becomes the feed water to the second tank. This water then feeds the third tank, and so on for the number of tanks in the line.

A multistage counter-current rinse system allows greater contact time between the workpiece and the rinse water, greater diffusion of process chemicals into the rinse solution, and more rinse water to come into contact with the workpiece. The disadvantage of multistage counter-current rinsing is that additional tanks and work space are needed.

- Minimization of the production of poor-quality finishes in painting operation. Poor-quality finishes will have to be removed by stripping and replaced, thereby generating unnecessary stripping wastes.

B. Material Substitution

Substitution of solvents is intended to result in the use of less hazardous or nonhazardous materials, as well as reduction in waste. Potential methods of material substitution are given below.

- Instead of using products containing halogenated hydrocarbons, use a commercial product containing mineral spirits, xylene, acetone, or ethyl acetate.

- Standardize solvent use within the DoD installation as much as possible to reduce the complexity of solvent management and increase the potential for recycling. Several AFRES bases have successfully converted to use of a single solvent, typically mineral spirits, to replace the wide variety of products previously used. Advantages include selection of a solvent less toxic than those previously used, cost savings through volume purchasing, and simplified waste reporting and recycling.

- Replace halogenated organic solvents with aqueous cleaners or water-soluble cutting fluids where possible. Aqueous cleaners do not emit fumes and vapors and may be biodegradable. This type of cleaner includes alkaline solutions of sodium carbonate or sodium phosphate, finely dispersed mineral spirit emulsion cleaners in aqueous solution, and the citrus-based d-limonene organic cleaner. Costs for substitution range from $0.50 to $0.60 per gallon for emulsions, $0.80 to $2.40 per gallon for alkaline cleaners, and $9.50 to $17.00 per gallon for cleaners containing d-limonene. Traditional solvents cost $2 to $6 per gallon for virgin solvent, plus $1 to $8 per gallon for waste disposal or recycling. Substitutes are generally less toxic but in some cases less effective and more corrosive than traditional solvents.

- High-pressure water washing may also be an effective method of parts cleaning. The water and contaminants can usually be separated in an oil/water separator.

- Use of nonphenolic solvents in paint stripping.

- Paint stripping with solvents may be replaced with dry paint stripping technologies such as plastic media blasting, a stripping technology pioneered at AF aircraft maintenance facilities. During this process, fine polymer beads are delivered in an enclosed chamber by high-pressure air to physically remove paint from the metal surface. After being used, the plastic beads are separated from the paint chips for reuse. No liquid waste is generated, and only comparatively small amounts of dry fine plastic dust and paint chips containing heavy metals are produced. Estimates, based on the stripping of 215 F-4 aircraft, show that substitution with plastic media stripping at a military installation can reduce hazardous waste generation by 99% and waste disposal and wastewater treatment costs by about 65%. Another dry paint stripping technology is dry ice blasting. In this system, carbon dioxide pellets are used as a blasting media. The dry ice pellets vaporize after being used, and the only waste product is the dry paint chip. Additional technologies currently under development are laser paint removal (based on a pulsed carbon dioxide laser paint removal system) and flashlamp paint removal (based on the use of electromagnetic pulses to remove paint).

C. On-Site Recycling

On-site solvent recycle and recovery can extend solvent life and reduce solvent costs. The following are common recovery methods:

1) Decanting - drawing off the liquids from the settled sludge; alternatively, draining out the bottom sludge.

2) Filtration - passing the solvent through a porous medium to remove the solids.

3) Distillation - separation in specialized equipment, which takes advantage of differences in boiling point between different liquids. For large military bases, distillation is the most commonly used method of recycling spent organic solvents.

Strategic Air Command	1790	2374	2759
Tactical Air Command	1779	577	3102
Air Force Logistics Command	51876	87883	1134072
Other Commands	812	959	1209
Total	60486	95986	1146641a
Army			
Forces Command	812	2764	7478
Training Command	2883	2341	1288
Army Material Command	103771	133502	56645
Command	**1985 (Tons generated)**	**1986 (Tons generated)**	**1987 (Tons generated)**
Other commands	59	190	542
Total	107524	138798	65954
Navy			
Space and Warfare Systems Command	b	73	45
Naval Supply Command	333	2307	1068
Pacific Fleet	8183	12439	105675
Naval Air Systems Command	37383	30165	6014
Naval Sea Systems Command	50835	56404	51627
Naval Facilities Engineering Command	90554	63135	640
Other commands	84088	18743	10156
Total	271375	183267	175225

[a]Data furnished by the Air Force for 1987 reflect gross generations, which include reclaimed, recycled, and reused chemical and wastewater that is subsequently treated and removed prior to disposal.

C. Plastic Media Blasting

Plastic media blasting (PMB) is a process for the rapid, economic and safe removal of coatings from almost any workpiece without the use of toxic chemical strippers. Being a dry stripping process, it also eliminates the need for costly and sophisticated wastewater treatment facilities. PMB resembles sandblasting, however, it does not use hard abrasives, such as silica sand. The process uses recyclable plastic particles, varying in hardness from 3.0 to 4.0 Mohs. Hard abrasives are in the 7 Mohs range. Since the plastic particles are softer than the workpiece, yet harder than the coating, PMB can remove primers and topcoats without harming substrates such as aluminum (alclad and anodized), brass, copper, magnesium, thin steel and titanium. These materials would be easily damaged by sandblasting. PMB can also by used on surfaces where solvents cannot be used, or must be applied with caution, such as honeycomb, engineered plastics, fiberglass and advanced composites. It can be used to remove virtually any primer, paint or surface coating, including urethanes, chemically resistant coatings and even carbon build-up. It is possible to remove coatings one layer at a time, leaving primer and surface fillers intact, if desired; and it does not remove conversion coatings.

When the DoD began using PMB, only three types of blast media were authorized for use (as set forth in the original draft specifications of the Department of Navy dated January 6, 1986):

Type I - Polyester (Thermoset)
Type II - Urea formaldehyde (Thermoset)
Type III - Melanine formaldehyde (Thermoset)

By May of 1988, the Navy had approved two additional types of media:

Type IV - Phenol formaldehyde (Thermoset)
Type V - Acrylic (Thermoplastic)

In March 1990, the Navy introduced a sixth type of media:

Type VI - Poly (allyl diglycol carbonate (Thermoset)

And in April 1990, a seventh type of media was introduced at the DoD Advanced Coatings Removal conference:

Type VII - a nonpetroleum amylaceous polymer, which is biodegradable

VII. HAZARDOUS WASTE PRODUCTION ASSOCIATED WITH SOLVENT USE AT DOD INSTALLATIONS

The Department of Defense is a major generator of hazardous waste. Hazardous waste includes contaminated sludge, solvents, acids, and heavy metals that are dangerous to humans and the environment if disposed of improperly. DoD generates over 400,000 tons each year from industrial processes primarily used to repair and maintain weapon systems (e.g., F-16 aircraft) and equipment (e.g., trucks). Data provided by the armed services showing hazardous waste that the Air Force, the Army, and the Navy generated between 1985 and 1987 are shown in Table 1.

Table 1. Hazardous Waste Generation Data.

Command	**1985 (Tons generated)**	**1986 (Tons generated)**	**1987 (Tons generated)**
Air Force			
Air Force Systems Command	197	446	1150
Air Training Command	605	660	870
Military Airlift Command	3462	3086	3481

B. Material Substitutions

Command	Original material	Substitute material
Air Force		
Ogden Air Logistics Center	Cyanide strippers	Noncyanide strippers
San Antonio Air Logistics Center	Perchloroethylene	Nonhazardous PD-680 (Type III)
	Perchloroethylene	1,1,1-Trichloroethane
	Perchloroethylene	Biodegradable solvent
Randolph Air Force Base	Trichloroethylene	PD-680
Berstrom Air Force Base	PD-680 Type I	Safe T Solvent
	Trichloroethylene	Solvent 140; PD-680 Type III
Army		
Chorpus Christi Army Depot	Phenolic paint stripper	Less hazardous stripper
Anniston Army Depot	Petroleum-based solvent	Nonhazardous steam cleaning compound
Redstone Arsenal	Trichloroethylene	PD-680
Fort Stewart	PD-680 Type I	PD-680 Type III
	Product Sol 913	Citrikleen
Navy		
Naval Aviation Depots Norfolk Alameda	PD-680	Citrikleen
Shipyard, Pearl Harbor	Chemicals for cleaning bilges/tanks	Citrikleen

IX. SUMMARY

This lesson presented background information on solvents and their use in DoD activities. A brief overview of pollution prevention strategies associated with solvent use was given. Driven by environmental concerns, process modification, material substitution, and recycle/reuse must be considered in DoD cleaning operations. Students will now have a basic understanding in solvent pollution prevention strategies.

[b]The Space and Warfare Systems Command was not established until 1986.

In 1984, a DoD Inspector General report was issued covering the recycling activities of 34 installations during 1982 and 1983. According to the report, 12 of the installations were recycling used solvents. Nine of these 12 installations reclaimed, through recycling, 496,000 gallons of solvents - about 25 percent of the solvents they used in fiscal year 1982. In 1985, the General Accounting Office (GAO) surveyed 14 DoD installations and found that 4 of the 14 recycled about 490,000 gallons of solvents in 1984. Reviews of records indicated that 13 installations dispose of an estimated 410,000 gallons of waste solvents annually that could be recycled.

VIII. IMPLEMENTATION OF POLLUTION PREVENTION STRATEGIES BY DOD INSTALLATIONS

Listed below are several examples of waste minimization efforts carried out by several DoD installations. This list is by no means all inclusive.

A. Solvent Reduction Process Changes

1. Air Force

Ogden Air Logistics Center, Hill Air Force Base

- plastic media blasting
- eliminate methyl ethyl ketone

San Antonio Air Logistics Center, Kelly Air Force Base

- plastic media blasting

Bergstrom Air Force Base

- banned methyl ethyl ketone
- PD-680 Type III
- trichloroethylene

2. Army

Anniston Army Depot

- in-line still to recover trichloroethylene
- holding tanks for chemicals while cleaning sludge from vats

3. Navy

Naval Aviation Depot, Norfolk

- plastic media blasting

Naval Aviation Depot, Alameda

- plastic media blasting
- in-line solvent recycling

Parts cleaning is an integral process operation for industries that repair, maintain, or manufacture parts and equipment. Examples of such industries are automobile repair, equipment repair, and transportation maintenance industries (trucks, trains, ships, and aircraft). Manufacturing groups include furniture manufacturers, metal fabricators, machinery manufacturers, electric and electronic equipment manufacturers, and instrument manufacturers, among many others.

Five types of cleaning media are utilized by industry: (1) solvents (both halogenated and nonhalogenated); (2) alkaline cleaners; (3) acid cleaners; (4) nonchemical, abrasive materials; and (5) water. Alkaline and acid cleaners are usually referred to as aqueous cleaners (EPA/625/7-90/006). Mixtures of solvents and alkalines are frequently used. Mixtures where a water-immiscible solvent is emulsified in water (often containing other additives) are termed emulsion cleaners.

Although metal parts cleaning is frequently thought of as a simple operation requiring little more than washing a part in solvent, many metal parts require sophisticated and rather complex sequences of cleaning steps. The design of a cleaning operation is generally dependent upon three interrelated factors:

- The nature of the contamination.
- The metal substrate.
- The degree of cleanliness required.

Cleaners, except for abrasives, are normally contained in large open tanks, with the parts to be cleaned mounted on racks or in perforated horizontal barrels. The decision to use racks or barrels depends on the size and shape of the part as well as the type of coating it requires.

Solvents are the most widely used class of cleaners. They are employed for removing oil-based contaminants, in either cold cleaning, diphase cleaning, or vapor phase cleaning operations.

Table 15-1
Cleaning and/or Degreasing Media, Listed by Action

Action	Cleaning/Degreasing Media
Detergency	1. Alkaline salts and caustics. 2. Surfactants (soaps and synthetic soaps). 3. Alkaline cleaners (1 and 2 combined). 4. Emulsion cleaners (solvents and surfactants).
Solvency and Degreasing	1. Aliphatic hydrocarbons: naphtha, kerosene, diesel fuel. 2. Aromatic hydrocarbons: benzene, toluene, xylene. 3. Non-flammable solvents (halogenated hydrocarbons: TCA, TCE, PCE, methylene chloride, chlorofluorocarbons). 4. Polar solvents (ketones, alcohols, esters, ethers, terpenes, amines). 5. Emulsifiable solvents (flushed away with water). 6. Diphase cleaners (solvent and aqueous layered media).
Chemical Reaction	1. Acidic baths (pickling) yield soluble salts by reaction with oxides, sulfides, etc. a. Mineral acids: sulfuric, hydrochloric, phosphoric acids. b. Passivating acids: nitric, chromic. c. Organic acids. d. Specialty acids containing surfactants for wetting-out action or a foam blanket or pickling inhibitors to prevent excessive attack on the metal. 2. Alkaline baths. a. Alkaline de-rusters containing organic sequestrants which solubilize metal oxides and also remove soils. b. Molten alkali with or without hydride (reductant) or nitrate (oxidant) or electric current; also removes soils. 3. Chelating agents react with soils to form soluble complexes. 4. Electropolishing (reverse current cleaning), electrodissolution of metal substrate at the anode. 5. Oxidizing or reducing agents to chemically render the soil soluble.

BLOCK 15: CASE STUDIES: CLEANING AND DEGREASING

1.0 Introduction

Block 15 presents case studies that demonstrate pollution prevention opportunities in cleaning and degreasing operations common to the DoD environment. The types of pollutants associated with cleaning and degreasing and new and emerging products and processes relevant to this type of operation also are reviewed. Chemicals of concern in these operations are identified along with innovative approaches to limiting their use. Block 15 also includes a computer exercise using SWAMI to develop and analyze pollution prevention strategies for cleaning and degreasing operations.

2.0 Objective

To present case studies that demonstrate pollution prevention opportunities in cleaning and degreasing operations common to the DoD environment. Chemicals of concern in these operations (e.g., benzene, carbon tetrachloride, dichloromethane, methylethylketone (MEK), methylene chloride, PD-680, Trichloroethylene (TCE), and 1,1,1-trichloromethane) are identified along with innovative approaches to limiting their use (e.g., alternative solvent treatment methods, and solid and liquid waste treatment). Discussions on jet washers, citra-clean (possible carcinogen), Dyna-mold, and similar new products or processes are included.

1. Students will understand the types of pollutants associated with cleaning and degreasing.

2. Students will understand the pollution prevention opportunities in cleaning and degreasing common to the DoD environment.

3. Students will know the innovative approaches to limiting the use of pollutants associated with cleaning and degreasing.

4. Students will know about new and emerging products and processes relavent to this type of operation.

3.0 Key Concepts

I. INTRODUCTION

Equipment *cleaning* is a maintenance function typically performed for the following reasons:

- To restore or maintain the operating efficiency of equipment, e.g., to restore adequate heat transfer rate and low pressure drop in heat exchangers.
- To avoid or limit product contamination, e.g., when a paint mix tank needs to be cleaned between batches of varying paint formulations.
- To minimize corrosion and extend equipment lifetime.
- To allow for inspection and repair of equipment.
- To improve appearance (exterior surfaces only).
- To prepare the surface for further treatment.

Degreasing involves the removal of an oil-based coating from a metal part prior to further material processing, and in this way is a specific type of cleaning. Oil-based coatings are applied to metal parts to prevent corrosion and/or surface oxidation during such operations as transport or storage. If the part were to undergo some further surface operation (e.g., plating), then it must be cleaned (degreased) prior to this process.

A large variety of compounds and techniques are used for these processes. Organic compounds include hydrocarbons, chlorinated hydrocarbons, alcohols, and ketones. Inorganic compounds include acids, bases, or chelating agents. Even mechanical action can be used to clean parts and equipment. Table 15-1 in your text presents a representative list of cleaning and/or degreasing media which are used to varying degrees by industry.

II. CLEANING/DEGREASING OPERATIONS

Table 15-2
Metal Parts Cleaning Wastes

No.	Waste Description	Process Origin	Composition
1	Abrasive	Removal of rust, scale polishing of metal.	Aluminum oxide, silicon carbide, water, grease.
2	Solvents	Removal of oil-based soils.	Halogenated and non-halogenated solvents, oil-based contaminants.
3	Alkalines	Removal of organic soils, descaling.	Alkaline salts, additives, organic soils, water.
4	Acids	Removal of scale, smut.	Acids, additives, dissolved metal salt, water.
5	Rinse Water	Removal of previous cleaning material.	Water with traces of cleaners and additives.

IV. POLLUTION PREVENTION MEASURES FOR CLEANING/DEGREASING PROCESSES

The recommended strategy for developing effective pollution prevention options for parts cleaning operations relies on systematic exploration of the following <u>sequence</u> of steps:

1. Avoid/reduce the need to clean.
2. Select the least hazardous medium for cleaning (source reduction).
3. Maximize cleaning efficiency (process modification).
4. Prevent loss of cleaning medium.
5. Segregate cleaning wastes.
6. Maximize recycling and reuse.

This strategy is consistent with the multi-media approach and general emphasis of reducing the waste at the source. Each step is discussed in the following sections.

In many instances, by controlling the factors that contribute to surface contamination of the parts, the need for cleaning can be reduced or eliminated altogether. Control of parts contamination starts with a study of contamination sources. Sources can be incoming chemicals applied by metal vendors or reagents applied in house (i.e., coolants, stamping fluids, drawing compounds, rust inhibitor, etc.).

Upon identifying the type and origin of the contamination, it is worthwhile to examine whether cleaning can be avoided or its extent reduced. For example, protective coatings of grease or paint (which require solvents for removal) can be replaced with peel coatings or shrink-wrapping of items with polymeric sheeting. Moisture which can lead to rust can often be reduced or eliminated by allowing the parts to dry more thoroughly between operations or by storing them indoors to avoid condensation and/or rain.

Also of importance is the location of cleaning operations in manufacturing sequence. Articles to be cleaned prior to finishing should only be cleaned at the point in time when they are ready for coating. Parts should not be cleaned and conversion-coated and then warehoused or staged for subsequent batch coating. During storage, the parts can become contaminated by air-borne oils or by handling. These contaminants will interfere with ultimate finish quality and increase the rate of rejects.

Generally, the need for cleaning can be reduced or avoided altogether by the application of the following measures:

- *Inhibition of fouling*. Inhibition of fouling is of particular importance in heat transfer applications where it can be accomplished through a variety of means, including use of smooth heat transfer surfaces, lower film temperatures, increased turbulence, control of fouling precursors, and proper choice of exchanger type.

Mechanical Action	1. Turbulence/agitation. 2. Abrasives. 3. Deformation. 4. Ultrasonic cleaning. 5. Heat. 6. Electrocleaning (direct current hydrogen scrubbing at the cathode).

Source: EPA/530/SW-89/049.

Cold cleaning generally employs unheated or slightly heated nonhalogenated solvents, and is the most common type of cleaning. The four categories of cold cleaning are: (1) wipe cleaning; (2) soak cleaning; (3) ultrasonic cleaning; and (4) steam gun stripping. Wipe cleaning consists of soaking a rag in solvent and wiping the metal part clean. Soak cleaning involves the immersion of the parts in a solvent tank. Ultrasonic cleaning is identical to soak cleaning, except that an ultrasonic unit is added to the tank, which provides a vigorous cleaning action throughout the tank. The main application of steam gun stripping is for paint removal from metal objects. A stripper made up of nonhalogenated solvents is fed into a steam line, through an adjustable valve, mixed with the steam and ejected at high speed from a nozzle.

Diphase cleaning systems are so named because they use both water and solvent phases for cleaning. Parts to be cleaned first pass through a water bath, then a solvent spray. Vapor phase cleaning, also called vapor degreasing, consists of a tank of halogenated solvent heated to its boiling point. Parts to be cleaned are placed in the vapor zone above the liquid solvent. The vapor that condenses on the cooler part dissolves oil-based contamination and rinses the part clean. Since the potential exists for considerably greater air emissions from vapor phase cleaning than from cold cleaning tanks, special recovery equipment is installed, consisting of cooling jackets and/or finned coil condensers. By cooling the air above the vapor, a dense cool air blanket is formed which helps suppress vapor from escaping. The second unit, a finned coil condenser, is installed inside the tank and condenses any vapor that reaches it.

The cleaning action of aqueous cleaners relies mainly on displacement of contaminants rather than on their dissolution, as is the case with organic solvents. Since both alkaline and acid aqueous cleaners and strippers use the same equipment, they are discussed together. Alkaline cleaning solutions contain builders and surfactants. Other additives may include anti-oxidants and stabilizers as well as small amounts of solvents. Alkaline cleaners and strippers are employed to remove soil, old plating, and paint from metal parts. Acidic cleaning solutions may contain mineral acids, organic acids, detergents, chelating agents, and occasionally small amount of solvents. Acid cleaners remove rust, scale, and "smut", which is formed from electrocleaning. "Pickling" is the removal of an oxide layer with an acid bath. Very strong alkaline cleaners containing cyanide and cleaning agents have recently been formulated to replace acid cleaners. No matter what type of aqueous cleaner is used, soak tanks similar to those used for solvents are the most common cleaning method employed. Some aqueous cleaners, however, are used in electrochemical cleaning, in which the workpiece is connected to a source of current. In direct current electrochemical cleaning, the workpiece is attached to the cathode, causing hydrogen gas to be formed at the part's surface that provides a scrubbing action. Smut formation (the plating of metal contaminants in the solution onto the workpiece) and hydrogen embrittlement of the metal sometimes occur, however. These disadvantages are avoided in reverse current cleaning, or electropolishing, in which the workpiece is attached to the anode. Metal substrate is dissolved electrolytically, liberating the surface contaminant.

III. WASTE STREAMS

The waste streams from these various cleaning operations should be expected to contain not only the removed contaminants (e.g., grease or oxide materials), but also the cleaning agents. Therefore, solvent waste streams will contain not only dissolved greases and oils, but also solvents, be they halogenated or nonhalogenated. Halogenated solvents typically comprise carbon tetrachloride, chlorobenzene, methylene chloride, tetrachloroethylene, 1,1,1-trichloroethane, trichlorethylene, or any of the CFC compounds. Nonhalogenated solvents that are typically used include: acetone, benzene, ethyl ether, methyl ethyl ketone, methanol, toluene and the xylenes.

Alkaline cleaners, which are often applied to remove contaminants from metal surfaces, contain not only those materials, but also such materials as phosphates, hydroxides or carbonates, soaps and detergents, and chelating agents. Acidic cleaners can contain not only mineral acids such as sulfuric, nitric, or hydrochloric acids, but also organic acids such as acetic or oxalic acids. These wastes will also contain dissolved metal salts. Abrasives typically are composed of aluminum oxide or silicon carbide. A summary of these waste streams is shown in Table 15-2.

plants and pine trees) are "generally recognized as safe" substances. However, carcinogenicity of terpenes and other cycloalkenes has not been well explored. The terpene cleaners are commercially in neat form or as water solutions with surfactants, emulsifiers, rust inhibitors, and other additives. Terpenes have tested very favorably as substitutes for halogenated solvents for removal of heavy greases, oily deposits, and carbonized oils. Terpenes are also being actively tested as alternatives to chlorofluorocarbons in electronic parts cleaning.

Four Star Tool, Inc., located in Rosemont, Illinois, is a medium-sized fabricating firm employing approximately 150 people. The plant manufactures custom tools for a variety of industries and has been in operation for more than 30 years. As with most metal fabricating companies, Four Star has utilized a halogenated degreasing solvent for removing oils and greases. The degreasing operation used was labor intensive and involved hand dipping a basket of small parts into an open tank of TCE. The basket was hung up to dry and any ferrous parts were treated with an antirust compound to preserve the clean surface until it could be plated.

Due to increasing frustration with local regulators and increasing concern for employee health, the management at Four Star made a change that would avoid most future liabilities. By switching to a new cleaning agent, Four Star eliminated the generation of approximately 15 to 20 drums of spent TCE solvent per year. The associated cost savings that resulted from the switch (mainly from reduction of waste disposal costs) were reported to be $5,805/yr.

Four Star was put in contact with a local solvent supplier by way of a representative of the Chicago Metal Finishing Institute. By closely working with this company (Todco Chemical Co., Inc.), Four Star was able to substitute a nontoxic degreasing agent, d-limonene, for the TCE. D-limonene is a naturally occurring organic chemical that is extracted from the rinds of citrus fruits. This natural chemical is a member of the terpene family and has been used for a variety of applications. D-limonene has been used in hand cleaners for its orange fragrance; however, it is strong enough to separate oils and greases from most surfaces and therefore can be utilized in manufacturing processes.

To incorporate the new degreasing system into Four Star's operations, Todco Chemical determined the optimum operating parameters of the new process through daily experimentation. One particular hurdle that had to be overcome was the proper heating temperature for the new degreasing tank, so the potent d-limonene odor of oranges would not be spread over a radius of many blocks. Also, to accelerate the relatively slower cleaning process of the new solvent (as compared with TCE), the addition of small amounts of supplementing cleaning chemical (such as surfactants) was found to be necessary. Four Star acquired the new biodegradable degreaser premixed.

The new heated degreasing tank has a capacity of 400 gal. As a result, it will accommodate large cleaning loads and largely overcomes any reduction in speed since the baskets can be hung in the bath while the operator attends to other responsibilities. Prior to the new system, the baskets were dipped manually in 3-gal drums of TCE.

The proprietary and limonene-based cleaning agent mixture is added to tap water in a ratio of 1:10 and is then maintained at 100 F. The cleaning agent works best at this modest temperature, which can be attained by heat supplied from a small gas heater. As the degreased oils and particulates are separated from the immersed parts, they float to the surface and are removed by a skimmer. After degreasing, the baskets are hand removed, drained and rinsed in 150 F heated tap water contained in an adjacent tank. Two to three water rinses within this same tank may occur before rack drying. Plated parts receive an additional rinse in deionized water heated at 125 F. No residue remains following evaporation. Unplated ferrous items are treated in a third tank (100 gal) containing a diluted anti-rust agent heated to 100 F. The d-limonene cleaner tends to get the parts cleaner than the TCE solvent did.

The residuals from this operation include the diluted cleaning solution in the bath and the oily material removed by skimming. The discarded cleaner (pH of 7) has approval from the local waste treatment plant for direct disposal to the sewer. The skimmed oily material is put into barrels and shipped to a commercial waste handler who burns the waste.

The selection and design process for the new system took approximately 2 mo. and an additional month was required for construction and installation of the new tanks and plumbing. Capital costs were approximately $10,000 and a pay-back on this investment is expected in about 2 years.

- *Maximizing dedication of process equipment.* Maximizing dedication of process equipment to a single process function or formulation will reduce cleaning frequency, as well as the frequency of switching to different formulations. Maximum dedication means either converting from a batch to a continuous process or using the equipment intermittently just for one formulation.

- *Proper production scheduling.* Proper production scheduling is a commonly-invoked method to decrease cleaning frequency. Equipment utilization strategies and the resulting production schedules should be derived through optimization analysis, where the objective is to meet the desired production goals with due consideration of such constraints as available equipment, cost of turnaround, labor availability, storage, etc. Meeting production goals is to be accomplished with minimum cost, which includes minimization of cleaning frequency. However, in a typical situation a formal optimization analysis is not often used. Rather, a common-sense approach to production scheduling is used based on trial-and-error preparation of production bar charts.

- *Avoidance of unnecessary cleaning.* Avoidance of unnecessary cleaning should be one of the goals of waste minimization audits. At times, equipment cleaning is performed routinely with little or no consideration of the rationale for the cleaning activity. An actual case is known where a ball mill was used periodically to wetgrind a certain powder. The ball mill with corrosion-proof internal parts was totally dedicated to the same formulation, a stable mixture of inorganic powders. Yet the ball mill was cleaned after each use for no apparent reason. Upon questioning, the only justification provided was that the other nondedicated ball mills at the facility were cleaned after every use.

In looking for a new cleaning medium or procedure, a company should consider the least toxic or most environmentally acceptable medium, then, if this is not satisfactory, progress to more toxic or less environmentally desirable alternatives. This pattern dictates that cleaning media be evaluated in the following order (EPA/530/SW-89/049):

- Water or air, or mechanical action.
- Abrasive media with water or air as carrier.
- Aqueous detergent solutions.
- Alkaline solutions.
- Acids.
- Solvents.

Ideally, the cleaning method of choice would involve the shortest cleaning sequences, employing the least toxic cleaning medium, generating the least amount of wastes, and still providing the necessary minimum level of cleaning to the part at minimum cost. For facilities attempting to change from one cleaning medium to another, the impact on subsequent operations must be considered. Any proposed changes to the cleaning process requires careful evaluation of potential effects of the cleaner on the substrate that might affect the integrity of downstream processes (anodizing, plating, painting, etc.). The impact of cleaner drag-out on the lifespan of downstream process solutions should also be addressed.

Source reduction strategies, then would involve replacing the current cleaning material with one higher on the list. Within each of these categories, it would also be possible to substitute one material with another from that category (e.g., solvent substitution).

When substituting one solvent for another, a critical examination of the properties of both the proposed substitute and the solvent currently in use must be conducted. (Texts such as "The Handbook of Solvents", by Scheflan and Jacobs, or "Organic Solvents: Physical Properties and Methods of Purification", by Riddick, Bunger, and Sakano are useful tools in this regard.) For example, when attempting to substitute one degreaser for another, the substitute must:

- have comparable volatility;
- solubilize oil and grease;
- not leave residues; and
- not corrode the base material.

As an example, the University of Dayton Research Institute is beginning an examination of the feasibility of using terpenes as substitute degreasers. Although photochemically reactive, terpenes (derived from citrus

- Reduce exhaust velocities to provide adequate protection of workers, but do not draw vapors out of the degreaser. Adjusting exhaust velocities can achieve up to a 50 percent reduction in solvent loss.
- Cover open-top degreasers, especially during idle times. This is the most significant solvent conservation method it can reduce solvent loss up to 55 percent. Sliding covers do not cause turbulence when moved, unlike hinged covers.
- Extend the freeboard. Units with freeboard heights that are 40 percent of the width of the degreaser can use up to 50 percent more solvent than units with ratios of 75 to 100 percent.
- Use cold traps, an upper set of very cold coils that cool the air above the vapors. Properly used, cold traps provide a dense air blanket that helps prevent vapor escape.
- Check the water jacket for proper water flow and temperature on the outside of the degreaser to prevent migration of hot vapor up the side walls.
- Prevent drafts over the degreaser. Fans, air conditioners, heaters, windows, doors, general plant air movement, and equipment movement can blow the vapor-air mixture out of the degreaser. Locate the degreaser to minimize natural drafts or use baffles to prevent upset of the vapors and achieve up to a 30 percent reduction in solvent loss.

- Avoiding solvent contamination

  - Avoidance of cross-contamination of solvent is an issue to be addressed, especially when the types of solvents being used have similar sounding names. As little as one-tenth of one percent 1,1,1-trichloroethane mixed into a tank of trichloroethylene can cause an acid condition and render the bath unusable for many applications.
  - Sludge that collects in the bottom of the tank should always be removed promptly. Contaminants such as paint absorb solvent, dissolve into solution, and reduce cleaning efficiency. Zinc and aluminum fines, which are particularly reactive in chlorinated solvents, can lead to acid formation, if allowed to collect. Organic soil contamination should not be allowed to exceed 10 percent for cold cleaning operations and 25 percent for vapor degreasers. When these levels are exceeded, acid formation can occur.
  - Using appropriate makeup solutions for the solvent bath. As solvents are used, their ability to neutralize acid lessens. Often, when an acid acceptance test indicates that a solvent is close to going acid, fresh solvent is added to boost the level of stabilizers in the tank. This, however, is a poor practice, since the level of stabilizers in the tank can never be made equal to the level of stabilizers in fresh solvent. The proper technique is to analyze the solvent and add specific components rather than fresh solvent.
  - Solvent standardization. For facilities using a large number of cold cleaning tanks, standardizing the solvent used would help by increasing the potential for recycling and minimizing the chances of cross-contamination from other solvents. Standardizing in this context implies using a minimum number (preferably one) of types of solvents in all operations in the plant.

- Avoiding water contamination

  - Avoid adding water. This is important to prevent depletion of stabilizers, which results in solvent decomposition and corrosion from acid formation by hydrolysis. Also, wet parts can introduce water, particularly as a component of water-soluble cutting oils.
  - Dewater the solvent. A water separator should be able to reduce dissolved water in the solvent. Also, skim floating water off the top of the solvent, since this represents excessive water content.
  - Install a separate water trough for refrigerated coils. Cold trap coils can build up a heavy dew. A separate discharge for this condensate is necessary to avoid introducing the water to the solvent at a common water separator, which reduces the water separator's effectiveness and perhaps could overload its capacity.

Water is used to remove or dilute cleaning solutions that are dragged out with cleaned parts. If these cleaning solutions are not removed, they can affect the quality of the work and contaminate subsequent cleaning and processing operations. Since rinsing is essentially a process of dilution, the general trend in the past was to use large volumes of water. Today, however, efficient rinsing is required to achieve the proper level of dragout dilution and also conserve water. By conserving water, capital and operating costs for waste

The d-limonene cleaner is biodegradable and eliminates the generation of hazardous spent solvents, as well as reducing toxic air emissions (thus reducing exposure to operators). The separated surface oil can be burned for energy recovery or reclaimed for reuse.

In order to evaluate process modifications for cleaning operation, it is first necessary to separate these cleaning operations into specific processes. We have already discussed the types of cleaning operations, and we can therefore discuss process modifications for the following cleaning operations: cold cleaning, vapor degreasing, and rinsing.

The most common piece of equipment used for solvent cleaning is the soak tank, followed by the vapor degreaser. The main methods for reducing waste from both types of equipment are the same. The two most important source reduction goals are to minimize evaporation vapor loss and to maintain solvent quality. By reducing evaporation loss, the composition of the solvent will be maintained as close as possible to its original composition. By maintaining solvent quality, the need for replacement is reduced. Halogenated solvents contain chemical stabilizers that help prevent acid formation and remove acid contaminants from the bulk of solution. As a solvent is used, its ability to neutralize or prevent acid formation lessens. Unless measures are taken to maintain quality and prevent a solvent from "going acid", the entire quantity of solvent will have to be replaced more often. Measures that are considered helpful in maintaining quality and minimizing vapor loss include:

- Insuring proper operation

  - Leave the unit on to maintain the vapor level unless it will not be in use for long periods of time.
  - Do not expose heating coils to vapor. This could result in a breakdown of the solvent and corrosion problems in the unit, in addition to loss of solvent.
  - Provide proper maintenance. Remove visible corrosion and repair leaks. Repairing leaks alone can result in up to a 50 percent reduction in solvent loss.
  - Use and maintain appropriate design and safety devices. These devices include solvent level controls and vapor, condenser water, and boiling sump thermostats.
  - Ensure parts are up to temperature before removal. The cleaning cycle is not complete until the parts have reached the temperature of the vapor so that condensation has ceased. If condensation is still forming, solvent carryout will increase.
  - When cleaning metal parts with spray, spray below the vapor zone. Spraying above the vapor zone generates a vapor-air mixture which is immediately lost. Also, falling droplets of solvent disrupt vapor interface, causing more vapor-air mixing. Spraying below the vapor zone can achieve up to a five percent reduction in solvent loss.
  - Move the work slowly. Control the hoist speed to less than 11 ft/min of vertical travel and ensure the proper conveyor speed.
  - Don't overload the degreaser. Too large a mass of metal creates inefficient cleaning, excessive vapor drop, slow vapor recovery, and longer cleaning cycle, resulting in increased solvent consumption.
  - Use properly sized baskets. Large baskets that fill the area of the degreaser opening create a piston action when entering and leaving. This forces vapor out, which creates more solvent- vapor-air mixing. The basket should have an area of less than 50 percent of the degreaser opening.
  - Drain the parts. Solvent not allowed to drain properly from parts is lost immediately to evaporation outside the degreaser. Adjust the spacing in the baskets or the racks so drainage can occur.

- Maintaining the proper heat balance

  - Use the least amount of heat required to keep the solvent at a slow boil and to give adequate vapor production. High heat provides only rapid vapor recovery, not improved cleaning.
  - Regulate the cooling level either by adjusting the temperature of the cooling water or by altering the flow rate of the cooling water. The vapor level should balance at the midpoint of the condensing coils a fluctuating vapor level pumps the vapor-air mixture out of the unit.
  - Locate cold cleaning tanks away from heat sources.

- Minimizing vapor diffusion

and forms it into mirror housings for use on both automobiles and trucks. Raw materials in use include sheets and rolls of galvanized steel, stainless steel, zinc die-cast parts, plastic stock, hardware, and mirror glass.

The steps involved in making the mirrors which are specifically tied to cleaning are:

- Raw materials undergo stamping, pressing, and cutting operations to form mirror housings and arm braces.

- Galvanized steel mirror housings and parts and stainless steel mirror housings are rinsed in water to remove any residual dirt or grease. Buffing stones are added to the tank for parts degreasing to aid in the removal of dirt and grease. Contaminated water from the degreasing operation is sent to the plant's on-site water treatment facility.

- The degreased stainless steel mirror housings are mechanically buffed. Spent buffing compound, metallic waste, and soiled cleaning rags are discarded in municipal waste.

- Degreased galvanized steel parts, zinc die-cast parts, and high temperature plastic parts are cleaned and their surfaces are prepared for priming and painting in a nine-stage washer. The nine-stage washer consists of an alkaline-wash tank followed by two water rinse tanks, a titanium conditioner tank, a zinc phosphate-accelerator additive tank for further surface preparation followed by a water rinse tank, and a chromic acid rinse tank followed by two water rinse tanks. Contaminated wash and rinse water is sent to the on-site water treatment facility. Spent ion-exchange columns used to produce deionized water are taken off-site by an outside contractor.

The type of cleaning waste currently generated by the plant, the source of the waste, the quantity of the waste, and the annual management costs are given in Table 15-3 of the text.

Table 15-4 of the text shows the opportunities for waste minimization that were recommended for the plant. The type of waste, the minimization opportunity, the possible waste reduction and associated savings, and the implementation cost along with the payback time are given in the table. The quantities of waste currently generated by the plant and possible waste reduction depend on the production level of the plant. All values should be considered in that context.

It should be noted that, in most cases, the economic savings of the minimization opportunities result from the need for less raw material and from reduced present and future costs associated with waste treatment and disposal. Other savings not quantifiable by this study include a wide variety of possible future costs related to changing emissions standards, liability, and employee health. It should also be noted that the savings given for each opportunity reflect the savings achievable when implementing each waste minimization opportunity independently and do not reflect duplication of savings that would result when the opportunities are implemented in a package.

Process Modification Case Study #2

Facility S-1A/B, located in Southern California, produces submarine aircraft, helicopters, and aircraft carriers of the Pacific Fleet. Facility S-1A operations are mostly performed by military personnel, while facility S-1B operations are performed by civilians (EPA/600/52-87/057).

There are over 100 solvent end use points in the entire base. Solvent is used in many servicing operations, especially parts degreasing and paint stripping. Due to the magnitude and diverse nature of the operations performed, four stations were selected from the ten initially audited for a detailed analysis. The stations selected were Station #1 Cold Cleaning Tank, Station #4 Ball Bearing Cleaning, Station #6 Vapor Degreasing, and Station #7 Epoxy Paint Stripping. These stations represent a fair cross-section of the types of activities that occur at the base.

treatment units are minimized. Source reduction methods for reducing cleaning solution drag-out and the amount of water required include:

- Proper design and operation of rack system.
- Proper design and operation of barrel system.
- Proper design and operation of rinse system.
- Installation of spray rinses.
- Installation of fog nozzles.
- Chemical rinsing.
- Deionized water use.

Proper design and operation of rack system. Through proper design and operation of a rack system, solution drag-out can be significantly reduced. Parts should be racked so that the surface is nearly vertical and the longest dimension is horizontal. Also, the lower edge should be tilted from the horizontal (this allows run-off to occur at a corner rather than the entire edge). Withdrawal from the cleaning solution should be made slowly and the part allowed to drain over the tank for a minute or two. Additional drainage time can be provided by installing sloped drain boards at the end of the tank.

Proper design and operation of barrel system. While barrels are normally fully immersed during electroplating operations, maximum rinsing efficiency occurs when the barrel is only immersed partially. The proper depth and rate of rotation depends on many factors but normally occurs when the barrel is immersed to about 38 percent of its diameter. In most plants, rinse tanks for barrel operations are designed and operated the same way as electroplating baths (i.e., the barrel is fully immersed). After immersing the barrel, it is raised over the tank while rotating and is allowed to drain. At a minimum, two counterflow cold rinses and a final hot rinse should always be used.

Proper design and operation of rinse system. Since the process of rinsing is one of dilution, good practice should assure that the rinse tank is well mixed at all times. Tanks can be mixed by agitating the water with oil-free air, introducing fresh water at the bottom of the tank, and by other mechanical means. The water in the tank should exhibit a rolling turbulence without undue splashing. For cleaners that are not very easy to rinse off, heated rinse tanks are often employed.

Installation of water sprays on rinse tanks. For installations with single rinse tanks and limited space, rinsing efficiency can easily be increased by installing a spray system. By spraying work items with fresh water as they are raised above the rinse, the equivalent of an extra one-half counterflow bath is obtained. Sprays should be properly designed to provide uniform coverage on the part and not produce undue splashing. Spray rinsing is also beneficial on multitank, counterflow systems where each spray unit is fed water form the succeeding rinse tank.

Installation of fog nozzle on heated aqueous cleaner tanks. A fog nozzle is a special high pressure water spray unit that produces a finely atomized mist of water or fog. Since the water is so finely dispersed, only a small amount of water is used compared to a normal spray unit. Therefore, fog nozzles can be used over heated cleaner tanks for rinsing work items without introducing a surplus of water. Two main benefits of using fog nozzles are that: (1) they help cool the part so that the cleaning solution has less chance of drying on the part; and (2) they reduce drag-out by diluting the solution retained on the part.

Chemical rinsing. In some facilities, rinse water from an alkaline cleaning operation is reused to rinse parts from an acid cleaning operation. The basic premise is to combine rinsing and waste treatment in one operation. While this procedure reduces the amount of waste rinse water generated and the degree of wastewater treatment required, the potential for contaminating the parts with metal hydroxide precipitates is increased. Therefore, this method should be limited to those parts not requiring rigorous cleaning.

Use of deionized water for rinsing. Use of regular tap water is major source of impurities in any closed loop system. By employing deionized water, many rinses can be reclaimed using a simple evaporation system. In addition, use of deionized water can extend plating bath life by reducing impurity drag-in as well as the number of rejects produced. Many packaged systems commercially available can supply deionized water of adequate quality because most electroplaters do not require extremely high purity water.

Process Modification Case Study #1

The study plant manufactures exterior mirrors for motor vehicles (EPA/600/S-92/020). The plant operates 6,120 hr/yr to produce approximately 3 million mirrors. This plant takes galvanized and stainless steel stock

Table 15-4
Summary of Recommended Waste Minimization Opportunities

Waste Stream Reduced	Minimization Opportunity	Annual Waste Reduction		Net Annual Savings	Implementati nCost	Paybac k Years
		Quantity	Percent			
Evaporated solvent and primer and paint overspray collected on plastic sheets.	Install an electrostatic powder coating system to replace painting of galvanized steel and zinc die-cast parts.	12 bbl[1] 3,076 gal[2] 766 gal[3] 616 gal[4]	100 55 80 80	$113,418	$236,880	2.1
Contaminated wash and rinse water from the nine-stage washer.	Install a metal recovery system (an ion-exchange or electrodialysis system) to recover and reuse zinc phosphate from the nine-stage washer.	8 bbl[5]	5	17,349	74,600	4.3
Evaporated solvent.	Recover solvent from the paint curing oven stacks using a freon-refrigeration system.	3,794 gal	68	11,337	104,000	9.2
Contaminated wash and rinse water from the degreasing, five-stage, and nine-stage washing processes.	Construct a water recirculating system in conjunction with the on-site treatment facility.	855,135 gal	90	11,027	42,760	3.9
Contaminated wash and rinse water from the nine-stage washer.	Install air curtains in the nine-stage washer to reduce solution contamination and loss.	79,715 gal 13 bbl[5]	10 8	7,197	6,500	0.9

[1]Primer/paint overspray.
[2]Solvent.
[3]Cleaning solvent.
[4]Still bottoms.
[5]Sediment.

Table 15-5
Summary of Source Control Options Investigated for Facility S-1

Station	Control Method	Waste Reduction		Capital Cost	Savings	Payback
		(%)[c]	(gal/yr)			
1	Closed tank[d].					
1	Increased agitation.	75(37)	495	$2,910	$ 360 620[a]	8.1 Years
4	Counter-current cleaning.	50(33)	300	600	220 380[a]	2.7 Years 1.6 Years
6	Level alarm.	62(40-50)	246	600	980[b]	7 Months
7	Sludge removal.	50(64)	364	6,820	2,770	3.0 Years

[a]Assumes no credit for the waste solvent.

Table 15-3
Summary of Current Waste Generation

Waste Generated	Source of Waste	Annual Quantity Generated	Annual Waste Management Cost
Contaminated wash water	Degreasing of galvanized steel and stainless steel components.	142,800 gal	$7,688
Spent buffing compound and metallic waste	Buffing of stainless steel components.	1,123 bbl	5,100
Contaminated wash and rinse water	Nine-stage washer.	797,150 gal	9,188
Spent ion exchange columns	Nine-stage washer.	24 units	9,057
Evaporated solvents	Primer and paint application.	5,620 gal	0[1]
Primer and paint overspray collected on plastic sheets.	Primer and paint application.	12 bbl	8,925
Contaminated water.	Five-stage washer.	10,200 gal	4,687
Evaporated solvent.	Spray gun and paint-line cleaning.	957 gal	0[1]
Still bottoms.	Distillation unit for recovering spray gun and paint line cleaning solvent.	770 gal	15,097

[1]The plant reports no waste management cost associated with solvent evaporation.

Fractional distillation

Fractional distillation is carried out in a refluxed column equipped with either trays or packing. Heat is supplied by a reboiler located at the bottom of the column while heat is removed at the top of the column by a condenser. Fractional distillation allows for separation of multi-component mixtures or mixtures of solvent and oils with very similar boiling points.

Evaporation

Evaporation can be employed for solvent recovery from viscous liquids, sludges, or still bottoms resulting from distillation. Scraped or wiped-film evaporators utilize revolving blades which spread the liquid against a heated metal surface. The vapors are recovered by means of a condenser. Another type of system, a drum dryer, employs two heated counter-rotating drums through which the liquid feed must pass. While both systems can handle viscous wastes, the drum dryer is more tolerant of polymerizable contaminants.

Off-Site Recycling

If recycling of waste solvent on site is impractical, several off-site recycling schemes are available. Some viable off-site recycling arrangements include toll recyclers, and waste exchange/brokerage.

V. SUMMARY

As increased regulation raises the cost of waste treatment and disposal, efforts to decrease waste volumes and toxicity become more economically justifiable. Implementing waste minimization techniques to reduce cleaning waste can produce treatment and disposal cost savings which more than offset the expenditure. In addition, material costs, regulatory compliance, and other costs can be cut since the life of the cleaning solutions will be lengthened.

Most of the measures discussed in this pamphlet would involve minimal capital outlays. For example, proper equipment operation requires only that management thoroughly train the employees using the equipment and that the equipment be correctly maintained. These low-cost measures generally have a fast payback and are among the first a firm should implement. Making employees aware of the cost of waste generation due to cleaning operations and involving them in identifying solutions may encourage more efficient production processes.

With the adoption of efficient production processes and the waste-minimizing measures presented here, companies with parts cleaning operations should be able to reduce their waste disposal costs and liabilities, and reduce their contribution to the environmental problems associated with waste disposal.

These case studies have been presented to show you pollution prevention alternatives in cleaning and degreasing operations that may be used at your installation. This lecture and the case studies have been presented to show you how to access pollution prevention alternatives, and to carefully examine current processes and practices to search for these alternatives.

[b]Excludes savings due to reduced disposal costs.
[c]Quantity in parentheses represents percent reduction in virgin solvent use.
[d]Modification of the existing tank would not be viable.

For the four stations selected, a total of 36 source reduction options were considered. Several of these options were then selected for further investigation, based on their high future reduction index. Additional information was obtained from further searches of the available literature and from contact with equipment vendors. The measures evaluated in detail included: use of a closed tank and increasing the cleaning efficiency of Station #1 by increasing the degree of agitation; increasing the cleaning efficiency of Station #4 by employing a two-step counter-current cleaning sequence; reclaiming solvent from spent 1,1,1-TCE at Station #6 by using the degreaser as a still; and continuous filtering of stripper solution at Station #7 (see Table 15-5). Measures that involved changes in operating procedures only were not considered for additional analysis.

In addition to the savings in solvent that result from minimizing losses during use, overall solvent consumption can be reduced by segregating solvent wastes and recycling or reusing them. The U.S. EPA estimates that up to 50% of all solvent wastes are currently being segregated and managed for energy recovery, reclamation, or recycling.

In the recycling process, it is much easier to separate a solvent form its impurities than to separate two solvents. Specific recommendations are always to segregate:

- Chlorinated from non-chlorinated solvent wastes.
- Aliphatic from aromatic solvent wastes.
- CFCs from methylene chloride.
- Water waste from flammable waste.

Recycling can be implemented either on-site or off-site. Typically, on-site recycling of cleaning solutions involves extending the service life of a given process solution. Off-site recycling often involves separating the cleaning media from the impurities and then reselling the cleaner, or incinerating the waste stream without separation. Some recycling options also exist for still bottoms. A more detailed description of recycling options has been given in a previous lecture.

On-site recycling is economical when approximately 8 gallons of solvent waste is generated per day. The simplest form of solvent reuse is termed "downgrading," which is the use of a solvent that has become contaminated through initial use for a second cleaning process. For example, precision bearings need very high purity solvents for cleaning. The solvent acquires very little contamination in usage and can be downgraded or used for less demanding cleaning operations.

Greater effort is required to recycle solvent that has become heavily contaminated, and the possibilities for both on-site and off-site recycling or reclamation need to be explored. In vapor degreasing and cold cleaning, the soil removed accumulates in the equipment. Eventually the solvent becomes too contaminated for further use and it must be reclaimed or disposed of via incineration. For on-site recycling, many different separation technologies are available. Commonly used separation technologies for contaminated solvents include gravity separation, filtration, bath distillation, fractional distillation, evaporation, and fuel use.

Gravity separation

The use of settling to separate solids and water from solvent often permits the reuse of solvent. For example, paint thinners may be reused many times if solids are allowed to settle out.

Filtration

Filters can be used to remove solids from many solvents thus extending solvent life.

Batch distillation

A batch still vaporizes the used solvent and condenses the overhead vapors in a separate vessel. Solids or high boiling residues (>400 F) remain in the still as a residue. Solvent batch stills range in size from 5 gallon to 500 gallon capacity. A vapor degreaser can be used as a batch still for recycling solvent. This is often done by employing proper boil-down procedures. Detailed discussion of these procedures is available from major solvent suppliers.

Electrochemical Treatments: Anodic coatings are conversion coatings applied by electrolysis. The coatings are formed by oxidation of the metal in certain electrolytes. The metal being oxidized is the anode in the system. The metal in the electrolyte used should be capable of producing a thin and virtually continuous integral oxide film. Because of its electrical resistance, the oxide film will build to a specific thickness under the fist-applied potential. With additional time, the oxide film continues to thicken, and its characteristics are altered, i.e., as it thickens it becomes more porous. Anodic oxide coatings are usually applied to cast or wrought aluminum, magnesium, or zinc alloys. Cast or hot pressed titanium or beryllium are anodized for special purposes. Titanium is a difficult metal to coat by conventional plating methods because its surface oxidizes very rapidly, and the oxide interferes with adhesion.

The types of anodized coatings used vary with the basis metal, and the properties of the coating vary with the type of solution in which it is formed. Sulfuric acid and chromic acid are two of the most common anodizing electrolytes for aluminum alloys. Chromic acid and sodium hydroxide are two electrolytic solutions generally preferred for anodizing beryllium alloys. Almost any electrolyte, either acidic or basic, can be used to form anodic coatings on titanium.

Though they are more expensive, anodic coatings offer greater protection to aluminum and magnesium because they are denser, thicker, harder, and more adherent than the chemical coatings. They are also more resistant to corrosion, more resistant to abrasion, and more readily and permanently dyed. Anodized coatings afford long-lived protection if they are not mechanically damaged.

Sometimes, anodic coatings may lead to the lowering of fatigue strength of the metals to which they are applied. This effect may be compensated for or completely nullified by peening the metal prior to anodizing it. Anodic coatings also lack elasticity. This causes the coatings to develop fissures when the substrate material is subjected to tensile stresses.

Metallic Coatings

The main purpose of metallic coatings is to alter the characteristics of a surface so it can 1) withstand corrosive agents, 2) resist abrasion, erosion, or galling, or 3) provide lubricity. Metallic coatings can be applied by electrodeposition, electroless deposition, hot-dipping in molten metals, metal spraying, thermal decomposition of vapors or mechanical (peen) plating, or metallizing.

Metallic coatings can be grouped according to: 1) coatings that function by sacrificial protection, 2) coatings that provide barrier layer protection, and 3) coatings used to achieve specialized surface characteristics.

Sacrificial Coatings: These coatings are more active electrochemically than the substrate and corrode sacrificially to protect the basis metal at any discontinuities in the coating. Sacrificial coatings are most commonly applied to steels. Cadmium is the most widely used sacrificial coating in military and aerospace applications. It excels in lubricity, solderability, electrical conductivity, and compatibility with aluminum alloys. Cadmium produces relatively nonbinding corrosion products that are not of themselves corrosive. Cadmium coatings are produced principally be electrodeposition. Zinc and aluminum are additional metals used for sacrificial metallic coatings.

Barrier Coatings: These coatings are more noble than the metal onto which they are deposited and therefore tend to promote corrosion of the basis metal at discontinuities in the coating. The protective ability of barrier coatings depends on their degree of porosity and their rate of corrosion in the environment. Nickel on steel is the most commonly used barrier coating for military equipment. Electrodeposits of nickel are widely used for protecting substrates of steel, zinc die castings, aluminum, and copper alloys against corrosive attack. Non-reflective nickel deposits can be produced by scratch brushing of regular nickel deposits for fine abrasive blasting the nickel deposit. Copper, diffused nickel-cadmium, tin, lead, and Terne (lead alloys) are also used as barrier coatings.

Specialized Coatings: This group contains coatings used to obtain specialized surface characteristics, such as resistance to high temperature or extreme wear. High temperature coatings include those used for preventing corrosion, hot corrosion, and sulfidation of nickel and cobalt base superalloys over the temperature range of 650 to 1250 C. High temperature coatings are used primarily in aircraft gas turbine engine components requiring protection from high temperature oxidation and sulfidation. Generally, these include turbine blades and vanes, combustion ducts, combustion chambers, and seal rings. Diffusion coatings and overlay coatings are two common types on high temperature coatings.

BLOCK 16: BASICS OF SURFACE COATINGS

1.0 Introduction

Block 16 overviews tbe major types of surface coatings used at DoD installations. Processes used in metallic coating applications and corrosion problems are discussed as well as metal finishing and plating. The physical/chemical and toxicological properties associated with commonly used surface coatings are reviewed. Lastly, pollution prevention strategies associated with surface coatings and alternative and innovative coating technologies are presented. The introduction to basics of surface coatings is computer-based instruction.

2.0. Objective

To explain what surface coatings are and how they are used in DoD activities. To discuss the applicability of replacements, including pros and cons. Note: Includes computer-based instruction.

1. Students will know and understand the purposes and major types of coatings by surveying the paints and coatings used in DoD activities.

2. Students will know and understand the potential impacts of solvents, biocides and other chemicals used in coatings by reviewing the major classes of materials present and their properties.

3. Students will know and understand the basic strategies for pollution prevention associated with coatings by reviewing material substitutions possible in coating formulations and the new technologies and process substitutions possible for applying coatings.

4. Students will know and understand the pollution prevention potential associated with coatings by viewing statistics on the quantities of coatings used in DoD activities.

3.0 Key Concepts

I. MAJOR TYPES OF SURFACE COATINGS USED AT DOD INSTALLATIONS

Use of surface coatings at DoD installations serves four basic purposes: 1) corrosion resistance, 2) durability, 3) aesthetics, and 4) electrical conductivity.

Protective coatings are usually classified into three groups: inorganic coatings, metallic coatings, and organic coatings. Inorganic coatings, produced by chemical and anodic treatments, include chromates, phosphates, oxides, and anodized coatings. Metallic coatings include electroplates, sprayed metal coatings, and hot-dip coatings. Organic coatings include paints, lacquers, enamels, and varnishes.

Inorganic Coatings

Chemical Treatments: During the application of chemical coatings, also known as conversion coatings, the metal surface is converted to a chemical compound. This chemical layer is strongly bonded to the underlying metal. Chemical coatings include oxides, phosphates, and chromates, and are usually applied by dipping. These coatings mostly serve as paint bases for improving adhesion of the paint and other organic coatings, but they may be used alone. Materials that chemical coatings may be formed on include iron, steel, aluminum, magnesium, cadmium, zinc, and other metals and alloys.

Black oxides are most often applied to iron and steel by immersion. The oxide is a good base for rust inhibiting oils and waxes, however, corrosion protection is limited. Application of black oxide coatings to military equipment is for the prevention of reflected light which could be detected by an enemy, or to avoid stray reflections that would interfere with the effective use of optical instruments. Another treatment commonly used for coating iron and steel are phosphates. In addition, phosphating is occasionally used for zinc and aluminum alloys. Coating of large articles is done through spraying, whereas smaller items are coated by immersion. Good corrosion resistance or a good base for oil, paint, wax, and solid film lubricants can be provided by phosphate coatings depending upon their thickness. Chromates are applied to zinc, cadmium, aluminum, and magnesium. Under mild conditions, the bare coating offers reasonable protection, however, chromating has poor abrasion resistance but is self-healing, if scratched. It improves corrosion resistance and paint bonding and has some aesthetic value. In some instances, chromating can replace aluminum anodizing.

used nitrocellulose is a tough, hard material which, when compounded with suitable plasticizers, resins, stabilizers, and pigments in a properly formulated solvent vehicle, yields a wide variety of useful and durable coatings with exceptionally fast air-drying properties. Nitrocellulose lacquers are used in numerous military applications as primers and coating on ammunition, tanks, trucks, and aircraft.

Epoxy Resins: Epoxy resins are condensation products of epichlorohydrin and bisphenol. They may also be reacted with organic acids or esterified with long chain fatty acids such as linseed and soya oils to yield alkyd-like resins. Based on composition and use, epoxy resins fall into three categories: 1) unmodified (unesterified) baking types, 2) unmodified (unesterified) air-dry types, and 3) esterified types for either air-dry or bake. Unmodified air-dry types, most used by the military, are two-component products that are mixed with amines or polyamide resins shortly before use. These amine-catalyzed coatings possess very good chemical resistance, toughness, and durability.

Polyurethane Coatings: Polyurethane coatings are available either as two-component systems (using alphatic or aromatic polyurethanes) that are mixed shortly before use and cured by direct crosslinking or as single-package materials that cure when exposed as a film to moisture, oxygen, heat, etc. Polyurethanes can be made to provide hardness with flexibility, excellent abrasion and mar resistance, resistance to alkali, hydraulic fluids, and oils, as will as excellent exterior durability. MIL-C-46168, Coating, Alphatic, Polyurethane, Low Reflective, Chemical Agent Resistant is a polyurethane coating used on military combat equipment.

II. PROCESSES USED IN METALLIC COATING APPLICATIONS

Processes for Applying Sacrificial Coatings (Aluminum)

1) Electrophoresis - A liquid formulation containing aluminum particles is employed in which the parts are electrically connected to a rack or basket, immersed, and an electrical current is impressed.

2) Electroplating, Ether Bath - Aluminum compounds are dissolved in an ether solvent and plated out on racked or barrel tumble parts when an electric current is passed. The process must be housed in a protective enclosure to keep moisture and air out and to prevent inhalation or explosion of the highly volatile solvent.

3) Electroplating, Fused Salt Bath - Aluminum salt and other compounds are melted at a fairly low temperature and parts are raced for electrical continuity. A current is then impressed to produce the coating. The process must be kept free from moisture contamination.

4) Electroplating, Hydrocarbon Bath - This process is similar to that of the ether bath except for the solvent, which is considerably less hazardous. Safety precautions must be taken as well as precautions to prevent atmospheric bath contamination.

5) Ion Implantation - Aluminum can be bombarded into the substrate of a metal or alloy by this vacuum process.

6) Ion Vapor Deposition - This vacuum process employs an electrically charged plasma to accelerate the aluminum onto the substrate. The process is not hazardous and provides a high quality coating.

7) Liquid, Chemical Decomposition - Organoaluminum compounds decompose when a threshold temperature is reached. Parts to be coated are preheated to a temperature higher than the threshold and are subsequently quenched in the liquid organoaluminum compound.

8) Liquid, Molten Metal - In this process, the part to be coated is simply dipped into a liquid aluminum bath at approximately 700 C (1300 F) and then drained.

9) Peening, Mechanical - In this process parts to be coated are tumbled in a barrel with a media such as a slurry of aluminum particles plus glass beads. The beads provide a gently peening action which builds the coating thickness.

10) Spray, Liquid - Aluminum-ceramic coatings are spray applied to surfaces that have been degreased and grit blasted. The aluminum powder is in an inorganic binder. The coating is then dried and thermally cured at a temperature between 260 and 430 C (500 and 800 F).

Diffusion type aluminum coatings are the most widely used coatings for the protection of superalloy turbine airfoils. The coatings are normally prepared by slurry spraying, hot dipping, and/or pack cementation, followed by interdiffusion of aluminum with the substrate alloy at elevated temperatures. Overlay type coatings, which provide improved oxidation/corrosion protection, use a process on aluminum for protective Al_2O_3 formation, yttrium for oxide adherence, and chromium for promotion of aluminum oxide formation and enhancement of hot-corrosion resistance. MCrAlY (metal + chromium + aluminum + yttrium) overlay coatings may be applied by electron beam vapor deposition, plasma spray, or sputter techniques.

Electroless nickel is a commonly used wear resistant coating. In electroless plating of nickel on material, the deposits formed are more uniform in thickness than conventional electroplated deposits. In addition, unlike electrolytic nickel, thinner electroless nickel deposits are generally capable of protecting smooth steel substrates exposed to a given environment because the electroless deposits tend to be less porous. Electroless plating baths provide unique opportunities to coat a variety of substrate materials, including bearing surfaces, gears, molds, and rollers.

Organic Coatings

Three basic functions of paint includes 1) protection of surfaces, 2) perform special functional job, and 3) serve as a decorative coating. Organic coatings are more durable than some metals of equal thickness, providing critical protection of a surface. An example of a specific functional job is that of camouflage coatings for minimizing detection. Decorative coatings provide color and aesthetic appeal.

Most organic coatings are based on a film former, or binder, which is dissolved in a solvent or emulsified water. This film forming liquid constitutes the vehicle by which pigments are dispersed to give color, opacity, and other properties to the dried film. Other ingredients may be added to the vehicle to achieve specific film properties, such as driers to aid in curing, plasticizers to impart flexibility or other properties, and stabilizers to lesson deleterious effects of heat and sunlight. Examples of film forming material include oils, varnishes, synthetic resins, and polymeric material such as cellulose, vinyl, epoxy, and polyester. In general, the major performance characteristics of the coating depend on the binder used.

Pigments are fine particles which are substantially insoluble in the vehicle used in preparation of paint. Two basic groups of pigments include hiding and non-hiding (also referred to as extenders) pigments. Hiding pigments are used to provide color, to hide the underlying surface, to inhibit corrosion, and to provide functional properties such as fire retardation and antifouling protection and infrared reflectance. Non-hiding pigments can provide the following properties: decreased permeability of the paint film, low sheen or high sheen, bond or "tooth" for subsequent coats, and antisettling, antifloating, and antisagging properties.

A brief description of the most commonly used film formers in military coatings is given below.

Acrylic Resins: Acrylic resins are prepared by the polymerization of acrylic or methacrylate esters. The esters may be polymerized by themselves, with each other, or with other unsaturated compounds. These resins, which are soluble in aromatic or chlorinated hydrocarbons, esters, ketones, etc., have a variety of melting points and, therefore, vary from soft, tacky materials to hard, tough solids. They are water white in color and have excellent resistance to water, acids, alkali, etc. They may be used alone or with other film formers such as nitrocellulose, vinyl and melamine resins. MIL-L-19537, Lacquer, Acrylic, Nitrocellulose, an example of an acrylic resin used by the military, is a general purpose, exterior, protective coating for metal surfaces formulated particularly for resistance to diester lubricating oil.

Alkyd Resins: Alkyd resins are made by the condensation polymerization of polyhydric alcohol, polybasic acid, and vegetable oils or fatty acids. These resins may be either air-drying or baking types, yellowing or non-yellowing, weather or chemical resistant, or flexible or hard, depending on the type of oil. Alkyds may be physically blended with tough resins, such as nitrocellulose and vinyl chloride acetate, to plasticize them or to improve their gloss and chalk-resistance. They may also be chemically combined with reactive monomers, such as styrene or silicone, to obtain copolymers with intermediate properties. Alkyds are known for their versatility of formulation, application, overall economy, and general properties of durability, flexibility, adhesion, color retention, and high gloss retention. An example of an alkyd used by the military is TT-E529, Enamel, Lusterless, Quick-Drying, Styrated Alkyd Type, Solar Heat-Reflecting which is used as a coating to minimize heat build-up in the interior of weapons system.

Cellulose Polymers: Cellulose polymers are esters and ethers of cellulose. Cellulose nitrate (or nitrocellulose), cellulose acetate, and cellulose acetate butyrate are esters. Ethyl cellulose is an ether type. These polymers are tough, thermoplastic solids available in a wide range of molecular weights. The widely

Corrosion (the destruction of a substance, usually a metal or its properties, because of a reaction with its surroundings) in metals is caused by the flow of electricity from one metal to another or from one part of the surface of one metal to another part of the surface of the same metal where conditions permit the flow of electricity. In order for this flow of energy to take place, a moist conductor or electrolyte must also be present. In other words, the energy (electricity) passes from a negative area to a positive area through the electrolyte media. Therefore, if corrosion is to take place in a metal there must be an electrolyte, an area or region of the metallic surface with a negative charge in relation to a second area having a positive charge in opposition to the first.

There are many forms of corrosion resulting from different conditions. The major types include:

- General Corrosion - Corrosion in a uniform manor.

- Intergranular Corrosion - A socialized type of attack that takes place at the grain boundaries of a metal.

- Pitting Corrosion - Highly localized corrosion resulting in deep penetration at only a few spots.

- Stress Corrosion Cracking - The results of accelerated corrosion which is caused by either residual internal stress in the metal or an externally applied stress.

- Corrosion Fatigue - The combined action of corrosion and fatigue (cyclic stressing) in causing metal fracture.

- Galvanic Corrosion - Occurs when two or more dissimilar metals are in contact, or when metals having the same analysis have different surface conditions, and an electrolyte is present.

- Cavitation Corrosion - Corrosion damage resulting from cavitation (formation and sudden collapse of vapor bubbles in a liquid) and corrosion: metal corrodes, pressure develops from collapse of cavity and removes corrosion product, exposing bare metal to repeated corrosion.

- Impingement Attack - Localized erosion-corrosion caused by turbulence or impinging flow at certain points.

- Fretting Corrosion - Damage occurring at the interface of two surfaces in contact, one or both of which are metal, subject to slight relative slip.

- Hydrogen Embrittlement - Hydrogen entering a metal either through a corrosion reaction which liberated hydrogen at the surface or by cathodic polarization causes the metal to lose ductility.

- Graphitic Corrosion - Corrosion of gray cast iron in which the metallic constituents are converted to corrosion products, leaving the graphite flakes intact.

- Dezincification and Parting - The corrosion of a zinc-containing alloy in which the zinc corrodes preferentially leaving a porous copper residue and corrosion products.

- Biological Corrosion - Corrosion of a metal caused by the metabolic activity of aerobic and anaerobic microorganisms.

A classification of corrosive environments encountered in military service is presented in Table 1.

Various means for preventing or retarding metallic corrosion are available, including:

- Selecting a metal or alloy that is resistant to attack by the environment to which it is exposed.
- Preventing access of moisture or oxygen to the metal.
- Avoiding adverse dissimilar metal couples.
- Designing equipment properly to eliminate sump areas and crevices.
- Avoiding differential cells due to aeration, salt concentration, temperature, agitation, etc.
- Adding chemical corrosion inhibitors to liquid or vapor environments.
- Applying cathodic current using sacrificial or impressed current anodes; anodic current may also be effective under specialize conditions.
- Applying protective coatings.

11) Spray, Powder or Wire (Metallizing) - Aluminum may be applied by flame-spray metallizing, i.e., by a fine spray of molten metal.

12) Sputtering - This is a gas plasma discharge process which can coat articles in a line of sight. Positively charged gas ions are attracted to the aluminum cathode at high velocity. Their impact frees the aluminum ions which then migrate to the part (anode).

13) Vapor, Chemical Decomposition - The chemical employed in this process is an organoaluminum compound which is vaporized in a closed chamber. A heated object brought into contact with the vapor is quickly coated while its temperature is above the threshold value for decomposition of the organoaluminum compound.

14) Vapor, Physical - This process entails the vaporization of the aluminum by heat in a vacuum chamber and its subsequent condensation onto selected surfaces at a lower temperature.

Processes for Applying Diffusion Coatings

1) Slurry Spraying Process - Parts to be coated are sprayed with a slurry containing the desired combination of metal powders in a suitable vehicle. The sprayed parts are heated in a hydrogen or inert atmosphere to 1090 C (2000 F) to diffuse the coating into the substrate metal.

2) Pack Cementation Process - Parts to be coated are packed in a metal retort with a powdered mixture of the elements to be deposited and a volatile halide. When heated in the retort, the halide reacts with the metal powder to form a volatile metal compound which decomposes at the surface and diffuses into the parts.

3) Hot Dip Process - The component to be coated is dipped, either with or without a flux, into a molten aluminum bath. After dipping, the aluminum coated component is given a diffusion heat-treatment in an inert or hydrogen atmosphere. The deposited aluminum is combined with the substrate to form a permanently bonded coating.

Processes for Applying Overlay Coatings

1) Electron Beam Physical Vapor Deposition (EBPVD) - An electron beam is directed onto the surface of material contained in a crucible. The material in the crucible melts and evaporates producing vapor. To receive the vapor and be coated, parts are positioned above the molten material in the crucible. The process is conducted in a vacuum to permit generation of the electron beam and vaporized species, as well as to avoid contaminating the molten material in the crucible, the vapor phase, or the condensate (coating). Because the vapor travel in essentially a line-of-sight manner to the substrate surface, parts are rotated during coating to achieve completed coverage.

2) Sputtering - This is a vacuum coating technique in which inert gas ions, typically argon, are accelerated form a plasm into the source or target material to be deposited. On bombarding the target, the ions eject (or sputter) atoms and/or molecules from the target surface, to create a coating flux emanating from that surface. The part to be coated is held in the flux, and the ejected or sputtered material collects and recombines to form a solid coating representative of the target material composition.

3) Plasma Spray - The plasma spray process involves the use of a torch in which a gas, usually argon, is passed between the anode and the cathode. The gas is ionized, creating a gas plasma of very high temperature (approximately 15,000 C). Coating material in powder form is injected into the plasma stream and is melted, or very nearly melted, and accelerated to a high velocity. Such particles, upon contact with the surface being coated, deform plastically and bond to the surface or to previously deposited particles, thus producing a coating.

III. CORROSION

In military and aerospace applications, materials are required to perform in severe environments. Through the use of the highest strength materials, the constant objective of increased system performance can be realized. Yet, in these same materials, the combination of stress and corrosion has the most adverse or catastrophic effects. Prevention of corrosion and wear, therefore, are of prime importance.

Electroplating (the electrodeposition of an adherent metallic coating upon an electrode for the purpose of securing a surface with properties or dimensions different from those of the basis metal) is carried out in a solution containing a chemical compound of the metal to be deposited. Direct current, transformed from the utility's alternating current by means of rectifiers or motor generators, is passed through this solution (called the bath by platers) from anodes (the positive electrodes) to the cathodes (the negative electrodes), which consist of the work to plated as well as the means for positioning this work in the bath. Anodes are usually made of the metal being deposited. Under the flow of the electroplating current they dissolve, maintaining the metal content of the bath by replacing the metal plated out at the cathodes. With chromium plating, anodes are "inert" (they do not dissolve in the bath but merely serve to introduce the current) and replenishment is by chemical means. The cathodes, or work, can be placed in the bath in essentially two ways: they may be hung on racks individually or they may be loaded into a barrel.

The electroplating cycle includes a series of tanks and stations:

1) A racking or loading station where a worker hangs the parts on the racks (or a barrel to be loaded).
2) Tanks containing cleaners to prepare the work for electroplating.
3) A picking tank to remove the alkaline residue and residual oxides.
4) One or more electroplating tanks.
5) A final rinse tank, to remove, as far as practical, the last traces of electroplating solution so that salts will not dry on the work.
6) Means for drying the work, by heat, compressed air, sawdust, or other.
7) An unracking station, where a worker removes the finished parts from the racks. (Station where barrel is emptied).

Autocatalytic (Electroless) plating is similar to electroplating in several ways, in that aqueous solutions are used in which the articles to be coated are immersed. No current, however, is employed; instead the reduction of metal compounds to metal takes place by the action of a chemical reducing agent in the solution. Autocatalytic plating has essentially perfect "throwing power" (the ability to cover deep recesses and deposit less excess plate on projection). Only a few metals can be deposited by the autocatalytic or electroless method; the principal ones are nickel and copper.

Waste Generation

Wastewater, solid waste, and air emissions are generated by the metal finishing process. The primary source of waste in metal finishing occurs in the rinsing operation.

Wastewater includes:

- Industrial wastewater - rinse water, cooling water, stream condensate, boiler blowdown, wash water, and exhaust scrubber solution
- Spent plating baths - contaminated or spent electroplating or electroless plating baths
- Spent process baths - etchants and cleaners that are contaminated or spent
- Strip and pickle baths - nitric, sulfuric, hydrochloric, and hydrofluoric acids used to strip metals from workpiece racks or parts
- Exhaust/scrubber solution - solutions collected in exhaust and air emission control devices.

Solid waste includes:

- Industrial wastewater treatment sludge - sludge containing metals such as cadmium, copper, chromium, nickel, tin, and zinc
- Miscellaneous solid wasted - absorbants, filters, empty containers, aisle grates, and abrasive blasting residues
- Solvents - contaminated solvents used for degreasing.

Air emissions include vapors from degreasing and solvent cleaning and mists from chromium plating operations.

V. PHYSICAL/CHEMICAL AND TOXICOLOGICAL PROPERTIES ASSOCIATED WITH COMMONLY USED SURFACE COATINGS

Cadmium

Table 1. Classification of corrosive environments.

Military Service Environment	Military Environment Description	Example
4 (Very Severe)	Exposure to marine climatic conditions (salt water, salt water spray); may include exposure to sulfur dioxide form engine exhaust or stack gases.	Exterior surfaces of surface ships and submersibles, deck storage, and other unprotected locations on ships or salt water docks.
3 (Severe)	Exposure to land climatic conditions (airborne dust, salt particles); may include exposure to industrial and vehicular airborne contaminants.	Exterior surfaces of unsheltered land-based vehicles and structures beyond salt spray impingement zones.
2 (Moderate)	Interior of unsheltered vehicles and unheated, nonhumidity controlled buildings protected from direct impingement of salt spray, rain, snow, and blowing dust.	Interior surfaces of land, sea, and airborne vehicles and buildings; surfaces of equipment installed or stored inside vehicles and buildings.
1 (Mild)	Humidity controlled to 60% RH Maximum	Computers and other equipment located in air-conditioned building.

The use of coatings to protect exposed metal surfaces is probably the most common form of protection and ranges from relatively simple paint applications to the use of more sophisticated materials of both metallic and nonmetallic substances. Coatings help prevent corrosion by providing passivation of the steel using inhibitive pigments or a barrier against corrosion.

IV. METAL FINISHING/PLATING

Metal finishing is used to improve the surface of a basic material by:

- cleaning it,
- hardening or softening it,
- smoothing or roughening it,
- depositing another metal on it by chemical exchange,
- electroplating another metal or series of metals on it,
- converting its surface by chemical deposition,
- coating it with organic materials,
- electrocoating it with organic material, or
- oxidizing by electrolysis

The metal finishing industry uses a wide variety of materials and processes to clean, etch, and plate metallic and nonmetallic surfaces to provide desired surface properties. The materials include solvents and surfactants for cleaning, acids and bases for etching, and solutions of metal salts and other compounds to plate a finish onto a substrate. Physical, chemical, and electrochemical processes are all used to finish metal workpieces. Physical processes include buffing, abrasive blasting, grinding, tumbling, and polishing. Chemical processes include degreasing, cleaning, pickling, etching, coating, and electroless plating. Electrochemical processes include plating, electrocleaning, electropolishing, and anodizing. The processes may simply polish the surface to provide a bright appearance or apply another metal to change the surface properties or appearance.

Physical, chemical, and electrochemical processes are typically performed in baths (tanks) and are then followed by a rinsing cycle. Figure 1 illustrates a typical chemical or electrochemical process step in which the workpiece enters the process bath containing process chemicals that are carried to the rinse water (drag-out). When the workpiece is transferred from the bath to the rinse, process solution will fall to the floor unless it is captured and returned to the process bath. In such cases, waste can be minimized by containing the process solution and returning it to the bath, which reduces the rinse flow and extends the life of the bath. Physical processes involve the use of a solid material (or abrasive) to change the surface characteristics of a workpiece, and do not generate as much waste as chemical and electrochemical processes. The waste generated contains the abrasive and the material removed from the surface. The use of sand for point stripping operations is an example of a physical finishing process.

General Techniques of Electroplating

CAS Registry Number: 7440-47-3
Chemical Formula: Cr

Chemical and Physical Properties

Boiling Point:	2672 C
Melting Point:	1857 C
Molecular Weight:	51.97
Water Solubility:	Insoluble
Vapor Pressure:	1 mm Hg at 1616 C

Natural Sources: Cadmium is an element found in the earth's crust.

Artificial Sources: Electroplating, leather tanning, and textile industries release large amounts of chromium to the environment. Of the total atmospheric chromium emissions from man-made sources in the United States, approximately 64 percent is due to chromium (III) from coal and oil combustion and steel production, and 32 percent is due to chromium (VI) form chemical manufacture, primary metal production, chrome plating, and cooling towers.

Human Health Exposure: The general population is exposed to chromium by eating food drinking water, and inhaling air that contain chromium. The mean daily dietary intake of chromium from air, water, and food is estimated to be <0.2-0.4, 2.0, and 60 μg, respectively. Exposure to chromium for occupational groups can be two orders of magnitude higher than the exposure to the general population. The respiratory tract is a major target of inhalation exposure to chromium compounds. Chromate sensitive workers acutely exposed to chromium (VI) compounds may develop asthma and other signs of respiratory distress. It has also been noted to cause severe liver effects in workers in the chrome plating industry.

Environmental Fate: Most of the chromium released into water will ultimately be deposited in the sediment. A very small percentage can be present in water in both soluble and insoluble forms. Chromium in soil is present mainly as insoluble oxide $Cr_2O_3 \cdot nH_2O$, and is not very mobile in soil. Surface runoff from soil can transport both soluble and bulk precipitate of chromium to surface water. Soluble and unadsorbed chromium (VI) and chromium (III) complexes in soil will leach into groundwater. Chromium is not expected to biomagnify in the aquatic food chain. The bioconcentration factor for chromium (VI) in rainbow trout is approximately 1.

VI. POLLUTION PREVENTION STRATEGIES ASSOCIATED WITH SURFACE COATINGS

The specific approaches recommended for waste minimization for metal finishing facilities include source reduction and recycling/resource recovery. Source reduction technologies are designed to reduce the volume of waste initially generated. In recycling and resource recovery,
waste is used as a raw material for the same or another process or valuable material are recovered from a waste stream before the waste is disposed of.

Source reduction approaches decrease the amount of generated waste, and they are usually the least expensive method of minimizing waste. Many source reduction options require only simple housekeeping changes or minor in-plant process modifications. Source reduction for the metal finishing industry at the process bath level can be achieved by material substitution, extending bath life, and drag-out reduction. Examples of source reduction are given below.

Material Substitution:

- Hexavalent Chromium Alternatives - Trivalent chromium plating solutions can be used for decorative chromium plating to replace hexavalent chromium. In doing so, drag-out is reduced, an extra treatment step (which reduces the chromium from the hexavalent to trivalent state before precipitation) is eliminated, and problems associated with hexavalent chromium bath misting and fugitive emissions in air scrubbers are eliminated. Other chromium alternatives include sulfuric acid and hydrogen peroxide and bexotriazole or water-based proprietaries.

- Nonchelated Process Chemicals - Chelators are used in chemical process baths to control the concentration of free metal ions in the solution. They are usually found in baths used for metal etching, cleaning, and electroless plating. Several chelators are used in metal finishing processes. In general, mild chelators such as phosphates and silicates are used for cleaning and etching processes, whereas electroless plating baths are

Substance Identification

CAS Registry Number: 7440-43-9
Chemical Formula: Cd

Chemical and Physical Properties

Boiling Point:	767 C
Melting Point:	320.9 C
Molecular Weight:	112.40
Water Solubility:	Insoluble
Vapor Pressure:	1 mm Hg at 394 C

Natural Sources: Cadmium is an element found in the earth's crust, primarily in association with zinc ores. Volcanic action is considered to be the major natural source of cadmium.

Artificial Sources: Cadmium (as cadmium oxide) is obtained mainly as a by-product during the processing of zinc-bearing ores, and also from the refining of lead and copper from sulfide ores.

Human Health Exposure: Individuals living near zinc or lead smelting operation, municipal incinerators, or other industrial processes emitting cadmium to the air will have above-average exposure. Cadmium has been detected in human blood, urine, breast milk, liver, kidney, and other tissues, both in occupationally-exposed individuals and in the general population. Acute toxicity most notably occurs after cadmium ingestion or inhalation of cadmium fumes. Poisoning from inhalation is relatively rare but dangerous. Initial signs/symptoms of cadmium poisoning resemble initial symptoms of the flu: cough, dyspnea, bronchitis, nausea, vomiting, abdominal pain and cramping, etc.

NIOSH has recommended that cadmium (dust and fumes) be treated as a potential human carcinogen. The OSHA 8-hr Time-Weighted average (cadmium fume) is 0.1 mg/m^3; acceptable ceiling concentration 0.3 mg/m^3. ATSDR (Agency for Toxic Substances and Disease Registry) has derived a chronic inhalation minimum risk level (MRL) of 0.0002 mg/m^3 based on kidney effects. The EPA has calculated oral chronic reference doses (RfDs) for cadmium of 0.001 and 0.0005 mg/kg/day for ingestion from food and water, respectively.

Environmental Fate: In soil, transformation processes for cadmium are mediated by sorption and desorption from water, and include precipitation, dissolution, complexation, and ion exchange. Important factors affecting transformation in soil include the cation exchange capacity, the pH, and the content of clay minerals, carbonate mineral oxides, organic matter, and oxygen. Many studies have shown that loss of Cd due to leaching is not a major component of the total losses from soil.

In aquatic environments, cadmium is more mobile than most other heavy metals, such as lead. Cadmium is primarily present as the cadmium(+2) ion, however, if high concentrations of organic material are present, more than half may occur in organic complexes. Cadmium precipitates as cadmium sulfide in reducing environments. The most important removal processes for cadmium compounds are the precipitation and sorption to mineral surfaces and organic materials. Sediment bacteria may also assist in the partitioning of cadmium from water to sediments. In the aquatic fate of cadmium compounds, photolysis is not an important mechanism, and biological methylation of cadmium is unlikely to occur. Cadmium is not known to form volatile compounds, so partition to the atmosphere from water is unlikely to occur.

Cadmium bioaccumulates in all levels of the food chain. In freshwater and marine species, cadmium concentrations have been reported at hundreds to thousands of times higher than in the water. Levels of cadmium in plants grown in uncontaminated soil are normally less than 1 ppm in dry matter, but levels up to several hundred ppm in edible plants grown on cadmium-contaminated soil has been observed. Evidence shows that cadmium is quite phytotoxic for a number of crops (levels greater than 20 ppm are generally undesirable for crop production), with the adverse effect being largely a consequence of the ease with which cadmium enters the plant through the root system.

Chromium

Substance Identification

- Process Bath Operating Concentration - Drag-out can be reduced by keeping the chemical concentration of the process bath at the lowest acceptable operating level. Generally, the greater the concentration of chemicals in a solution, the greater the viscosity. As a result, the film that adheres to the workpiece as it is removed from the process bath is thicker and will not drain back into the process bath as quickly.

- Process Bath Operating Temperature - Higher temperature baths reduce the viscosity of the process solution, which enables the chemical solution to drain form the workpiece faster, thereby reducing drag-out loss. However, very high temperatures should be avoided because brighteners break down in most plating solutions. Operating process baths at higher temperatures will also increase the evaporation rate from the process tank.

- Wetting Agents - Adding wetting agents to a process bath reduces the surface tension of a solution and, as a result, can reduce drag-out loss by as much as 50 percent. However, wetting agents can create foaming problems in process baths and may not be compatible with waste treatment systems.

- Workpiece Positioning - Drag-out loss can be reduced by properly positioning the workpiece on the rack. Workpieces should be oriented so that chemical solutions can drain freely and not get trapped in grooves or cavities.

- Withdrawal and Drain Time - The faster an item is removed from the process bath, the thicker the film on the workpiece surface and the greater the drag-out volume, therefore workpieces should be withdrawn slowly.

- Air Knives - Air knives can be used above process tanks to improve draining. As the workpiece rack is raised from the process tank, air is blown onto the surface of the workpieces to improve drag-out solution draining into the process bath. High humidity air can counteract workpiece drying.

- Spray or Fog Rinses - Spray or fog rinse systems can be used above heated baths to recover drag-out solutions.

- Plating Baths -Contaminated plating baths increase drag-out by as much as 50 percent because of the increase in solution viscosity. Excess impurities also make application of recovery techniques difficult, if not impractical. Therefore, efforts should be made to reduce the level of impurities in the bath.

- Drain Boards - Drain board capture process chemicals that drip form the workpiece rack as it is moved from the process bath to the rinse system. This prevents chemical solutions from dripping onto the floor.

- Drag-Out Tanks (dead or static rinse tanks) - Process chemicals that adhere to the workpiece can be captured in drag-out tanks and returned to the process bath. Chemical concentrations in the drag-out tanks increase as workpieces are passed through. Eventually, the chemical concentration of the drag-out tank solution will increase to the point where it can by used to replenish the process bath.

Recycling and resource recovery technologies either directly use waste from one process as raw material for another process or recover valuable materials from a waste stream before they are disposed. Some spent chemical process baths and much rinse water can be reused for other plant processes. Also, process chemicals can be recovered form rinse water and sold or returned to process baths. Segregating waste streams is essential for most recycling and resource recovery technologies. To reuse a waste material for another process, recovery valuable chemicals from a waste stream, or recycle rinse water, the waste stream must be separated from other wastes that would prohibit recycling or reuse opportunities.

Reusing Waste Material:

- Rinse Water - After rinse solutions became too contaminated for their original purpose, they may be useful for other rinse processes. For example, effluent form a rinse system following an acid cleaning bath can sometimes be reused as influent to a rinse system following an alkaline cleaning bath.

- Spent Process Baths - Typically, spent acid or alkaline solutions are dumped when contaminants exceed an acceptable level. However, these solutions may remain sufficiently acidic or alkaline to act a pH adjusters. For example, alkaline solutions can be used to adjust the pH in a precipitation tank.

Recycling Rinse Water and Process Baths:

typically chelated with stronger chelating compounds (citric acid, maleic acid, and oxalic acid). Nonchelated process chemistries can be used for some processes (e.g., alkaline cleaning and etching) in which it may not be necessary to keep the metals removed form workpiece surfaces in solution. However, for electroless plating, it is less feasible to use nonchelated chemistries because the chelators play a significant role in the chemical processes that allow the plating bath to function.

- Noncyanide Process Chemicals - Alternatives to cyanide plating bath chemistries include acid tin chloride, which works faster and better that tin cyanide. In contrast to a heavy copper cyanide plating bath, copper sulfate baths are highly conductive and have a simple chemistry. Sulfate baths are economical to prepare, operate and treat. The copper cyanide strike may still be needed for steel, zinc, or tin-lead base metals. One disadvantage of alternatives to cyanide plating bath chemistries is that noncyanide chemistries often cost more than conventional cyanide baths. Alternatives to cyanide cleaners include trisodiumphosphate or ammonia; both provide good degreasing when used hot in an ultrasonic bath. However, they are highly basic and may complex with soluble metals if used as an intermediate rinse between plating baths where metal ions may be dragged into the cleaner.

Other substitutions include the use of deionized water, alkaline cleaners, and alternative cleaners.

Bath Life Extension:

- Filtration - Filtration systems remove accumulated solids that reduce the effectiveness of the process bath operations. Continuous filtration of the bath removes these contaminants, thereby extending the life of the bath.

- Replenishment - The effectiveness of a cleaning bath decreases with use. Instead of disposing of the entire bath, part can be retained and replenished with fresh chemicals and water. Replenishing reduces drag-out in the early life of the bath, but ultimately increases the concentrations of chemicals in spent solutions when the bath must be replaced.

- Electrolytic Dummying - Metal contaminants (such as copper) introduced into plating baths with workpieces degrade the effectiveness of the plating process. In zinc and nickel baths, copper can be removed by a process called "dummying." When the copper content becomes too high, an electrolytic panel is placed in the process bath. A "trickle current" is run through the system. At this current, the copper in the solution plates out on the panel, but the plating bath additives (such as brighteners) are unaffected. While some of the plating metals (zinc, nickel) are inadvertently removed, the savings realized by extending bath life justifies the slight metal loss.

- Precipitation - Metals such as lead and cadmium enter the bath as impurities in anodes and can be removed from certain plating baths by precipitation. For zinc cyanide bath, zinc sulfide can be added to precipitate lead and cadmium, and the precipitant can then be removed by filtration. Care must be taken to ensure that precipitating reagents are compatible with the constituents.

- Monitoring - The key to determining the need for added chemicals or removal of contaminants, and hence extending the life of process bath, is the continuous analysis of bath parameters, e.g., pH and metal content.

- Housekeeping - Preventing foreign material from entering or remaining in a bath prolongs its life.

- Drag-In Reduction - Liquids clinging to workpieces from preceding baths can shorten useful life and reduce effectiveness of subsequent baths. Rinsing helps prevent cross-contamination between baths by rinsing the drag-out from one process bath before the item is processed in another.

- Purer Anodes and Bags - Impurities contained in anodes will contaminate a process bath. Pure anodes do not contribute to bath contamination, but may cost more.

- Ventilation/Exhaust Systems - Scrubbers, demisters, and condensate traps remove entrained droplets and vapors from the air passing through ventilation and exhaust systems. If segregated, some wastes from scrubbers can be returned to process baths after filtering. Updraft ventilation allows mist to be collected in the ductwork and flow back to the process tank.

Drag-Out Reduction:

Radiation Curable Coatings: Radiation curable coatings comprise ultraviolet, electron beam, infrared, and microwave cured system. Ultraviolet (UV) curing is the most common of the radiation processes. The main components are a low-molecular resin containing olefinic bonds, a reactive solvent, also containing unsaturated groups, and a photoinitiator. A reduction of solvent use up to 100% is feasible with UV curing.

Powder Coatings: Powder coatings are unique among all present day compliance coatings in that they are dry solid coating materials, as opposed to the liquid materials of high solids, waterborne, and radiation curable coatings. Powder coatings are finely pulverized pigmented resin particles that are electrostatically sprayed onto a metal part to be coated. The charged particles adhere to the surface and the part is conveyed to a curing oven where the powder melts under heat to form a uniform, durable high quality finish. The use of powder coatings an alternative to liquid, solvent based coatings results in a significant reduction in VOC emissions. Powder coating has been characterized as the lowest VOC content coating among the options available to industrial finishers.

VIII. SUMMARY

This lesson presented background information on surface coatings and their use in DoD activities. A brief overview of pollution prevention strateges associated with solvent use was given. Driven by environmental concerns, process modification, material substitution, and recycle/reuse must be considered in DoD cleaning operations. Students will now have a basic understanding in surface coatings pollution prevention strategies.

- Evaporation - Evaporation has been successfully used to recover a variety of plating bath chemicals. This simple technology is based on the physical separation of water from dissolved solids such as heavy metals. Water is evaporated from the collected rinse water to allow the chemical concentrate to be returned to the process bath. Evaporation is most economical when the amount of water to be evaporated is small or when natural atmospheric evaporation can be used.

- Reverse Osmosis - Reverse osmosis is a pressure-driven process in which a semipermeable membrane permits the passage of purified water under pressure greater than the normal osmotic pressure, but does not allow larger molecular weight components to pass through. These concentrated components can be recovered and returned to the process bath, and the treated rinse water is then returned to the rinse system for reuse. Reverse osmosis is limited by the ability of the membranes to withstand pH extremes and long-term pressure. Reverse osmosis membranes are not generally suitable for solutions having high oxidation potential (such as chromic acid).

- Ion Exchange - Ion exchange can be used to recover drag-out from a dilute rinse solution. The chemical solution is passed through a series of resin beds that selectively remove cations and anions. As the rinse water is passed through a resin bed, the resin exchanges ions with the inorganic compounds in the rinse water. The metals are recovered by cleaning the resin with an acid or alkaline solution. Ion exchange is commonly used to treat rinse water from chromic acid process baths. Ion exchange equipment requires careful operation and maintenance. Recovery of chemicals from the resin columns generates significant volumes of regenerant and wash solutions, which may add to the wastewater treatment load.

- Electrolytic Recovery (electrowinning) - Electrowinning is a process used to recover the metallic content of rinse water. It operates using a cathode and an anode, which are placed in the rinse solution. As current passes between them, metallic ions deposit on the cathode, generating a solid metallic slav that can be reclaimed or used as an anode in an electroplating tank. The electrowinning process is capable of recovering 90 to 95 percent of the available metals and has been successfully used to recover gold, silver, tin, copper, zinc, solder alloy, and cadmium.

- Electrodialysis- Electrodialysis is used to concentrate and separate ionic components contained in rinse water solution. A water solution is passed through a series of alternately placed cation- and anion-permeable membranes. These membranes are placed parallel to the flow of water, and an anode and cathode are placed on opposite sides of the membrane stack. The anode and cathode create an electropotential across the stack of membranes, causing the ions in the rinse solution to migrate across the membranes. The selectivity of the alternating membranes caused both anions and cations to migrate into alternating channels, and ion-depleted water remains in the other channels. The concentrated solution can be returned to the plating baths, while the treated water is recycled through the rinse system.

VII. ALTERNATIVE COATING TECHNOLOGIES

Most painting (organic paints) is performed by conventional liquid spray technology. In spray painting, the paint is mixed with a carrier, usually an organic solvent, and is applied to the surface with an air-pressurized sprayer. Spray painting is usually done in a horizontal or downdraft paint spray booth. During painting processes, two significant sources of hazardous wastes are generated: paint sludges and waste solvents. Alternatives to conventional solvent based spray painting can reduce hazardous wastes. These alternatives require an integrated approach in which painting techniques are improved and process optimized to reduce or eliminate hazardous wastes.

High Solids Coatings: High solids coatings contain 25 percent to 60 percent solids by volume and compared to solvent based coatings, use lower molecular weight paint resins with highly reactive sites to aid in coating polymerization. The finished coat is comparable to typical solvent-based coatings. The major advantage is the ability to comply with more stringent VOC limitations. However, high solids require special spray equipment for application because of their high viscosity. Because less solvent is used, less is available to wet metallic surfaces that are contaminated with oils, therefore surface preparation for removal of oils is more critical.

Waterborne Coatings: In a waterborne system, the pigments are similar to those used in a solvent system. The binder is usually an organic polymer, such as alkyd, polyester, vinyl acetate, acrylic, and epoxies, and can be dissolved, dispersed, or emulsified. No major equipment changes are needed to apply waterborne coatings with conventional equipment. Recovery of paint overspray is simple. Overspray can by collected with water in the spray booth. The solution may be concentrated and reused.

- Modem - 2400 baud is OK, 9600 is faster.
- Phone line - data line not needed, noisy lines are frustrating

C. Software

- Communications program - many available
- Decompression program - PKUNZIP is most common
- Virus protection software
- Word processor, text editor

D. Helpful Hints for Newcomers to Computer Telecommunications

- Practice on a local BBS before you call long distance
  - test-drive your hardware and software
  - learn general BBS procedures
  - practice uploading and downloading files
  - learn sending and receiving messages
- Join a user's group
- Problems WILL come up, learn where to go for help

II. COMMON ELEMENTS OF MOST SYSTEMS

A. Basic Concepts

SYSOP - System Operator

System Security - All systems need to protect themselves against hackers.

"Sanitation" - You must have AND USE virus detection software.

Good Manners - DON'T USE ALL CAPS, IT'S THE BBS EQUIVALENT OF SHOUTING.

File Compression - Makes for speedier file transfers.

B. Basic Procedures

Registration - BBSs often allow on-line registration on first call

Logon - Log in by name or identifier

Password - WRITE IT DOWN

Announcements - Often important

Main Menu - Explore, much may be hidden in sub-menus

Conferences - Groupings of mail and files by interest groups

Downloading - File transfer

Mail - Public messages, "private" mail

Logoff - If you simply disconnect without logging off, you may hang up the system and/or annoy the Sysop

C. Getting Help

On-Line Help
Using Mail to Request Help/Information from Other Users
Ask the Sysop (Last Resort)

D. MISCELLANEOUS SYSTEMS

BLOCK 17: POLLUTION PREVENTION MODELS, DATABASES, AND GUIDELINES

1.0 Introduction

Block 17 provides a comprehensive review of information resources and tools used in the design, implementation, and analysis of pollution prevention programs and activities. Block 17 describes specific databases, models, and electronic bulletin boards (BBSs) which are used to gather and analyze information to develop or improve pollution prevention programs. Several common features of BBSs and databases are overviewed.

2.0 Objective

To review models, databases, and guidelines to turn to for support and assistance in conceptualizing, designing, and implementing a new pollution prevention program or improving upon an existing one. Note: Includes computer-based instruction.

1. Students will know the major databases and resources available to them for accomplishing pollution prevention initiatives.

2. Students will know and understand the access requirements, operating prodecures, and information collection techniques for computer-based information systems and bulletin board systems (BBSs) by viewing sample sessions.

3. Students will know and understand the purposes and characteristics of the major computer information systems by performing a practice information retrieval task that includes selecting a system to access.

4. Students will know and understand the use of computer support systems and BBSs by practicing logon and system use in a hands-on practice session.

5. Students will know and understand how to access, interact with, and obtain information from the "network community" of experts and colleagues.

6. Students will be given opportunities for "hands" on time with the following systems:

   - Students will learn the possible ways to access the Pollution Prevention Information Clearinghouse (PPIC). Students will learn the types of information contained in PPIC, including the Pollution Prevention Information Exchange System (PIES).

   - Students will learn about the Environmental Technical Information System (ETIS), and its component subsystems, such as the Economic Impact Forecasting System (EIFS), the Computer-aided Environmental Legislative Data System (CELDS), and the SOILS systems. Students will learn how to access ETIS.

   - Students will learn about the Toxic Chemical Release Inventory (TRI) produced by the Environmental Protection Agency. Students will learn to access TRI using GRATEFUL MED to access the National Library of Medicine's TOXNET system.

3.0 Key Concepts

I. INTRODUCTION TO COMPUTER-BASED INFORMATION SYSTEMS

A. Basic Requirements

- Hardware
- Phone line
- Software
- Time (e.g., to practice new skills and digest new information)

B. Equipment

- Computer - "obsolete" models are OK.

collect this data nationwide on an annual basis. The law also mandates that this data be made publicly available through a computer database. TRI data is arranged in the following categories:

- Facility Identification
- Substance Identification
- Environmental Release of Chemicals
- Waste Treatment
- Off-Site Waste Transfer

TRI is a component file of the National Library of Medicine's (NLM) TOXNET systems. TRI is available through various telecommunication networks, including Sprintnet, Tymnet, Compuserve, and Internet. TRI can be searched using the NLM's GRATEFUL MED search software. GRATEFUL MED is a software tool designed to simplify the process of searching NLM's MEDLARS and TOXNET systems. It contains a special input screen for searching TRI. This template allows the user to search on facility name, chemical name/RN, State, and City/County. By using the F10 key, the user can obtain a list of available data fields. The user can select up to five of these fields for searching for data in these fields. After filling in the special input screen, the user can allow GRATEFUL MED to establish the telecommunications link, run the search, and download the search results.

For further information, contact:

TRI Representative, Specialized Information Services
National Library of Medicine
8600 Rockville Pike
Bethesda, MD 20894
(301) 496-6531

3. Bibliographic Databases

In addition, there are literally dozens of bibliographic databases that contain citations to the literature related to pollution prevention. These citations include journals, books, dissertations, conference proceedings, and reports. These databases are all available through various database vendor systems, and range in price for connect hour charges from $25.00 to well over $200. Many are also available now on compact disc, or may be available in nearby university or community libraries. The National Technical Information Service produces the NTIS database of government-sponsored report literature. This database consists of unclassified government sponsored research, development, and engineering reports, as well as other analyses prepared by government agencies, their contractors or grantees. NTIS is available in both a dial-up mode, as well as on compact disc.

C. Compact Disc Based Systems

1. Environmental Safety Library (ESL)--The ESL is a full-text system containing the following:

- Public Laws administered by the EPA;
- OSHA Act of 1970 (with amendments);
- 29 CFR 1900-end;
- OSHA related publications;
- OSHA Technical Manual and OSHA Field Operations Manual;
- 40 CFR
- 42 CFR parts 80-89
- 49 CFR parts 100-199 (DOT regulations on the transport of hazardous materials);
- Federal Register final and proposed rules pertaining to the above CFR parts;
- Industry Standards pertaining to OSHA;
- Industry Standards pertaining to EPA;
- State regulations related to environmental and safety compliance;

The ESL is compiled by IHS and distributed by Micromedex, Inc. It is updated every 30 days, with a newsletter update in the interim. It is searchable using keywords with Boolean search capabilities.

WIN - the Waste Information Network - operates on a VAX at HAZWRAP

EPA's ORD Publications Database

HMIS

III. OVERVIEW OF SYSTEMS

A. PC-Based BBSs

PIES - the Pollution Prevention Information Exchange System - is part of the Pollution Prevention Information Clearinghouse (PPIC). PPIC is sponsored by the U.S. EPA, Office of Environmental Engineering and Technology Demonstration (OEETD) in the Office of Pollution Prevention. PIES is operated for EPA by Science Applications International Corporation (SAIC) and the PIES Technical Support Hotline number is (703) 821-4800 (voice). The BBS phone number is (703) 506-1025. The system contains:

1. Mini-exchange on EPA's 33/50 program
2. Mail
3. Databases, including case studies
4. Files available for downloading

B. Dial-in Systems

1. Environmental Technical Information System (ETIS)

ETIS is a collection of online systems that provide planners, economists, and environmental specialists with current environmental information. ETIS was developed by the U.S. Army Corps of Engineers Construction Engineering Laboratory (CERL) to facilitate writing environmental impact statements and environmental assessments. The primary systems available through ETIS are:

a. Economic Impact Forecasting System (EIFS). Contains socioeconomic data from a variety of sources for every county in the nation. EIFS helps the user do complex impact analysis based on input-output coefficients. The forecast models are applicable to various scenarios, including industry closings or openings, construction projects and large-scale personnel changes.

b. Computer-aided Environmental Legislative Data System (CELDS). Contains abstracts of current environmental regulations for all 50 states, the District of Columbia, Puerto Rico, and the federal government. The abstracts are written in a long, narrative style and offer a quick method for identifying applicable standards. Each record contains a legal reference, agency addresses and telephone numbers and effective dates for the regulations.

c. ETIS - the Environmental Technical Information System - operates on a VAX at the University of Illinois at Champaign-Urbana.

For further information on ETIS, contact:

ETIS Support Center
1003 West Nevada
Urbana, IL 61801
(217) 333-1369

2. Toxic Release Inventory (TRI)

Contains information on the annual estimated releases of toxic chemicals to the environment. Based upon data collected by the EPA. Title II of the Superfund Amendments and Reauthorization Act (SARA) of 1986 mandated reporting by industry on the releases of over 300 toxic chemicals into the air, water and land. Data submitted to the EPA include names and addresses of facilities that manufacture, process, or otherwise use these chemicals, as well as amounts released to the environment or transferred to waste sites. Title III of SARA, also known as the Emergency Planning and Community Right-to-Know Act, requires the EPA to

For further information, contact

Micromedex, Inc.
600 Grant St.
Denver, CO 80203-3527
(303) 831-1400
(800) 525-9083

2. TOMES PLUS--A collection of databases providing medical and hazard information needed for the safe management of chemicals in the workplace and in the environment. Information is provided in the form of reference documents contained in a collection of standard and proprietary databases. Documents can be retrieved by chemical name, synonym, formula or identification number (CAS, NIOSH/RTECS, STCC, UN/NA, ENT or USAF). Movement within and between documents is accomplished through the use of menus and function keys. TOMES includes the following databases:

   Hazardous Substances Data Bank (HSDB)--produced by the National Library of Medicine. HSDB contains information addressing the impact of over 4,000 hazardous substances on health and the environment. Specific information on environmental fate, animal studies, chemical handling, and manufacturer data is included and is peer reviewed.

   Integrated Risk Information System (IRIS)--produced by the Environmental Protection Agency. IRIS contains EPA health risk assessment information. The effects of chronic and acute exposure to carcinogens on human health are detailed and regulatory status of over 450 chemicals is provided. Evaluations of the data are included and assist with comparison of information.

   Registry of Toxic Effects of Chemical (RTECS)--produced by National Institute for Occupational Safety and Health. Provides toxicology information on over 100,000 substances. Studies are sorted by effect, test type and species. Specific data on mutagenicity, carcinogenicity, and reproductive hazards of chemicals is included. Toxicology data is extracted from scientific literature.

IV. SUMMARY

We have covered many types of information here today. We hope that you will now feel more comfortable and more knowledgable about using some of these information sources. We encourage you to contact these information sources to obtain more information about accessing or obtaining these sources.
In order to more effectively use the vast amounts of information available to help you, you must become familiar with these sources of information. Although the amount of information available may seem overwhelming, once you get "information smart" you can easily manage your information needs and uses.

These are just some of the information sources available to you in your pollution prevention duties. Please utilize them in order to "work smarter".

- Alkaline-based cleaners can cause corrosion if not adequately rinsed

- REFERENCE: Groshart, E., et al., 1991. Alternatives for CFC-113 and Methyl Chloroform in Metal Cleaning, U.S. EPA, EPA/400/1-91/019, Office of Air and Radiation (ANR-445), Washington, DC.

C. Similar studies and conversions done by General Dynamics and U.S. Air Force

D. USAF study involved pilot research at Engineering and Services Center, Tyndall AFB, field testing at Tinker AFB

- The most effective cleaner, 3-D Supreme, affected wastewater treatment plant operations, caused clarifier sludge to float.

E. Lessons Learned: Substitutions and conversions such as these require thorough study and evaluation on case-by-case basis.

III. CASE STUDY 2: PAINTING LINE MODIFICATIONS, ANNISTON ARMY DEPOT

A. Large Vehicle Repair Operation

- Anniston Army Depot = "Tank Rebuild Center of the Free World"
- Uses urethane-based camouflage paint with high solids content
- Installed 8 waterfall-type spray paint booths
- System uses clay dust as paint detackifying compound to promote coagulation of paint particles
- Cyclone separator removes particles, produces more concentrated paint sludge

IV. MORE PAINTING MODIFICATIONS

A. Transfer Efficiency. Anything you can do to increase your efficiency reduces waste.

B. Conventional Spray Painting Techniques

- Carrier is usually organic solvent
- Application with air pressurized sprayer
- Horizontal or downdraft paint spray booth
- Major wastes: paint sludges and waste solvents

C. Case Study 3: Optimizing Spray Painting Efficiency, Bridge Wheel Company, Bloomington, MN.

- Overspray captured in water wash paint booths with circulating baths below
- Consulted with equipment and paint manufacturers
- Adjusted air pressure, fluid pressure, spray time, and paint viscosity to optimize transfer efficiency
- REFERENCE: Young, Steve, 1987. Reducing Overspray for a Conventional Air-atomizing Paint System. Minnesota Technical Assistance Program, Minneapolis, MN, 52 pp.

D. Waterborne Coatings

BLOCK 18: CASE STUDIES: PAINTING AND COATING

1.0 Introduction

Block 18 reviews painting and coating processes common to the DoD environment. Waste reduction opportunities using material reformulation and process modification are presented as well as the environmental risks and impacts associated with use of paints and coatings.
Lastly, a computer exercise using SWAMI to develop and analyze pollution prevention strategies for painting and coating processes.

2.0 Objective

To present case studies that involve the use of at least one of the EPA's seventeen priority chemicals in painting or coating processes, e.g., toluene, xylene, diisocyanates, alodine, and chromates. Processes focused on are those relevant to DoD environments, e.g., aircraft and ship painting. Waste reduction opportunities include material reformulation and process modification, e.g., processes that reduce overspray.

1. Students will know and understand the major uses of solvents in paint and coatings by surveying case studies in which other materials have been substituted.

2. Students will know and understand the potential impacts and benefits of processes that reduce paint overspray by examining one or more case studies of process modification in a DoD environment.

3. Students will know and understand the environmental risks and impacts associated with use of antifoulant paints on naval vessels by learning about the case study of tributyltin (TBT) and the Organotin Antifouling Paint Control Act.

4. Students will know and understand the potential pollution prevention benefits of substituting other antifoulants for TBT and reformulation of TBT-based paints.

3.0 Key Concepts

I. INTRODUCTION TO POLLUTION PREVENTION FOR PAINTING AND COATINGS

A. Scope - Block considers only painting, coating, and integral surface preparation, not depainting or degreasing.

B. Apply the full spectrum of pollution prevention techniques

- Reduce, reuse, recycle
- Material and process substitution
- Use common sense - don't ignore "low-tech" opportunities - DoD applies tons of ordinary paint to square miles of ordinary surfaces.

II. CASE STUDY 1: PHASE-OUT OF CFC-113 AND METHYL CHLOROFORM BY BOEING AIRCRAFT

A. CFC-113 and methyl chloroform (1,1,1-trichloroethane) are used for solvent degreasing and surface cleaning of metal parts, critical to the integrity of subsequent coatings.

B. Boeing Corporation began evaluating aqueous cleaning processes in mid-1987

- 48 aqueous cleaners were eventually evaluated

- Processes tested included immersion, spray cleaning, ultrasonic cleaning

- Cleaners capable of removing broad spectrum of soil agents in 10 minutes were retained for further testing

- Materials cleaned with candidate substitutes tested for corrosion and success in finishing processes - all cleaners passed

E. TBT Toxicity and Fate

Concentrations of TBT in waters with significant boating activity may be sufficiently high to cause effects to nontarget organisms. TBT is toxic to fish at levels as low as 0.2 ppb, and also presents high risks to crustaceans, bivalves, gastropods, phytoplankton, and zooplankton at comparable levels. TBT and its degradates concentrate in bottom sediments. TBT bioconcentrates in the food chain from bacteria to shellfish, crustaceans, and bottom-feeding fish. TBT is moderately toxic to humans. The primary health risks are ingestion of food that has bioaccumulated TBT and occupational exposure of shipyard workers.

F. Regulation of TBT Antifoulants

1. Federal Insecticide, Fungicide, and Rodenticide Act
2. The Organotin Antifouling Paint Control Act
3. The Clean Water Act

G. Current Status

Paints currently available use organotin compounds with cuprous oxide. Paints have been reformulated to limit release rates to OAPCA limits (4 $\mu g/cm^2$-day). OAPCA release rates may still produce toxic levels in harbors with large numbers of TBT-treated ships. Pollution prevention efforts are still needed. Scraping and depainting requires control and proper disposal of paint chips.

H. Antifoulant Substitution

Alternative antifoulant toxicants or systems still in experimental stages or limited to special uses.

VI. SUMMARY

This lesson presented case studies on paintings and coatings, emphasizing the pollution prevention potential in DoD activities. Material substitution, process modification, and reduction/reuse are considered. Driven by concerns over occupational exposures, toxicant emissions, hazardous waste disposal, and ozone depletion, pollution prevention for painting and coating activities is essential in DoD operations. Students will now have a basic understanding in surface coatings pollution prevention strategies.

- Replacing solvent with water may require reformulated paint, but conventional equipment may be useable

- Overspray can be collected with water

- Hazardous occupational exposures are reduced

- General Dynamics Fort Worth Division has become the world's largest user of water-reducible aircraft primer

E. Electrostatic Paint System

- Equipment puts charge on spray droplets, opposite charge on surface to be finished

- Increase in transfer efficiency

- Produces more even coat thickness, improves corrosion resistance

- REFERENCE: Emerson Electric Company Case Study in Huisingh, D., et al., 1986. Proven Profits from Pollution Prevention: Case Studies in Resource Conservation and Waste Reduction, Institute for Local Self-Reliance, Washington, DC.

F. Powder Coating Systems

- Finely pulverized pigmented resin particles

- Electrostatically sprayed onto a metal part to be coated

- Part conveyed to curing oven where powders melts to form uniform durable finish

- Dry systems for overspray recovery: cyclones, bag filters

V. CASE STUDY 4: ANTIFOULANT PAINTS USED ON DOD MARINE VESSELS

A. Introduction to Antifoulant Paints

Bottom fouling is caused by numerous marine organisms, e.g., barnacles, seaweeds, and tubeworms. Fouling reduces ship's speed, fuel efficiency, maneuverability. Fouling also requires dry dock time for removal of fouling organisms. Organotins, especially tributyltin (TBT), have been in wide use as antifoulants since the early 1970s. Use of TBT is being restricted by EPA because of hazards posed to non-target aquatic organisms. The Navy proposed using TBT paints on its fleet in 1985.

B. Marine Fouling

Fouling process involves successional stages: bacterial film, polysaccharide matrix, algae, early life stages of fouling organisms. Fouling causes roughness that increases turbulent flow, acoustic noise, and hydrodynamic drag. A 10-micron increase in average hull roughness can result in a 0.3-to-1.0 percent increase in fuel consumption.

C. Antifoulants

In ancient times, methods to prevent fouling included copper or lead sheets covering the hulls. Copper salt compounds in paints were widely used in the early 1900s. Organo-mercury compounds and stereoarsenicals were later used, but discontinued in the 1970s because of toxicity. These were replaced largely by TBT.

D. Types of TBT Antifouling Paints

1. Free association paints
2. Ablative paints
3. Self-polishing copolymer paints

BLOCK 19: VEHICLE MAINTENANCE TUTORIAL AND EXERCISE

1.0 Introduction

Block 19 reviews case studies of vehicle maintenance processes common to the DoD. A computer-based tutorial and exercise are used to present basic maintenance processes fundamental to pollution prevention.

2.0 Objective

To cover, in a computer-based tutorial exercise, such things as more frequent tune-ups to increase fuel efficiency, replacing anti-freeze after certain mileage numbers versus monthly etc. All techniques and technologies are put into a pollution prevention perspective. Note: Includes computer-based instruction.

1. Students will learn opportunity assessments for vehicle maintenance shops.

2. Students will learn how elements of the scheduled inspection contribute to pollution prevention opportunities.

3. Students will learn how elements of operations in the vehicle maintenance shop contribute to pollution prevention opportunities.

4. Students will learn technologies used in the vehicle maintenance shop that contribute to pollution prevention opportunities.

3.0 Key Concepts

The Vehicle Maintenance Tutorial and Exercise is Computer-Based Instruction.

What are the Steps of the PPBS?

(1) Each phase is structured to provide a product by an established calendar suspense date (e.g., the Defense Planning Guidance is to be published by October 1 of every other calendar year).

(2) The phases enable decisionmakers to translate national strategies and objectives into long-range program plans and planning guidance (planning), six-year defense programs (programming), and two-year budget requests (budgeting).

(3) The Defense Planning and Resources Board meets during each phase to facilitate decisionmaking by the Secretary and Deputy Secretary of Defense.

II. THE PLANNING PHASE

What is the Planning Phase?

By way of background, planning involves the systematic consideration of alternative actions to accomplish DoD objectives. Although resource requirements may be a consideration, the planning activity is primarily oriented towards goals or outputs. The planning objective is to identify strategies and capabilities which DoD must develop in order to support national security objectives. The plans developed are used to develop the Defense Planning Guidance. The Defense Planning Guidance sets forth broad policy objectives and military strategy.

III. THE PROGRAMMING PHASE

What is the Programming Phase?

The programming phase results in development of a six-year Defense Program for each military department, and for the DoD as a whole. The six-year program links national policies, strategy, and objectives to specific forces and major programs, including acquisition programs. It is based on the Defense Planning Guidance and on updated out-year fiscal projections. The six-year program proposals of each military department with programming responsibilities are described in a document called the POM. These POMs are submitted to the Secretary of Defense every other calendar year.

What are the limits of the Programming Phase?

Programming involves a review of capabilities which DoD must develop. However, the programming process is constrained by resources expected to be available. The resources currently available to the DoD are divided into six different categories. Funding requests are routed and placed in an appropriate category. The Base Budgeting Office should know how much money is available in each of the following categories:

- procurement 3010 - aircraft
  3020 - missile
  3080 - other procurement
- research, development, test and evaluation - 3600
- military construction - 3300
- operations and maintenance - 3400

The programming phase is a systematic review and consideration of the currently approved programs as expressed in the six-year Defense Program. Some programs may become infeasible when resources are considered and they will have to be modified to be considered affordable.

Documents Developed in the Programming Phase

Since not all resource requirements can be satisfied immediately, program priorities must be established. The programming process results in a scheduling of programs to be carried out based on their priority and availability of the resources necessary for those programs. The results of this review and approval process is reflected in the Six-Year Defense Program. The programming function is accomplished through four sets of documents: POMs, Joint Program Assessment

BLOCK 20: PARTICIPATION IN THE POLLUTION PREVENTION FUNDING PROCESS

1.0 Introduction

Block 20 addresses significant elements of the planning and funding process in the DoD that pertain to Pollution Prevention Projects. The DoD Planning, Programming and Budgeting Process (PPBS), and the Services' Program Objective Memorandum (POM) are described. The block discusses how to justify, follow-up, and ensure your proposal gets full consideration within the POM process. The second part of this block describes key funding inputs for the Air Force for Pollution Prevention. Guidance is provided on how to complete project justifications and examples are discussed.

2.0 Objective

To discuss various budgeting measures including the DoD PPBS, and the POM. To describe how to propose, justify, and follow-up funding for pollution prevention programs.

Students will be able to accomplish the following upon completion of the lesson:

1. Understand overall funding mechanisms of the DoD including each phase of the PPBS and where they contribute to the process to propose their funding needs for consideration;

2. Understand the importance of the POM and how it contributes to the consideration of their request for funding;

3. Know how to optimize their chances for receiving funding by learning when and how to provide information for the funding process;

4. Understand how to submit well documented funding requests and how to ensure thorough consideration.

3.0 Key Concepts

I. INTRODUCTION TO THE PLANNING, PROGRAMMING, AND BUDGETING SYSTEM (PPBS)

In 1966, Department of Defense Directive 7000.1, established the basic policies for improving resource management within the DoD. In general, the Resource Management Systems provide information to managers to allow them to effectively and efficiently establish objectives, translate those objectives into programs, and match resources (personnel, money, and material) to the program. These functions are accomplished within the PPBS.

The DoD uses three major decisionmaking support systems to accomplish acquisition policy goals:

- Requirement Generation System
- Acquisition Management System
- Planning, Programming and Budgeting System (PPBS)

(1) The Requirement Generation System identifies broad mission needs.

(2) The Acquisition Management System identifies and assesses alternatives to satisfying these needs by exploring projected technological development, productivity, industrial capability, and support infrastructure constraints.

(3) The products of the PPBS provide the basis for making informed affordability assessments and resource allocation decisions on defense acquisition programs. The PPBS is based on affordability goals, affordability constraints, and firm unit costs.

An overview of the PPBS is illustrated in Figure 1.

We will review the entire PPBS process for the course and focus on where your role makes a key contribution to the system to ensure appropriate planning and review. A thorough understanding of procedures is vital to enhancing chances of obtaining needed funding.

If yes,

a. Will the delivery date meet your requirements?

If yes,

Action: Track the progress of validation throughout the POM process and meet need.

If no,

Action: Go to the A-106 PROCESS or FINPLAN.

These situations are illustrated in Figure 2

2. Define Your Requirement

Whatever situation you find yourself in with respect to funding and your particular pollution prevention needs, it is essential to think through your specific requirements and describe them thoroughly. Here are factors to consider when defining your requirements.

- What is the required resource?
- What is the rationale behind the request? Why will the resource improve the pollution prevention efforts of the office or the Base as a whole? For example, why is it necessary to order X gallons of a new paint product? The rationale may be that the paint is nontoxic and therefore, does not leach into the groundwater supply and pollute the drinking water like the current paint does. The new paint may also last longer and therefore save money in the long run because it does not have to be purchased as often as the current paint.
- Quantity of the requirement? For example, you may request 200 gallons of non-hazardous paint strippers to replace formic acid or phenols as paint strippers.
- Scheduling requirements. When will you need the resource and why is it needed in that timeframe?
- What is the cost?

Where To Go For Assistance?

In the Air Force, the Major Command B, Air Force B, and PRO-ACT, Air Force Center for Environmental Excellence are points of contact to aid the student with their rationale and answer questions on requirement specifications. Technical Order Managers for specific processes are other sources. In each military department there are equivalent contacts.

How to Save Time by Networking

NOTE: Truly unique needs for solving pollution prevention problems are rare. No matter how unique your requirement may seem, it is possible that someone else has addressed it. Much time can be saved by identifying an existing proposal rather than initiating a new request to the POM and potentially waiting six years for your needs to be met. Re-inventing the wheel wastes time and money. To avoid the lengthy six-year process, it is essential to make contacts and find out who and where else similar requirements to your own have been defined. Making contacts and networking throughout the military will also eliminate duplication of requests. By researching other projects that are being supported elsewhere, you may discover that someone on another base has submitted a comparable request in the POM. You should communicate your additional need to reinforce the previous rationale that others are already requesting. The efforts can be coordinated to strengthen the request.

IV. THE BUDGETING PHASE

Memorandum (JPAM), Issue Papers, and Program Decision Memoranda (PDMs). We will focus on the POM because that is where your input is required and where your needs and requests are directly incorporated into the process.

A. Program Objectives Memoranda (POM)

What is the POM?

The POM includes the six-year program proposals of each military department. The POM enables each military department to identify the programs it must undertake to satisfy the guidelines in the Defense Planning Guidance. Each military department submits its own POM, describing its programs and justifying both costs and personnel resource requirements. Specifically emphasized are the programs for which the recommended level differs from the approved six-year Defense Program level. Each POM must recommend programs to be carried out within the budget in the Defense Guidance. **This ensures that military departments set priorities and make trade-offs between programs as they consider resource constraints.**

Why is the POM Important?

The POM from your service represents the key opportunity within the PPBS for you to get your priorities considered for budget approval. **If a requirement is not identified in the POM, it has no chance of being approved or funded. Thus, the POM is the most important document for the program manager who is attempting to obtain funding for programs.**

All the POMs from the Services are reviewed by the staff offices of the Secretary of Defense, the Commanders in Chief of the Unified and Specified Commands, and the Chairman of the Joint Chiefs of Staff. The purpose of these reviews is to highlight major programmatic issues for discussion by the Defense Planning and Resources Board and to avoid redundancies of effort across Services.

B. Knowing When and How to Document your POM Proposed Requirements

Your key action in obtaining funding is your response to the annual request for information on your program needs including those of pollution prevention. To take full advantage of this event, you need to know the different situations associated with POM requests and then how to present your requirements with a view toward obtaining the fullest possible consideration.

The more research you do, the better you will be able present your requirement.

The following are your alternative actions when defining your POM requirements and ensuring thorough consideration [see Figure 2]:

1. Defining and Inputing to POM Requirements

As you examine how your requirements for pollution prevention compare or overlap with existing proposals, you may find yourself in one of the following situations relative to the status of your pollution prevention requirements.

Situation 1. Is the resource you are requesting already available (Is the resource you need on a Table of Allowances (TA)?

If yes,

Action: Provide requisition and documentation to obtain approval and receive resources.

If no,

Action: Initiate a new requirement for the POM.

Situation 2. The resource you need is part of an existing POM or is being validated as a new requirement?

The first block covers the overall process the PPBS and actions you need to take as part of the process to accomplish your pollution prevention goals. The complete PPBS is introduced to students so they can better understand the overall planning and programming system. Now that you have an understanding of the PPBS you can be active participants in the process. This course assists you in preparing pollution prevention program submissions that might otherwise get stalled without knowledge of the PPBS.

To carry out your responsibilities for a pollution prevention program you need to know how to provide input to the PPBS to ensure your requirements are part of the POM. Further information on the PPBS can be obtained from the Air Force School of Technology.

The second block reviews the background and purpose of the A-106 Process. How and when funding requests are made is described. Sample justification forms for pollution prevention projects developed by Air Staff Civil Engineering are reviewed. These forms are part of new FINPLAN guidance to be issued shortly assistance is given on completing the key information written forms to enhance the chances of funding.

The following discussion of the budgeting phase is designed to assist you track progress in the process of realizing your pollution prevention need whether it be product substitution, alternative manufacturing processes or recycling and recovery.

A. The budget proposals of each military department with budgeting responsibilities are forwarded to the Comptroller of the Department of Defense in documents called Budget Estimate Submissions. These documents are submitted on a two- year cycle in September of every other calendar year. They are distributed to the staff offices of the Secretary of Defense and to the Chairman of the Joint Chiefs of Staff for review.

B. Budget hearings are conducted by representatives of the Office of the Comptroller of the Department of Defense together with other members of the Office of the Secretary of Defense and analysts from the Office of Management and Budget. They focus on the execution status of specific programs, including programs reviewed by the Defense Acquisition Board.

   1. Documents called Program Budget decisions are drafted by the Office of the Comptroller of the Department of Defense as a result of the hearings. These documents present alternatives to the budget estimates submitted by the military departments with budgeting responsibilities.

   2. Budget wrap-up meetings, held in December by the Secretary and Deputy Secretary of Defense, provide the Service Secretaries; the Chairman of the Joint Chiefs of Staff; and others an opportunity to raise and resolve major issues before the budget request is finalized.

   3. The decisions made by the Secretary as a result of these meetings are reflected in the Department's biennial budget request, which is submitted to the President for approval. Once approved by the President, it is sent to Congress in January as part of the President's budget for the Federal Government.

Note: Biennial budgeting has not been strictly followed by the Congress. Budget review has occurred in the off-year of the two-year budget cycle of the Department. The extent of this review has varied depending on the magnitude of the expected change in topline fiscal guidance.

Once an apportionment is received by a military department, it is subdivided between the subordinate levels to receive those funds. The apportionment is transmitted from the OMB to Headquarters USAF. It is then automatically allocated by Headquarters USAF to the Major Commands (MAJCOMS). When the MAJCOMS receive an allocation, they may begin spending up to the amount of the allocation.

Once the MAJCOMS receive an allocation they will automatically distribute spending authority to subordinate units using either allotments or operating budget authority documents. Allotments apply to non-Operations and Maintenance appropriations, while operating budget authority applies to the Operations and Maintenance appropriation.

You cannot simply submit your proposal and wait. You will need to follow-up with the Base Budgeting Office to ensure that the rationale and priority are fully understood. Find out who is handling your proposal and make sure it is not on the back burner. Understanding the budgeting process will enable you to predict the timeframe in which your requirements will be met.

You should now have an understanding of the PPBS system and the actions you need to take within the process to achieve your pollution prevention goals.

Following a break we will discuss the EPA's A-106 process and provide guidance on preparing your funding requests. A sample single page justification for pollution prevention has to be completed as part of compliance with FINPLAN guidance that is finalized in September of each year.

V. SUMMARY

The AF has a stated goal to reach a "near paperless" TO operation. This in itself should serve as a waste minimization step, as anyone who has seen the reams of paper making up current AFTOs in most AF offices can easily understand. Weapons systems deployed during Desert Storm went with CD-ROM based TOs rather than paper, and this resulted in a significant logistical and operational advantage.

Included in the TO system are some requirements for the use of potentially hazardous materials.

The management of the TO system includes researching and adopting promising new techniques and technology.

I. METHODS (AFTO 00-5-1, Chap 6):

<u>T.O. Change</u>:

Application:

<u>AIR FORCE</u>:

Recommendations from field units for improvements in existing TOs are submitted using AFTO Form 22 to the respective MAJCOM. The AFTO Form 22 is a two-way form, used for both the report and a record of actions and replies. Reports are submitted by any person discovering a condition requiring a change. AFTO Form 22 is reviewed by supervisors, and quality assurance sections, for accuracy and appropriateness. AFTO Form 22 is considered Emergency, Urgent, or Routine. Emergency reports are submitted immediately, urgent reports on an expedited basis, and routine reports as soon as practicable. Emergency reports go directly to the agency having management responsibility with an info copy to the MAJCOM. Urgent and routine reports are forwarded to a control point designated by the MAJCOM.

The AFTO 22 is submitted to the agency having management responsibility (Table 6-1) in original and 2 copies.
<u>Temporary Engineering Authority</u>: Temporary Engineering Authority may be granted by the SPM/SPO/Item Manager--the same person who has the authority to authorize the TO Change. Ask for it to implement the change ASAP without waiting for the TO publication.

<u>ARMY</u>:

The Air Force, Army, and Navy share many joint technical manuals.

The U.S. Army calls them Technical Manuals.

The Army uses "proponents" who write and publish TMs. <u>EXAMPLE</u>: TM 5-4120-346-34, Jan 86, covers Air Conditioning Systems. It is maintained by U.S. Army Aviation and troop Support Command (USATCOM) in St. Louis, MO. The proponents are Mr. Edward Fulda and Mr. Darrell Geodier, who can be reached at DSN 693-3031.

Army TMs are maintained by an Army Logistics Center Department of the Army Publication Manager. Each Army Logistics Center has one assigned. TM changes are published and distributed by this person after being approved by the item manager/SPM/SPO.

Chapter one of each TM tells how and to whom to submit changes. In the back of each TM are several pre-addressed change forms, DA Form 2028. The submitter simply fills out the form and mails it to the address pre-printed on it. The SPM who receives the form will evaluate, advise the submitter, authorize TEA as needed, and forward the change to the publication manager if approved. The Army also treats changes as "urgent" for health and safety, and "routine" for all others. Publication turn-around time averages about 40 days.

<u>MIL-SPECS and Standards</u> (AFR 8-2, para 10, page 6)

AFR 8-2 para 10 b. says "no deviations are authorized w/o advance written approval of the designated preparing activity.

BLOCK 21: AFFECTING CHANGES IN TECHNICAL ORDERS AND MIL SPECS

1.0 Introduction

Block 21 presents the methods of changing Technical Orders (TOs), military specifications (MIL SPECS), and other requirements applicable to DoD pollution prevention programs. A discussion on the use of suggestion programs by the Air Force and other DoD branches is included. The use of "temporary engineering authority" to try new or previously unused products also is discussed. Examples of TO and MIL SPEC restrictions that require use of particular hazardous compounds are provided.

2.0 Objective

To present the capacity and methods of changing Technical Orders (TOs), military specifications (MIL SPECS), and other requirements based on the use of substitute materials and products and processes. The substitute materials are typically less toxic, or would be more easily treatable, or be smaller in volume than the previously used materials. A discussion on the use of suggestion programs by the Air Force and other DoD branches will be included. The use of "temporary engineering authority" to try new or previously unused products will also be discussed.

1. Students will learn the methods for changing requirements to allow the use of substitute chemicals or process modifications to minimize the potential of pollutant generation.

2. Students will be provided examples of TO and MIL SPEC restrictions that require use of particular hazardous compounds.

3. Students will learn suggestion programs to change procedures and requirements, as specified in TOs and MIL SPECs, and reduce the use and generation of hazardous materials/wastes.

3.0 Key Concepts

The objective of the Air Force Technical Order (AFTO) system is to provide concise but clear instructions for safe and effective operation and maintenance of Air Force systems and equipment. For the purposes of this discussion, the Air Force term TO is interchangeable with and equal to DOD terminology as it relates to technical manual (TM).

There are many types of TOs.

The AFTO system is the only official medium within the AF for disseminating technical information and instructions and one of the official media used to disseminate safety procedures for installing, operating, maintaining, producing, or modifying fielded AF equipment and materials.

A TO constitutes a military order and is issued in the name of the Chief of Staff of the respective service, and by order of the SecAF: Compliance is mandatory.

Excluded from the TO system are:

- Contractor-operated experimental equipment designed for research.
- The operation and maintenance of real property or reap-property installed equipment.
- Subjects more suitable for coverage in other AF publication systems, as specified in AFR 72-1 or AFR 5-1..
- Computer programs. However, operator manuals that provide instructions on loading and operating specialized software MAY BE managed in the TO system.
- Equipment to be maintained by a contractor over the equipment's life cycle.
- Nonstandard cryptologic equipment operated, maintained, or managed by HQ Electronic Security Command (CURRENT NAME?)
- Other forms of technical data specifically excluded by authority of HQ USAF.

C. If adapted, recognition and/or awards are given.
ARMY:

The Army program is outlined in Army Regulation 5-17, Management, The Army Ideas for Excellence Program, 1990. It functions very much like the AF Program, with different forms and addresses. The results are the same.

So Suggestion Program may be an appropriate vehicle to get changes implemented.

Good if:

Process is not covered by TO.
Change is not time-critical.
May be awards available.

Disadvantage:

May take longer than AFTO Form 22 action.
May not have as wide application as AFTO Form 22 action.

SUMMARY

The published orders and specifications may be stumbling blocks to the implementation of change. But there are established, workable ways around them. Getting an institutional change made will have effects service-wide, not just locally--and it ensures that once a change for the better is made, it won't be dropped without a thoughtful evaluation. Get out there and change the rules!

Specifications may by supplemented only by a formal specification amendment, as authorized in DOD manual 4120.3-M."

MIL SPECS are published as part of the Federal Standardization Documents, and are available from:

Standardization Document Order Desk
Building 4D
700 Robbins Avenue
Philadelphia, PA 19111-5094
COM: (215) 697-2179
DSN: 442-2179

The Superintendent of Documents. FED SPECS are written and owned by DLA or GSA. MIL SPECS and MIL STDS are written and owned by the services specification preparing activities. A document called the DOD Index of Specifications and Standards (DODIS), lists all MIL SPECS and MIL STDS, what they are and who is responsible for them.

To request a change to a SPEC or STD, complete a form, found on the back of the item's technical documents (available to procurement and supply personnel--or ask the GSA depot for the item.

EXAMPLE: Paints are managed by:

Ms. Patricia Pierson, Director of Engineering
Paints and Chemicals Commodity Center (9FT-10)
GSA Center
400 15th Street S.W.
Auburn, WA 98001
(206) 931-7110 FAX (206) 931-7039/7544

But--there are other tools to use in your quest to improve TOs or TMs.

II. SUGGESTION PROGRAM: AFR 900-4, Army Regulation 5-17

AIR FORCE: Another player in changing a TO is the formal service suggestion system. And there are times when the use of the suggestion system may be beneficial.

Suggestion program provides "...the award programs for suggestions, inventions, patents, and scientific achievements..." It is an organized, formal method for employees to submit constructive ideas.

AIR FORCE: AF Program implemented by AFR 900-4, which implements DODD 5120.15, 13 Aug 85, and DoDI 5120.16, 15 Jul 74.

AFCEE evaluates suggestions regarding pollution prevention. AFCEE/MS, Ms Gloria Holguin, receives from the base productivity office, Ms. June Martin, 4-2267--and directs to the appropriate subject matter specialist for evaluation--then sends back to Ms. Martin to be forwarded to further evaluation or final authority. Ms. Holguin has three in her log to date.

A. AF Suggestions submitted on AF Form 1000--suggestion must be timely (within 30 days of first expression), original, and complete. The more detailed, the better researched and annotated, the better the chance for approval. Must describe a problem or change (a "before" and "after" explanation) and a solution and the benefits of implementation. Ideas PREVIOUSLY submitted on AFTO Form 22 are ineligible for submission through the suggestion program. So....submit them concurrently, with a copy of AF Form 1000 attached to the AFTO Form 22, and a copy of the AFTO Form 22 attached to the AF Form 1000.

B. AF Management accepts, considers, and evaluates suggestions. Suggestions are evaluated at the lowest practicable level--starting with first-line supervisors, i.e., if a unit or base commander has the authority to implement the suggestion, evaluation would be done at that level. If the local commander doesn't have the authority to make the change, the evaluation is done at MAJCOM, Air Force, DoD, as appropriate. A suggestion implemented at a field level may be forwarded for more general applicability. The suggestion may have to get through several levels of evaluation before it gets to the person with the authority to implement a change.

die), extrusion (pushing the metal through a die), and bending or shearing. Metal addition involves adding different metals or elements to the piece to impart some desired characteristic to the metal. For example, plating is the addition of a metal different from the base metal to the surface of the piece, for corrosion resistance, wear resistance, or increased electrical contact. Surface hardening is the addition of elements such as carbon or nitrogen into the surface of the piece to form compounds which make the metal harder. Metal joining is the fastening of two fabricated pieces together. This is typically done by welding or brazing.

Mechanical removal of metal (machining) may be conducted by a variety of means. *Sawing* is a process to roughly shape the piece. *Grinding* is the use of abrasives to further shape the piece. *Deburring* involves using mechanical action to shape the piece. *Turning* processes and some *drilling* are done on lathes, which hold and rapidly spin the workpiece against the edge of the cutting tool. *Broaching* is a process whereby internal surfaces such as holes of circular, square or irregular shapes, or external surfaces like key ways are finished. *Drilling* machines are intended not only for making holes, but for *reaming* (enlarging or finishing) existing holes. This process is also carried out by reaming machines using multiple cutting edge tools. *Milling* machines also use multiple edge cutters, in contrast with the single point tools of a lathe. While drilling cuts a circular hole, milling can cut unusual or irregular shapes into the workpiece. *Finishing* and *polishing* use fine abrasives to produce smooth surfaces on the metal pieces.

Plating operations can be categorized as electroplating and electroless plating processes. Surface treatment includes chemical and electrochemical conversion, case hardening, metallic coating, and chemical coating. Most metal surface plating processes include: the actual modification of the surface, involving some change in its properties (e.g., case hardening, or the application of a metal layer); and rinsing or other workpiece finishing operations.

Chemical and electrochemical conversion treatments are designed to deposit a coating on a metal surface that performs a corrosion protection and/or decorative function. Processes include phosphating, chromating, anodizing, passivation, and metal coloring.

Case hardening produces a hard surface (the case) over a metal core that remains relatively soft. The case is wear-resistant and durable, while the core is left strong and ductile. Case hardening methodologies include carburizing (diffusion of carbon into a steel surface at temperatures of 845 to 955 C), carbonitriding and cyaniding (diffusion of both carbon and nitrogen simultaneously into a steel surface), nitriding (diffusion of nascent nitrogen into a steel surface to produce case-hardening), microcasing, and hardening using localized heating and quenching operations.

III. WASTE STREAMS

Each of these metal fabrication industries generate wastes which may be liquid, solid, or even gaseous in nature. For each of these wastes, an "in-process" examination must be conducted to answer the questions **WHERE** are they coming from, **WHY** are we generating these wastes, and **WHAT** can we do to eliminate them. The questions **WHERE** and **WHY** can be answered by examining each of the metal fabrication processes. Most wastes from metal fabrication processes come from machining or etching and from plating and/or surface hardening.

The major wastes from machining operations are liquid in nature. These include spoiled or contaminated metalworking (cutting) fluids which are treated as hazardous wastes because of their oil content, as well as other chemical additives such as chlorine, sulfur and phosphorus compounds, phenols, creosols and alkalies. While fresh metalworking fluids contain varying degrees of oil depending on their function, "tramp" hydraulic and lubricating oils also find their way into the fluids during the course of operations. Rinsewaters are used for grinding and deburring operations.

Many fabricated metal industries generate cuttings and other scrap metal. Scrap that is destined for reclamation is not regulated as hazardous waste. If metal chips from machining operations are mixed with hazardous metalworking fluid wastes, however, the waste stream is treated as hazardous. Some chip alloys, e.g., stainless steels, which contain chromium or nickel, can release these regulated metals if exposed to acids.

Minor quantities of solid wastes from machining operations include waste abrasives and polishes. These compounds may contain toxic metals; for example, chromium oxide is frequently used as a polishing agent. Volatilized components and fine dusts generated from these operations also pose an environmental hazard.

BLOCK 22: CASE STUDIES: MACHINING, METAL WORKING, AND METAL PLATING

1.0 Introduction

Block 22 discusses common machining and metal working operations at DoD installations. Case studies are covered that demonstrate leading approaches to minimizing wastes in these processes, including process changes, and recycling and recovery of spent products.
Block 22 provides an introduction to the types of pollutants associated with machining, metal working and metal plating and selected in-process recycling techniques. Also, source reduction methods that have been successful in the past and how to conduct an opportunity assessment for this type of operation are described. Block 22 concludes with a computer exercise using SWAMI to develop and analyze pollution prevention strategies for machining, metal working, and metal plating.

2.0 Objective

To present case studies that demonstrate leading approaches to minimizing wastes in machining, metal working, and metal plating processes, including process changes, and recycling and recovery of spent products. Machining and metal working are common operations and generate waste oils and lubricants. In addition, metal plating produces many by-products and spent wastes that are among the seventeen priority chemicals, including Mercury, Nickel, Cyanides, and Chromium.

1. Students will understand the types of pollutants associated with machining, metal working and metal plating.

2. Students will understand selected in-process recycling techniques.

3. Students will know the metal plating operations typically associated with DoD operations, and will understand the nature of plating wastes.

4. Students will know about source reduction methods that have been successful in the past.

5. Students will know how to conduct an opportunity assessment for this type of operation.

3.0 Key Concepts

I. INTRODUCTION

Fabricated metal processes are classified under Standard Industrial Classification (SIC) 34, and include processes such as machining, metalworking, and metal plating. These processes generate a variety of hazardous and nonhazardous wastes, including metal-bearing fluids, and organic contaminants. The principal chemicals of concern include:

- Cadmium.
- Chromium.
- Cyanide.
- Nickel.
- Mercury.

Other waste such as oils, lubricants, contaminated rags and sludges may also be produced from the processes. Degreasing and cleaning procedures prior to the actual metal-working operations are also inherent to these procedures, but as their pollution prevention aspects have already been addressed in a previous lecture, they will not be discussed here.

II. METAL FABRICATION OPERATIONS

Metal fabrication operations can be broken down into four general categories: metal removal, displacement, addition, and joining. Metal removal involves shaping the raw piece to the desired shape by removing metal in selected areas. Traditionally, there have been two ways to accomplish this: mechanically (machining) and chemically (etching). Metal displacement implies "pushing" or "pulling" the entire piece to the desired shape no metal is lost in the process. Examples include forging (which involves hammering or pressing the piece), rolling (plastically deforming the piece by passing it through rollers), drawing (pulling the metal through a

Liquid wastes are the major stream from metalworking operations. These consist of metalworking fluids such as cutting oils, waste etching solutions, lubricants, plating process waters, and rinsewaters. Pollution prevention measures for metalworking fluids include process modifications (preventive maintenance), source reduction, and recycling. A primary problem in water-based metalworking fluid management is contamination with tramp oil and the problems that result from this. While the best solution for tramp oil problems is to prevent the oils from entering the metalworking fluid, some contamination will occur as the machines and their oil seals and wipers wear. This can be reduced through preventive maintenance such as periodic seal and wiper replacement. Optional metalworking fluid performance starts with a preventive maintenance program that includes:

- Use of high quality, stable cutting and grinding fluids;
- Use of demineralized water for mixing purposes;
- Fluid concentration control;
- Control of fluid chemistry (pH, dissolved oxygen, etc.);
- Fluid contamination prevention;
- Periodic sump and machine cleaning;
- Periodic gasket, wiper and seal inspections and replacements to minimize tramp oil contamination;
- Regular cleaning of metalworking fluid through filtering or centrifugation, in order to minimize microbe growth by controlling tramp oil buildup; and
- Assignment of responsibility for fluid control to one person.

Source reduction for metalworking fluids can be accomplished using synthetic oils or gas/air streams in place of conventional formulations. Use of synthetic metalworking fluids can sometimes result in dramatically increased fluid life. Synthetic fluids are made up of chemicals such as nitrites, nitrates, phosphates and borates. Synthetic fluids contain only zero to one percent soluble oils in the fluid concentrate, compared to 30 to 90 percent soluble oil in non-synthetic metalworking fluid concentrates. While the lubricity of synthetic fluids is lower than many non-synthetic fluids, an advantage of synthetic fluids is that tramp oils are not able to contaminate them as easily as non-synthetic fluids, for they are not able to readily enter the fluid emulsion, which leads to breakdown of the fluid's qualities. Many synthetic fluids offer greater thermal stability at high temperatures, resisting oxidation better than non-synthetic fluids. Gases can sometimes be used in place of coolants, because they offer cooling of workpieces and tools with no workpiece contamination. Air is the most frequently used gas, and is employed both in dry cutting or with other fluids. Nitrogen and carbon dioxide are occasionally used as well, but their cost is high, and therefore, their applications are limited.

By recycling deteriorated or contaminated fluids, costly hauling and disposal can be reduced. Also, recycling will minimize the need for purchase of high priced fluid concentrates. While many shops engage off-site recycling companies to handle their spent fluids, it is very feasible for larger shops to recycle in-house. The processes recyclers employ separate oily wastes from water. The water is released to the sewer while the oil is refined or used as fuel. In-house recycling typically has a different focus than off-site: to extend the usable life of metalworking fluids, rather than to separate and refine the oils it contains. Continuous in-house filtration of fluids in machine sumps reduces the requirements for new fluids, avoids recycler's charges, and saves money by reducing machine downtime for cleaning and coolant recharge. Methodologies for recycling metalworking fluids include filtration, skimming, flotation, coalescing, hydrocycloning, centrifuging, and downgrading.

Viewgraph 19 shows an abbreviated process flow diagram for an aluminum machining operation after several of the pollution prevention strategies already discussed for machining processes have been implemented (EPA/600/S-92/031). The company sends its collected solid metal cuttings to a scrap recycler. Cutting fluids are sent off-site to be recycled, with waste fluid that can no longer be recycled incinerated as a fuel component. Deburring waters are allowed to settle (to remove fine suspended metal pieces), with the metal-rich sludge sent to a reclaimer. For this process, chrome plating is conducted after the parts are machined, which means that parts cleaning is required. 1,1,1-Trichloroethane (TCA), used for the cleaning process, is recycled using an on-site still. Rinsewaters pass regulatory requirements, and are sent to the sewer system.

The associated table in your text shows a summary of the current waste generation volumes and costs for each unit operation, as defined by the U.S. EPA (EPA/600/S-92/031). Much of the costs associated with the cutting oils is attributable to raw material costs. Both the aluminum chips and deburring sludge have a marketable recovery value.

Metalworking fluids are applied to the workpiece and cutting tool in order to facilitate the cutting operation (EPA/625/7-90/006). A metalworking fluid is used:

1. To keep tool temperature down, preventing premature wear and damage;
2. To keep workpiece temperature down, preventing it from being machined to a warped shape or within inaccurate dimensions;
3. To provide a good finish on the workpiece;
4. To wash away chips; and
5. To inhibit corrosion or surface oxidation of workpiece.

Also, and very important, metalworking fluids are frequently used to lubricate the tool-workpiece interface, in addition to simply cooling it.

Metalworking fluids can be air-blasted, sprayed or drawn through suction onto the tool-workpiece interface. Types of fluids include water (either plain or containing an alkali); emulsions of a soluble oil or paste; and "straight" oils (those that are not water-based) such as mineral, sulphurized, or chlorinated oil. Air drafts are often used with grinding, polishing, and boring operations to remove dust and chips, and to cool to a certain extent. Aqueous solutions containing approximately one percent by weight of an alkali such as borax, sodium carbonate, or trisodium phosphate exhibit high cooling properties and also provide corrosion prevention for some materials.

Etching operations generate wastes that are almost exclusively liquid in nature. (Solid wastes may include shop rags saturated with waste etching solutions.) These liquid wastes may include process wastewaters which contain not only acids or caustics, but also dissolved metal ions that were removed from the metal part. In addition, the metal parts are often rinsed to remove trace etching solutions, and these solutions will be contaminated with the same wastes.

Plating operations generate tremendous quantities of liquid wastes. These consist of not only waste process waters, but also rinsewaters. Because metals such as chromium, nickel, cadmium, copper or zinc are being plated out onto metal pieces, their presence in the liquid stream is required. Cyanides have typically been added to plating baths to increase the adherence between deposited and base metal. These liquid waste streams may also contain acids or bases (for pH control) or chelating agents such as EDTA or citric acid.

Plating wastes can also consist of solids such as shop rags. It is important to remember that solid precipitates such as hydroxides or sulfides are NOT residual wastes from the plating process they are residual wastes from an "end-of-pipe" treatment process. The wastes are simply transferred from one media to another. Plating processes also typically generate volatilized components which are an environmental hazard in the plating shop. Many surface hardening procedures are similar to plating in that the metal part is immersed in a liquid bath containing hazardous materials, the process completed, and the residual waste streams consist primarily of process wastewaters and rinsewaters.

IV. POLLUTION PREVENTION MEASURES FOR METAL FABRICATION PROCESSES

It is now important to identify **WHAT** are some possible pollution prevention measures that can be applied to these metal fabrication processes. One should recall that the three general types of pollution prevention methodologies are source reduction, process modifications, and recycling.

It has already been shown that the solid wastes one might experience in association with metal fabrication operations include chips and turnings; out-of-spec parts; waste abrasives, polishes, and joining rods; and saturated rags. When one is considering pollution prevention practices for these operations, it should be remembered that solid wastes will be generated the processes **DICTATE** that metal be removed, that holes be drilled, that parts be shaped. There will **ALWAYS** be some parts that don't meet specifications. Recycling and better operator awareness would be pollution prevention strategies for these wastes.

Vaporized inorganics and organics and fine dusts constitute a collection problem. More and more, shops are employing hoods and directed air streams to prevent the spread of airborne materials. For some processes (e.g., plating), lower operating temperatures will minimize the volatilization of hazardous materials. Floating polypropylene balls on the surfaces of plating baths have been proven to reduce volatile emissions.

Small washer rinsewater	Small, batch-type parts washer. Wastewater form the batch-type parts washer is sewered.	9,100 gallons	$10
Spent 1,1,1-Trichloroethane (TCA)	Parts degreasing. Spent TCA is distilled on-site and reused.	15,600 gallons	$2,800
TCA still bottoms	On-site solvent recovery unit. Still bottoms are accumulating on-site.	0	0
Aluminum chips	Machining. Scrap aluminum is sold to a recycler.	Not available.	Not available.

Certain processes can offer an alternative to electro- and electroless plating. Hot dipping of tin and other materials, for instance, in which the workpiece is immersed in a molten metal bath, could provide a way of reducing toxic effluent levels. A disadvantage of hot dipping is that it is energy intensive, for the metal in the bath must be maintained in a molten state. Chemical vapor deposition (CVD) is the gas-phase analog of electroless plating, in that it is catalytic and involves a chemical reduction of a species to a metallic material which forms the coating. CVD coatings are extremely pure, and thus suitable for many electronic applications. Metals can be bonded to the workpiece using mechanical techniques in which the coating material is forced under high pressure into contact with the workpiece (cladding). The pressure at the interface between the two metals must be high enough to disrupt and disperse boundary oxide films and initiate thermal interdiffusion and mechanical attachment. The reactions require temperatures up to 1500 C, although work is in progress to design low temperature processes that can be used on workpieces unable to withstand high temperature.

Waste rinsewaters account for the largest fraction of waste volume produced in surface treatment and plating processes. Any method of reducing the amount of rinsewater used will significantly reduce the total waste volume from a process. Large amounts of rinsewater are used to rinse off drag-out on a metal surface after the metal is removed from a plating of cleaning bath. Rinsewaters usually contain dilute solutions of bath salts, such as cyanides and heavy metals. There are several methods available to reduce the amounts and/or toxicity of waste rinsewater produced. The methods can be grouped into two techniques: drag-out minimization and rinsewater minimization. Drag-out minimization results in a decrease of the heavy metal content of the rinsewater and of the ultimate waste (treatment sludge). Decreasing rinsewater consumption without reduction in drag-out may thus result in a smaller, but more toxic, volume of treatment sludge.

By minimizing the amount of drag-out carried from a plating or cleaning bath to a rinsing bath, a smaller amount of water is needed to rinse off the workpiece. Also, less of the plating solution constituents leave the process, which ultimately produces savings in raw materials and treatment/disposal costs.

Drag-out minimization techniques typically include:

- Reducing the speed of withdrawal of workpiece from solution and allowing ample drainage time.
- Lowering the concentration of plating bath constituents.
- Use of surfactants.
- Increasing plating solution temperature.
- Proper positioning of the workpiece on the plating rack.
- Improved drip recovery.

Rinsewater can also be reduced through system redesign. The aim of rinsewater minimization is to use the smallest volume of water necessary to adequately clean the workpieces. While reducing rinsewater requirements does not directly reduce the quantity of hazardous materials in the plating line effluent, it does reduce the load on the treatment plant (which can result in more hazardous substance removal or neutralization from the waste stream) as well as saving money through reduced water requirements. Several system design methods exist for lowering rinsewater requirements, including:

- Rinsetank design.
- Multiple rinsing tanks.
- Fog nozzles and sprays.
- Automatic flow controls.

The harsh, environmentally-regulated acids typically used in etching solutions can be substituted for in some applications with milder acids which will perform the same function. Some etching solutions which contained hexavalent chromium are now being eliminated from use. Process modifications and recycling of etching solutions are aimed at life extension.

Viewgraph shows a conventional etching process for copper wire produced for electrical applications (Overcash, 1986). As the wire is removed from the rolling mill, it is passed through a mild acid bath (sulfuric acid), the wire rinsed, and then fed onto the spooling machine. This process resulted in two liquid streams which had associated with them acidic wastes the acid solution and the rinsewaters.

Viewgraph shows the pollution prevention strategy (process modification) that was implemented for this operation. An alcohol bath was implemented instead of the acid bath. This eliminated the need for rinsewaters, because after cleaning, the residual alcohol volatilized. Some additional modifications had to be performed for this substitution. For example, a higher bath temperature was necessary in order to initiate the etching reaction.

On a volume basis, contaminated rinsewater account for the majority of plating, surface treatment, and etching process wastes. These processes can involve many rinsing steps. Rinsewater is used to wash off the drag-out from a workpiece after it is removed from a bath. Drag-out refers to the excess solution that adheres to the workpiece surface and gets carried out of the solution bath upon withdrawal of the workpiece from the bath. In general, the use of small part barrels in the plating process (barrel plating) produces more drag-out than rack plating. This is because a barrel carries in it more plating solution upon withdrawal from the bath than a rack does, and because drainage of the drag-out back into the bath is more difficult with barrels. If the drag-out from one bath is carried into the next bath in the sequence due to incomplete rinsing, it is referred to as "drag-in," and is considered a contaminant in the latter bath.

Process solutions for surface treating and plating contain high concentrations of heavy metals, cyanides, and other toxic constituents. Process baths are not discarded frequently, but rather are used for long periods of time. (The chemicals they contain, however, are lost, sometimes at high rates, through drag-out on workpieces, spills and leaks). Nevertheless, the baths do require periodic replacement due to impurity build-up or the loss of solution constituents by drag-out. A contaminated or exhausted plating solution is highly concentrated with toxic compounds and requires extensive treatment. The source control methods available for reduction of spent plating and other process waste include increasing solution life and material substitution.

Summary of Current Waste Generation for Aluminum Machining Process

Waste Generated	Source of Waste	Annual Quantity Generated	Annual Waste Management Cost[1]
Cutting fluid wastes	Machining. Cutting fluid that can no longer be recycled, tramp oil, spilled cutting fluid, and waste cleaning solution are shipped off-site to a disposal facility where the waste is incinerated.	7,300 gallons	$13,190
Deburrer rinsewater	Large tumbling deburrer. Wastewater from the deburrer goes through a settling tank and is sewered.	413,556 gallons	$630
Clay-like sludge	Settling tank. Sludge from the settling tank associated with the deburrer rinsewater is sent to the recycler.	Not available.	0
Large washer rinsewater	Large, continuous line parts washer. Wastewater from the continuous line parts washer is sewered.	33,800 gallons	$50

2. The most common wastes generated by the metal finishing industry are metalworking fluids, rinsewater effluent, and spent process bath chemicals.

3. Waste reduction at the process-bath level can be established by material substitution, extension of bath life, and/or drag-out reduction.

4. The material substitution option includes the use of deionized water, use of a nonchelated process, and conversion to noncyanide process baths.

5. Process bath maintenance is important in extending the life of a process bath and subsequently reducing the frequency of the bath replacement. Filtration systems can be used to remove solids that build up in process baths (cleaning baths and etching baths).

6. The life of a cleaning bath can be extended by proper and regular bath maintenance (i.e., regular replenishing, pH measurement, metal content measurement, etc.).

7. The life of a plating bath can be extended through bath treatment that removes metal contaminants.

8. The available techniques of reducing process chemical drag-out are summarized in the following guidelines:

   - Maintain the minimum bath chemical concentration acceptable within operating range.
   - Maximize the bath operating temperature to lower solution viscosity.
   - Reduce surface tension by using wetting agents in the process bath.
   - Maintain proper racking orientations to achieve the best possible drainage.
   - Withdraw workpieces at slower rates and allow for sufficient drainage time.
   - Use a spray rinse above the process tank.
   - Use drainage boards between process baths and rinsetanks to collect drippage and return to the process baths.
   - Use drag-out tanks to recover process chemicals for reuse in the process baths.

9. The rinsing efficiency in rinsing baths may be improved by providing enough turbulence between the workpiece and the rinsewater, sufficient contact time between the workpiece and the rinsewater, and sufficient volume of water during contact time.

10. In the metal finishing industry, it has become more economical to recover metals and metal slats from process baths. Metal recovery may be used in two ways: (1) recovered elemental metals can be sold to a metal reclaimer and, (2) recovered metal salts can be recycled back to the process baths. The available techniques of recovering metals and metal salts are:

    - Evaporation.
    - Reverse osmosis.
    - Ion exchange.
    - Electrolysis.
    - Chemical recovery.

11. Frequent inspection can identify leaks in piping systems, storage tanks, and process tanks. Maintenance schedules should be developed to ensure that process baths and rinse systems are operating at their optimal efficiencies.

12. Strict procedures should be developed to ensure that chemicals are mixed properly for the process baths, minimizing spills and assuring the proper concentration (the lowest concentration acceptable to minimize the drag-out). A limited number of personnel should be designated to handle and mix the chemicals, to improve the consistency of the solution concentration and to minimize waste.

This lecture was designed to familiarize you with the pollution prevention opportunities in machining, metalworking, and metal plating, so that you can recognize these opportunities at your own installation.

A serious examination of the pollution prevention alternatives is warranted by virtue of the process in machining, metalworking, and metal plating that generate large volumes of waste.

- Rinse bath agitation.

Recycling and resource recovery include technologies that either directly use waste from one process as raw material for another process or recover valuable materials from a waste stream before the waste is disposed of. Some of the spent chemical process baths and much of the rinsewater can be reused for other plant processes. Also, process chemicals can be recovered from rinsewaters and sold or returned to the process baths.

The more thoroughly a metal finisher understands the chemistry of their waste streams, the better able they are to assess their potential for reuse as raw materials, or in other applications. Successful recycling requires a change on the part of management and plant staff, to view their waste streams as resources, rather than as something to be thrown away.

Metal recovery can be achieved in two ways: (1) recovered metal salts can be recirculated back into process baths, or (2) recovered elemental metal can be sold to a metals reclaimer or reused in the plating process. Some of the technologies that are being successfully used to recover metals and metal salts include:

Evaporation.
Reverse osmosis.
Ion exchange.
Electrolytic recovery.
Chemical recovery.

These recovery technologies can be used to recycle rinsewater in either a close-loop or open-loop system (Theodore, 1992). In a closed-loop system, the treated effluent is returned to the rinse system. In an open-loop system, the treated effluent is reused in the rinse system, but the final rinse is accomplished with fresh water. These figures illustrate these systems.

Viewgraph shows a conventional surface hardening system used to impart a nitride surface onto metal parts (Overcash, 1986). The metal parts are attached to a rack and immersed in a cyanide bath at an elevated temperature. The cyanide degrades, releases nitrogen, which diffuses into the metal part to form the nitride compound. The parts are then immersed in a hot oil bath to produce a surface temper. Finally, the parts are rinsed with sprayed water, the rinse collected, and the parts delivered.

Several waste streams exist with this system. Collected rinsewater contains both cyanide and petroleum hydrocarbons from the oil. The hot oil produces vapors which, although collected, still must be closely monitored. Finally, spent cyanide bath must be treated before disposal.

Viewgraph 32 illustrates the pollution prevention practices that were implemented for this process. Nitrogen gas at elevated temperatures is used for the nitriding operation. Larger lot sizes result in lower energy costs. No hazardous materials are used for this process used nitrogen can be vented to the atmosphere.

It would at first appear as though a major capital investment had to be expended in order to implement the changes shown. However, the new process is actually a modification of the old one, with tanks being replaced with small furnaces, and the rack system being modified. Due to the increased rack capacity, as well as improved energy efficiency of nearly 300%, the pay-back for this process was quickly achieved. In addition, the process modification/source reductions resulted in a much cleaner working environment.

V. SUMMARY

This lecture describes pollution prevention options available to the metal finishing industry, along with descriptions of the processes and wastes generated. For the metal finishing industry, the available pollution prevention technologies mainly involve extending the life of chemical process baths and reducing the volume of wastewater generated.

1. The metal finishing industry uses a variety of physical, chemical, and electrochemical processes to shape, clean, etch, and plate metallic and nonmetallic substrates. Chemical and electrochemical processes contribute more to waste generation than do physical processes such as blasting, grinding, and polishing. Chemical and electrochemical processes are performed in numerous chemical baths, which are followed by a rinsing operation.

The following table presents a summary of the pollution prevention measures discussed in this lecture for the metal fabrication industries.

Process	Waste Stream	Source Reduction Options	1
Machining Wastes	Metalworking Fluid	Use of High Quality Metalworking Fluid Demineralized Water Use Concentration Control Sump and Machine Cleaning Gasket, Wiper and Seal Maintenance Cleaning of Metalworking Fluid Assigning Fluid Control Responsibility	Filtration of Metalworking Fluids Skimming Coalescing Hydrocycloning Centrifuging Pasteurization Downgrading
Surface Treatment and Plating	Process Solutions	Increasing Solution Life Material substitution Process Substitution Chemical Coating Mechanical Cladding and Coating	Use of Cleaning Baths as pH Adjusters Metal Recovery Evaporation Reverse Osmosis Ion Exchange Electrolytic Recovery Electrodialysis
	Rinsewater	Reduction in Drag-Out of Process Chemicals: Speed of Withdrawal Surface Treatment Plating Bath Concentrations Source Reduction Options Surfactant Use Solution Temperature Workpiece Positioning Drag-Out Recovery System Design Considerations: Rinsetank Design Multiple Rinsing Tanks Reactive Rinsing Fog Nozzles and Sprays Automatic Flow Controls Rinse Bath Agitation	Rinsewater Reuse
	Treatment Wastes	Precipitating Agents and Other Treatment Chemicals Trivalent Chromium Use Waste Segregation Sludge Dewatering	
	Case Hardening Wastes	Selection of Clean Processes	

B. Discussion of life-cycle stages

1. Acquisition: considers the direct cost of the material; the quantity to be purchased; supplier issues; availability of product; packaging issues.

2. Use: in addition to meeting mission requirements, considers human health and safety issues involved in using the material; worker training; handling issues; Occupational Safety and Health Act (OSHA), other federal and state regulatory requirements; risk issues; accident contingency issues.

3. Storage: considers shelf life; facility requirements (building specifications, controlled temperature, access control/security); incompatible materials; space requirements; storage time requirements; permitting issues; cost of storage; risk issues; accident contingency issues.

4. Transportation: considers U.S. Department of Transportation (DOT) and state requirements; routing and scheduling issues; public and worker safety issues; cost of transportation; risk issues; accident contingency issues.

5. Disposal: considers disposal site issues; federal and state environmental regulations under EPA, RCRA, and resource-specific regulations (e.g. air quality, water quality); worker and public safety issues under OSHA and other regulations; method of disposal; treatment of waste by-products; potential liability issues.

C. Types of Life Cycle Costs

1. Direct: cost of the product; transportation or shipping costs; labor; equipment. These costs are certain to occur and can be reliably predicted, to a large extent.

2. Indirect: training; recordkeeping; regulatory compliance; health and safety costs. These costs are also certain and reliable.

3. "Uncertain": costs of spills and accidents; potential legal liability. These costs are referred to as uncertain for two reasons. First, if there is no accident or spill, no cost will occur. Second, if there is an accident or spill event, the costs resulting from it are uncertain, i.e., cannot be reliably predicted.

4. Social or external: many activities that involve the use of fuels, hazardous materials, or even nonhazardous materials, generate environmental impacts such as air or water pollution or the creation of solid waste. The cost of remedying this pollution often is not captured within the cost of the production process; it is paid by society as a whole rather than the consumers of the product. Hence the term "social" borne by society, or "external" external to the costing process that includes the costs of labor, materials, and production equipment and facilities.

II. LIFE CYCLE MANAGEMENT PROCESS

A. Acquisition Decisionmaking.

During the acquisition process, it is essential that the Base Supply personnel work closely with the industrial users, logistics experts who will be aware of storage and transportation requirements, the bioenvironmental office, and especially with environmental compliance personnel. This team approach is integral to effective life cycle management. Working together, the team should perform the following steps:

1. Determine the purpose of and need for the material.

BLOCK 23: CASE STUDIES: ACQUISITION MANAGEMENT OF HAZARDOUS MATERIALS

1.0 Introduction

Block 23 discusses the life cycle assessment of hazardous materials, including acquisition, use, storage, transport, and disposal. Case studies are provided to illustrate effective planning for use, recycling, or disposal of hazardous materials. Block 23 describes how pollution can be minimized or prevented through proper acquisition and management of the hazardous materials.

The life cycle phases for hazardous materials and examples of effective life cycle management of hazardous materials at various DoD installations are presented. The interrelationship of the various stages of acquisition, use, transport, and disposal of hazardous materials are discussed as well as alternatives to hazardous material use.

2.0 Objective

To introduce life cycle assessment of hazardous materials, including acquisition, use, storage, transport, and disposal. To learn to manage hazardous materials effectively by considering the life-cycle of the materials. Pollution can be minimized or prevented through proper acquisition and management of the hazardous materials. Proactive planning efforts can foresee problems and costs associated with hazardous materials or processes before those materials are finalized in system design. Case studies will be provided to illustrate effective planning for use, recycling, or disposal of hazardous materials.

1. Students will learn life cycle assessment of hazardous materials and application of knowledge to allow proactive planning and reduce pollution and hazardous waste generation potential.

2. Students will learn the life cycle phases for hazardous materials.

3. Students will understand the need for proactive planning in life cycle management of hazardous materials.

4. Students will learn examples of effective life cycle management of hazardous materials at various DoD installations.

5. Students will become familiar with the interrelationship of the various stages of acquisition, use, transport, and disposal of hazardous materials.

6. Students will know the identity and range of environmental impacts that can occur throughout the life cycle of hazardous materials.

7. Students will recognize alternatives to hazardous material use.

3.0 Key Concepts

I. INTRODUCTION

A. The life-cycle management concept

Comprehensive life cycle management of a hazardous material involves considering issues related to the entire life of the material, from acquisition through disposal, at all life cycle stages. For example, at the acquisition stage, the purchase price should not be the only factor in choosing among several alternative materials. Rather, the decisionmakers should also compare safety, health, and handling requirements during the use stage, transportation constraints, storage restrictions and requirements, and environmental problems and costs related to disposal of the spent or unused materials. Comprehensive life cycle management thus requires information feedback among personnel involved at all stages of the life cycle.

IV. CASE STUDIES

A. Hazardous Materials Management at the Naval Air Weapons Station, Point Mugu, California

In response to the requirement set by the Navy to reduce hazardous waste by 50 percent by the end of 1992, Point Mugu responded to the challenge by establishing a hazardous Materials Minimization (HAZMIN) program:

1. This program established a hazardous materials warehouse having sole responsibility over storage, management, and issue of all hazardous materials used in aircraft maintenance.

    a. All existing material stocks were collected from shop storage areas and were incorporated into warehouse inventory. This inventory is tracked on computer and issued in smaller units than it is acquired. These smaller units better match quantities needed for ongoing activities.

    b. As material requirements arise, shop personnel contact the warehouse and request the required materials. Warehouse personnel also collect unused material and return it to inventory for reissue. In addition, shop wastes are removed along with empty material containers.

    c. Warehouse personnel also monitor the remaining shelf-life of on-hand stocks, thus reducing shelf-life expirations.

    d. Individual shops are relieved of hazardous materials and waste storage and handling, because it all happens at the warehouse.

2. The HAZMIN program was implemented on 1 January 1991 as a prototype only handling the Aircraft Maintenance Department (AMD). After three months, additional base and tenant organizations were added at the rate of one per month. By phasing the implementation, the base was allowed to convert to the program in a controlled fashion. The last organization joined in February 1993.

3. In the first year of operation, the Aircraft Maintenance Department reduced its hazardous materials purchases from $132,000 to $55,000, exceeding the goal set by Point Mugu and the Navy one year earlier. Hazardous materials inventory was also reduced by 2/3, thus further lowering costs by reducing storage and administrative requirements. The following year, the AMD reduced costs to an even lower $43,000 in purchases per year.

4. In 1991, a material reutilization and recycling program was established which finds secondary uses for expired materials. That which has no secondary use is recycled. Disposal of the material is a last resort. By 1992, the recycling program was generating $58,000 of revenue per year, further reducing disposal costs.

5. The success of the HAZMIN program at Point Mugu has prompted the Navy to plan implementation for the program Navy-wide.

B. <u>Hazardous Materials Management at Hill AFB, Ogden, Utah</u>

The installation adopted a comprehensive hazardous material management program, which was based on a three-step process as follows:

1. Computer database set-up to track purchasing and usage of materials.

    Started this phase in 1990. Allows for a better method of tracking materials needed and delivered for the entire base. In the first year, incorporation of computers reduced the annual cost spent on hazardous materials from $14M to $11M.

2. Centralized office for all personnel dealing directly with HAZMAT.

2. Identify alternative materials that may be nonhazardous or less hazardous, but which will meet the required purpose.

3. Perform a life cycle cost analysis of each material under consideration, consistently capturing cost categories for each stage, including disposal costs.

4. Examine the "social" or "external" costs/impacts of using each material under consideration.

5. Choose the material that optimizes performance and life cycle cost and reduces external impacts.

B. Adoption of centralized management (as in the "pharmacy" approach) of hazardous materials to reduce overall quantities needed and minimize waste. [Refer to course on pharmacy approach that either precedes or follows this course...]

C. Requirement for suppliers to provide materials without excessive packaging, to reduce solid or hazardous waste. [Refer to course on pollution prevention that either precedes or follows this course...]

D. Identification and adoption of hazardous minimization (hazmin) procedures to recover product and/or reduce product waste, thus decreasing both the overall amount of material needed and the waste stream. [Refer to course on hazmin that either precedes or follows this course...]

III. BENEFITS OF LIFE-CYCLE MANAGEMENT

The government will save money in all phases of the life cycle. There will be less environmental degradation, and potential liability will be reduced. Examples of cost savings by life cycle stage follow.

A. Acquisition

Less may be required overall if product use and storage are optimized, and if centralized management and hazmin (product recovery) procedures are implemented. The initial purchase cost of an alternative material may be slightly higher. However, if all life-cycle costs are assessed, the overall cost of the alternative product could be substantially lower.

B. Use

use of a less hazardous material may reduce requirements for security, recordkeeping, safety procedures and equipment, etc. Implementation of hazmin procedures (product recovery) during the industrial process can also reduce both the amount of product required and the amount entering the waste stream.

C. Storage

Less space would be required to store smaller amounts of material; a less hazardous material would require less security, for example, or other storage constraints. Storage space and personnel costs could be reduced.

D. Transportation

A less hazardous material would reduce transportation safety constraints (and thus costs); smaller amounts would also reduce transportation costs.

E. Disposal

A less hazardous material, and/or smaller amounts, would have a lower environmental impact, and disposal could be less costly. The establishment of hazmin procedures and centralized ordering procedures would also result in a smaller quantity requiring disposal.

This phase was started in April 1992. All environmental management personnel, and those dealing with environmental contractors and materials purchasing, were moved into one building to increase communication dealing with hazardous materials. This alone has afforded the biggest savings for the program (total costs went from $11M to $3.6M in one year).

3. Pharmacy-like distribution of materials.

Started this phase in March 1993. Involves maintaining one (1) on-base storage facility for all bulk hazardous materials. All 55-gallon drums are received at this point and are then separated into smaller containers to be delivered as needed to the requesting department. The base originally had 6 different methods of receiving hazardous materials on-base, and this is now down to 1 method (through the pharmacy). Has not been in operation long enough to see benefits, although another decrease in hazardous materials spending is expected.

The base has experimented with substitution of less-hazardous materials for currently used hazardous materials. Some examples of this are using low-VOC (Volatile Organic Compound) paints and solvents, and replacement of ODCs (Ozone Depleting Chemicals) such as using R-22 or R-134 freon, or absorption, or ammonia chillers in place of the more harmful R-11 and R-12 units. The base anticipates they will be free from all ODC usage, with the exception of halon, by 1994.

V. SUMMARY

You have learned some of the basic approaches to using proactive planning in life cycle management of hazardous materials. The course case studies have provided you with a plan of how to put this knowledge into action. You now know more than most personnel about acquisition management. You have enhanced your ability to assess hazardous materials management in a more environmentally and financially efficient manner. Thank you for your patience! We have covered quite a bit of material in a short time, but I know you will be more confident in your ability to compare and assess the life cycles of hazardous materials. It is also my hope that you have seen the need for proactive planning in life cycle management of hazardous materials.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund)
42 USC §§ 9601 - 9675

Emergency Planning and Community Right-to-Know Act (EPCRA)
42 USC §§ 11001 - 11050

Federal Facilities Compliance Act
Pub. L. No. 102-386, 106 Stat. 1505

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
7 USC §§ 136 - 136y

National Environmental Policy Act (NEPA)
42 USC §§ 4321 - 4370b

Pollution Prevention Act
42 USC §§ 13101 - 13109

Resource Conservation and Recovery Act (RCRA) (Solid Waste Disposal Act)
42 USC §§ 6901 - 6992k

Safe Drinking Water Act (SDWA)
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Toxic Substances Control Act (TSCA)
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1. U.S. Air Force 1984. Introduction to Acquisition Management, Acquisition Process. Sys 100, Volume 1. U.S. Air Force Institute of Technology, Wright Patterson AFB, OH.

2. U.S. Air Force, 1984. Controlling The Program, Lessons III-1 thru III-4. Sys 200, Volume VI. U.S. Air Force Institute of Technology, Wright-Patterson, AFB, OH.

3. U.S. Department of Defense, 1991. Department of Defense Directive No. 5000.1, Defense Acquisition. U.S. Department of Defense, Washington, DC.

BLOCK 21: Affecting Changes in Technical Orders and MIL SPECS

1. Britford, D., 1987. Air Force Regulation 900-4 (including Change 4), The Air Force Suggestion Program. USAF HQ AFMEA/MERS, Washington, DC.

2. Burucker, S., 1993. Personal Communication. Army Publications Center, Baltimore MD, DSN 584-3775.

3. Deegan, W., 1989. Air Force Technical Order Management System. HQ AFLC/LMSC/SNT, Wright-Patterson AFB, OH.

4. Deming, W.E., 1986. Out of the Crisis. MIT Center for Advanced Engineering Studies, Cambridge, MA.

Telephone 202/939-3800

4. Environmental Liabilities of Government Contractors & Agencies
various dates and locations
Federal Publications, Inc.
(800) 922-4330

5. Environmental Regulation -- various dates and locations
Organized by: Executive Enterprises
Telephone 800/831-8333

6. Integrating Your Waste Management Plan
various dates and location
Executive Enterprizes, Inc.
2200 West 21st ST
New York, NY 10010
(212) 645-7880

7. Material Acquisition also courses in Minimization of Hazardous Materials and Wastes
U.S. Army Logistics Management College
Fort Lee, VA 23801-6053

8. Pollution Prevention: Practical Management Action Strategies
Tentatively scheduled for Feb/Mar 1994 in Orlando, FL
Government Institutes, Inc.
4 Research Place, Suite 200
Rockville, MD 20850
(301) 921-2366

9. Pollution Prevention Resources and Training Opportunities (annual publication developed by EPA Office of Pollution Prevention and Toxics and Office of Environmental Engineering and Technology Demonstration)
To order: Pollution Prevention Information Clearinghouse
Telephone: 703/821-4800

10. Public Outreach: Experience As Teacher - various dates and locations.
Organized by: Chemical Manufacturers Association
(202) 887-1215

11. Solid Waste Reduction and Recycling Course
various dates and locations
Government Institutes, Inc.
4 Research Place, Suite 200
Rockville, MD 20850
(301) 921-2366

8. U.S. Environmental Protection Agency, 1992. Environmental Research Brief: Waste Minimization Assessment for a Manufacturer Producing Galvanized Steel Parts. EPA/600/S-92/011. U.S. Environmental Protection Agency, Washington, DC.

9. U.S. Environmental Protection Agency, 1992. Environmental Research Brief: Waste Minimization Assessment for a Manufacturer of Machined Parts. EPA/600/S-92/031. U.S. Environmental Protection Agency, Washington, DC.

10. U.S. Environmental Protection Agency, 1992. Facility Pollution Prevention Guide. EPA/600/R-92/088. Office of Research and Development, Washington, DC.

BLOCK 23: Case Studies: Acquisition Pollution Prevention

1. Cohan, D., Wapman, K.R., and McLearn, M., 1992. Beyond Waste Minimization: Life-Cycle Cost Management for Chemicals and Materials. Pollution Prevention Review, Summer.

2. McCarty, B., and Short, J., 1990. U.S. Air Force Hazardous Materials Management Initiatives, in "International Confeence on Pollution Prevention: Clean Technologies and Clean Products", Washington, DC, pp. 413-422.

3. The Mitre Corporation, 1991. Acquisition Management of Hazardous Materials Technical Integration Plan. WP-91W00249, Draft Report. The Mitre Corporation, McLean, VA.

4. U.S. Army Material Command, 1992. Material Developer's Guide for Pollution Prevention. Army Acquisition Pollution Prevention Support Office, Alexandria, VA, 123 pp.

5. U.S. Environmental Protection Agency, 1992. Life-Cycle Assessment: Inventory Guidelines and Principles. EPA/600/R-92/036. Office of Research and Development, Cincinati, OH.

6. U.S. Environmental Protection Agency, 1992. Pollution Prevention Case Studies Compendium. EPA/600/R-92/046. Office of Research and Development, Washington, DC.

Courses for Follow-on Training

1. Environmental Compliance for Federal Facilities - various dates and locations.
   Organized by: Government Institute
   (301) 921-2345

2. Environmental Guides to State Policy (State specific topics)
   various dates and locations
   Government Institute
   (301) 921-2366

3. Environmental Law -- various dates and locations
   Organized by: Environmental Law Institute

Congress is developing legislation to set standards for solid waste management. Legislation will be the driving force in future solid waste management.

D. What is Municipal Solid Waste:

1. RCRA defines solid waste as:

"*any garbage, refuse, sludge* from a waste treatment plant, water supply treatment plant or air pollution control facility *and other discarded material, including solid, liquid, semisolid, or contained gaseous materials* resulting from industrial, commercial, mining and agriculture activities and from community activities but does not include solid or dissolved material in domestic sewage, or solid or dissolved materials in irrigation return flows or industrial discharges which are point sources subject to permits under section 402 of the Federal Water Pollution Control Act, as amended, or source, special nuclear, or byproduct material as defined by the Atomic Energy Act of 1954, as amended".

2. Municipal solid waste typically consists of:

- Paper and cardboard products, packaging
- Metals - nonferrous, ferrous, tin cans, scrap
- Food wastes
- Yard wastes, such as lawn clippings or tree branches
- Plastics
- Textiles and leather
- Rubber, includes tires
- Dirt, ashes, construction debris

3. MSW excludes:

- Hazardous waste, or recycled/reused hazardous waste
- Liquid wastes (except from residential areas)
- Medical waste
- Radioactive and mixed wastes

III. INTEGRATED SOLID WASTE MANAGEMENT

As previously stated, ISWM includes source reduction, recycling, waste transformation, and landfilling. The remainder of this presentation will address the various techniques of waste management within these four categories.

A. Source Reduction

Source reduction is the highest rank of the ISWM hierarchy. It involves reducing the amount and/or toxicity of the wastes that are generated. Source reduction can occur through:

- Design, manufacture and packaging of products with minimum toxic content

- Substitution of less toxic materials for mechanical processes

- Minimizing the volume of materials

- Creating products with a longer useful life

The majority of these techniques can be implemented in the manufacture of consumer products. A good example of source reduction that can be implemented on AF bases is the substitution of degreasing techniques, such as parts washers, for techniques which use hazardous constituents, such as trichloroethylene.

B. Recycling

The second highest rank in the hierarchy is recycling, which involves: