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Industrial Audit Background Paper:

Sulfur Chemicals Manufacturing Industry

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Development Alternatives, Inc.

USAID

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PREFACE/ACKNOWLEDGMENTS

This report presents the background materials for Sulfur Chemical Industry prepared with emphasis on the pollution prevention/waste minimization (PP/WM) and water conservation practices for this industry. The report was prepared by Mr. David Hair, of Science Applications International Inc. (SAIC), Falls Church, Virginia, under subcontract with Development Alternatives, Inc. (DAI), Washington, D.C.

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Review of Pollution Prevention and Waste Minimization Techniques Used by the Sulfur Chemicals Manufacturing Industry

FINAL REPORT

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1.0 INTRODUCTION

1.1 Background

Under a contract with the United States Agency for International Development (USAID), Development Alternatives Incorporated (DAI) is performing an Industrial Wastewater Discharge Prevention (IWDP) Program in Amman, Jordan. The IWDP Program is one of the four components of the Water Quality Improvement and Conservation (WQIC) project funded by USAID. The Program is being performed by DAI with full coordination between the Jordanian Ministry of Water and Irrigation (MWI) and the Amman Chamber of Industry (Chamber).

The IWDP will be performed in three phases. The first phase requires completion of eight pollution prevention/waste minimization (PP/WM) opportunity audits by DAI and its sub-contractors. The second phase requires completion of Feasibility Studies (FS) for four of the audited facilities. Finally, demonstration projects will be completed for selected FS facilities.

Due to the high cost of waste treatment, as well as the need to minimize waste of raw materials and resources, it is in the best interest of businesses and industries to minimize their waste generating practices. Companies with effective PP/WM programs may well be the lowest-cost producers of goods due to their efficient practices. Waste management practices can include:

1. Reduce waste generation

   - Substitution of less hazardous raw materials in product manufacture
   - Alteration of products manufactured to eliminate need for hazardous materials use
   - Replacement or upgrading of outdated or inefficient process equipment
   - Development of employee training programs to ensure employees efficiently manage raw materials and resources.

2. Reuse waste materials prior to disposal

   - Reuse of uncontaminated raw materials and resources (including water)
   - Reprocessing of previously discarded materials (e.g., off-spec materials, used materials)
   - On site recovery of reusable materials (e.g., used solvents, waste heat, scrap).

3. Recycle waste materials

4. Treat wastes and dispose of residues.

These options, in the order presented, represent the waste management hierarchy.

1.2 Objectives

The facility PP/WM audits are designed to assess the potential for pollution prevention and waste minimization at the study facilities. The goal of each audit is to evaluate and identify all possible PP/WM, wastewater clean-up, and water conservation techniques that are appropriate for the study facility. Audit documentation will consist of a background PP/WM assessment paper and an audit evaluation report. This document is intended to serve as the PP/WM background paper for the sulfur chemicals processing sector of the chemical manufacturing industry.

The specific objectives of this audit are as follow:

1. Review general industry background data and identify "state-of-the-art" processing and waste management practices.

2. Work on-site with industry representatives, ministry officials, and other interested groups to review current processing procedures and identify possible PP/WM options.

3. Develop a report that evaluates all possible PP/WM alternatives and provides recommendations to the industry.

In order to complete the first objective, a comprehensive literature review was performed. This review included searches of the U.S. EPA Pollution Prevention Information Clearinghouse (PPIC) repository (and its corresponding database PIES), on-line library catalog databases, pollution PP/WM bibliographical references, and personal contacts with pollution prevention specialists. The review resulted in the identification of numerous references with a range of very general to very specific PP/WM techniques. Source documents were assessed to determine their applicability to this project and categorized appropriately. Documents pertinent to this project are included as Appendix A (Fact Sheets), Appendix B (Case Studies) and Appendix C (Bibliography).

Following completion of the literature review, the audit team will perform the on-site audit of the industrial facility. The audit will be performed with close consultation of industry representatives to ensure that they are aware of and support proposed actions. Audit activities will included the careful gathering of baseline water use and waste generation data, identification and assessment of potential PP/WM options, and solicitation of ideas and proposals from management and production line staff.

Finally, the audit findings will be summarized, and all options evaluated in the audit report. The audit will recommend the development of a site-specific program that meets the specific needs and goals of the audited facility. Audit recommendations will include both technical PP/WM recommendations (e.g., housekeeping practices, treatment options, etc.) and suggestions for PP/WM training for facility staff and follow-up studies to assess program successes.

2.0 INDUSTRIAL HISTORY

2.1 General

The sulfur chemical industry is involved in the manufacture of a variety of organic and inorganic chemicals that contain sulfur and sulfur compounds. Sulfur chemicals produced by this industry group may be sold as raw materials for other manufacturing processes or, for certain formulations, may be sold as finished products. One of the major producers and end users of sulfur compounds is the soap and detergent manufacturing industry. Because the industry to which this background paper is directed is involved in manufacture of both sulfur chemicals, soap and detergent additives and builders, and soap and detergent products, this overview will focus on this specific sector of the industry.

Soaps and cleaning materials have been produced since the earliest recorded history of mankind; however, modern soap and detergent manufacturing practices trace their history to the early 1930s. It was during this era that synthetic surface active agents (surfactants) were developed and introduced to the commercial market. The industry soon developed polyphosphate detergent builders that allowed synthetic detergents to be substituted for traditional soap formulations. Due to environmental concerns over the use of polyphosphates, the industry began conversion to more biodegradable linear benzene sulfonates during the 1960s. Today, there are a wide variety of soaps and detergents available commercially for all types of applications. Applications can include; personal hygiene products, laundry detergents, dish washing detergents and machinery cleaning products (USEPA 1974).

The soap and detergent manufacturing industry most often purchases raw materials such as caustic, fats and oils and builders from bulk chemical suppliers; however, there are large scale facilities which produce and control their own raw material supplies. While raw materials are purchased from bulk suppliers, sulfation and sulfonation are almost always practiced by the manufacturers.

2.2 The Sulfur Chemicals Manufacturing Industry in Jordan

The Jordan Sulpho Chemicals facility consists of five plants. A description of each of the plants is provided below.

Sulfonic Acid Plant

The plant produces sulfonic acid from sulfur and linear alkaline benzene using a sulfonation process. The production rate for sulfonic acid is approximately 1 ton per hour yielding 24 tons per day. The plant also produces linear LSLES.

Soap Plant

The soap plant produces raw soap granules from palm oil.

Sodium Silicate Plant and Sodium Silicate Dissolving Plant

This plant produces sodium silicate from silica, soda ash, and sodium carbonate. The plant produces approximately 25-30 tons per day of sodium silicate.

The resultant sodium silicate is dissolved using water and steam in the dissolving plant. This unit is not operated on a continuous basis.

Sodium Thallium Sulfonate Plant

Sodium thallium sulfonate is produced through the reaction of sulfuric acid and thallium. The production rate is approximately 5 tons per day.

Amides Plant

Amides are produced at this facility using coconut oil, mono ethyl amine and diethyl amine. The production rate is approximately 5 tons per day.

3.0 PROCESS OVERVIEW

The production of organic chemical products involves the chemical reaction of various raw materials (feedstock), under varying reaction conditions and chemical engineering unit processes. It is common for a facility in this category to utilize its reaction facilities to produce several different products simultaneously, and to change its mix of raw materials and products on a daily, weekly or monthly basis (USEPA 1987).

Synthetic organic chemicals are typically produced by reactions involving naturally occurring raw materials such as petroleum, natural gas and coal. An industry study performed in the United States (USEPA 1987) reports that organic chemicals and plastics are produced commercially from eight major raw material classifications: methane, ethane, propene, butanes/butenes, higher aliphatic and aromatic compounds, benzene, toluene and xylene. Organic chemical manufacturers may use these chemicals directly, or may use intermediate products produced from these chemicals, as their feedstocks. A diagram of the relationship of various segments of the organic chemical industry is provided in Exhibit 3-1.

The production and manufacture of an organic chemical product consists of three steps:

1. The combination of reactants under suitable conditions to yield the desired product.

2. The separation of the product from the reaction matrix (e.g., by-products, co-products, reaction solvents.

3. Final purification and/or disposal of wastewater (USEPA 1987).

The sulfur chemicals industry uses these processes to produce chemical compounds for a variety of uses. The particular processes applicable to the sulfur chemical industry in Jordan include: sulfonic acid production, soap and detergent manufacturing, sodium silicate production, sodium thallium sulfonate production and amides production. A description of each of these processes is provided in the following sections.

3.1 Sulfonic Acid

The group of chemicals referred to as sulfonic acids include acids that are derived from sulfuric acid by replacement of a hydroxyl group by either an inorganic anion or a univalent organic radical. Sulfonic acids are, therefore, characterized by the chemical formulae: $-SO_2OH$ or $-SO_3H$. Where the substitution involves an inorganic ion (e.g., chlorine or fluorine) the general formula is represented by $X-SO_2OH$. Where the substitution involves an organic radical, the general formula is represented by $R-SO_2OH$. The properties of sulfonic acids are affected significantly by the characteristics of the "R" group. The majority of sulfonic acids, however, are characterized as strong acids and are generally hygroscopic, nonvolatile, soluble in water and chemically stable.

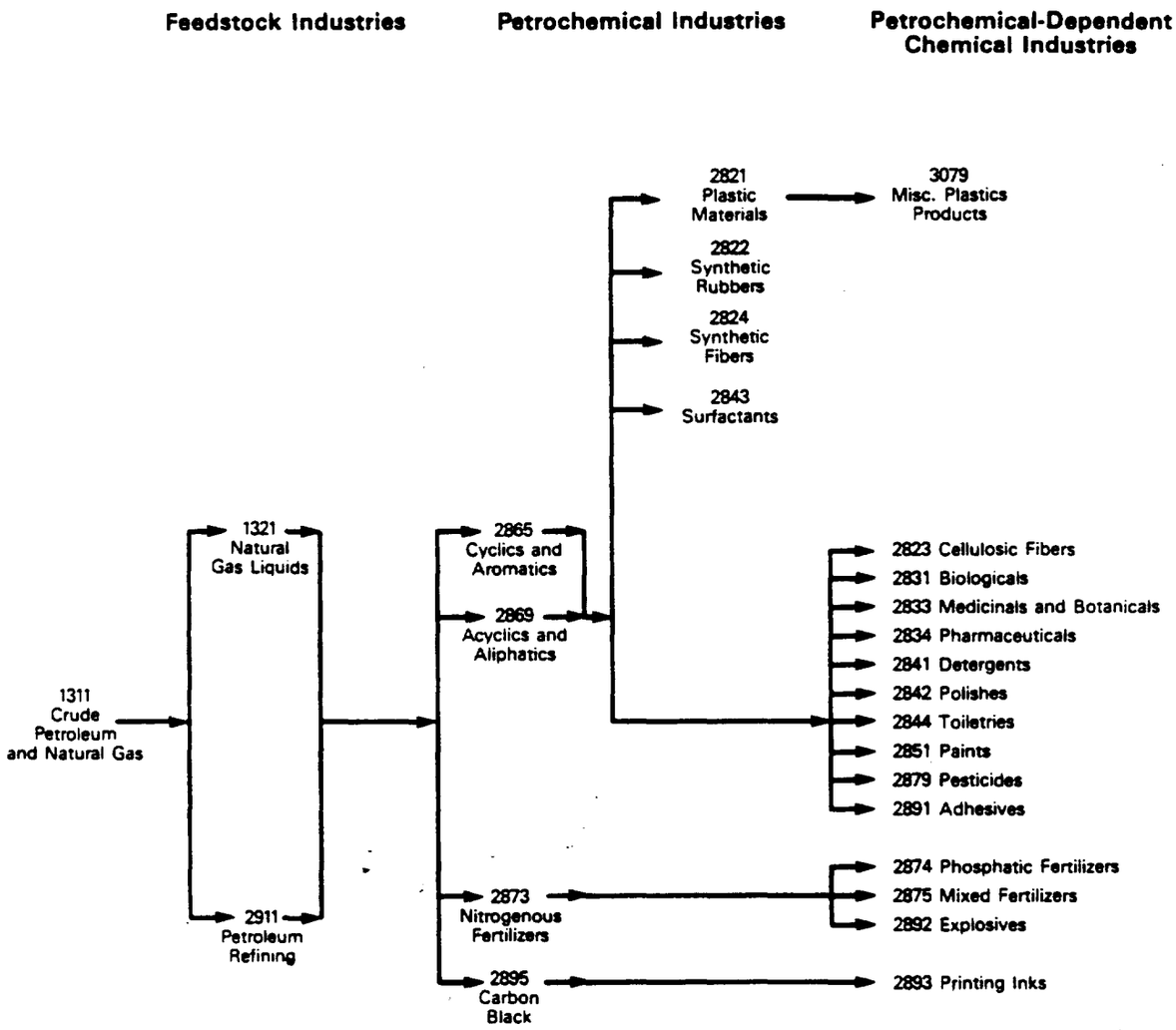

Exhibit 3-1 Relationship of Various Segments of the Organic Chemicals Manufacturing Industry
(From: U.S. Dept. of Commerce. *1981 U.S. Industrial Outlook.* Bureau of Industrial Economics, Washington, DC. 1981.)

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Sulfonates (salts of sulfonic acids) linked to alkyl, aryl, or alkylaryl hydrophobes are effective in detergent manufacturing. Sulfonic acids are relatively strong acids and their associated salts are not generally affected by pH. The alkylbenzenesulfonates (ABS) group are used widely in soap manufacturing. Produced from alkylbenzenesulfonic acids, these salts are effective surfactants and are widely used in detergent formulations.

Sulfonates are produced by reactions of sulfuric acid and the inorganic or organic functional group under prescribed conditions. Alkylbenzenesulfonates are produced by the reaction of sulfuric acid and linear alkyl-benzene (LAB). In this process the by-product of the reaction is water (Kirk-Othmer 1983).

3.2 Soaps and Detergents

Soaps are the salts of long chain fatty acids. Sodium, potassium and calcium are commonly used as the cation in these salts. The surface activity of soaps is the result of the hydrophilic functional group at one end of the long chain molecule combined with the hydrophobic group at the other. In solution, these molecules aggregate as micelles which result in the emulsifying and dispersing characteristics of soaps.

The common raw materials used in soap production are naturally occurring fatty acids and inorganic alkalies. Fatty acid feedstocks may include the following:

- **Tallow** - Animal fat rendered from the body fat of cattle and sheep
- **Coconut Oil** - Extracted from crushed fruit of the coconut palm
- **Palm Oil** - Extracted from the crushed fruit of the tropical palm tree
- **Palm Kernel Oil** - Extracted from the nut of the tropical palm tree.

Common alkali used in the manufacturing process include sodium hydroxide and potassium hydroxide. These chemicals can be used alone or in combination to yield specific characteristics in the final soap product.

The manufacturing processes used in soap production vary depending on the raw materials and final products being generated. In general, however, the process includes three basic steps: saponification, washing, and fitting. Saponification involves the mixing and reaction of the fatty acids and alkali feedstocks in a heated environment. In most processes the alkali is added slowly during the reaction until the point where it is no longer consumed by the reaction. The unreacted waste alkali (lye) is then removed from the reaction vessel for washing and glycerol recovery. Washing involves the series of steps that result in the removal of lye from the soap product. Fitting is the process where additional impurities are removed, additives are incorporated and final processing is performed. These manufacturing processes can be accomplished in very simple open tanks or in large fully automated systems (Kirk-Othmer 1983).

3.3 Sodium Silicate

Silicates, in the natural environment and manufactured commercially, are salts composed of silicon dioxide and an alkali metal. The alkali metal is usually sodium or potassium. Chemically, sodium silicates are the salts of a strong base and a weak acid. In solution, these salts form highly alkaline solutions and are useful in the manufacture of soaps and detergents.

Sodium silicates are widely used as soap builders in soap and detergent manufacturing. In the soap and detergent formulation, sodium silicates act as alkalies and aid in the saponification of oils and fats due to their alkaline nature and buffering capacity. Silicates are also effective in controlling the corrosive action of detergents on metallic washing machine parts and are effective in the sequestering of magnesium hardness ions in solution. Commercially available silicates are characterized by the ratio of SiO_2 to Na_2O in the silicate molecule. In detergent formulae, the ratio is typically 2.4:1.

Sodium silicate is produced commercially through the reaction of quartz sand (silica) and sodium carbonate (soda ash) at a high temperature. To ensure a high quality glass, the sand and soda ash should be of high purity. The resultant molten sodium silicate is extremely caustic and can damage equipment if not handled properly. The molten glass is formed in to lumps for subsequent dissolving or can be drawn directly into a dissolving unit.

3.4 Sodium Thallium Sulfonate [RESERVED]

3.5 Amides

Fatty acid amides are generally produced by the reaction of a fatty acid with a ammonia or an amine and have the chemical formula: $R\text{-}CONH_2$, where R may be a saturated or unsaturated alkyl chain derived from a fatty acid. Fatty acid amides are generally insoluble in water.

Fatty acid amides are produced most commonly by the reaction of a fatty acid with anhydrous ammonia. These materials are combined and heated under slightly increased pressure for approximately 10 to 12 hours. During the reaction, ammonia and water are constantly vented to ensure completion of the reaction. Various materials can be used to catalyze the reaction including boric acid, and titanium and zinc alkoxides.

4.0 WATER USE AND WASTE GENERATION IN THE CHEMICAL MANUFACTURING INDUSTRY

The variety of raw materials, reaction processes, intermediates and final products manufactured by the chemical industry results in an equally diverse inventory of wastes generated by these processes. Pollutants generated by the organic chemicals industry can include pH, Biochemical Oxygen Demand (BOD), Suspended Solids (TSS), oil and grease, a wide variety of toxic organic compounds and toxic metals. For the inorganic chemicals manufacturing industry, pollutants generated can include, pH, suspended solids, nutrients, and a wide variety of toxic inorganic compounds (including metals) (USEPA 1987, USEPA 1980).

Both organic and inorganic chemicals manufacturing use large volumes of water during production processes. Water is used for cooling reaction vessels, as a blending agent or carrier for raw materials, intermediates, and final products, and as a component in chemical reactions. Water is also used in large volumes at many facilities for cleaning reaction vessels and production areas and for removal of airborne materials (scrubbers). A more comprehensive description of water use and waste generation for the chemicals industry, in general, and the sulfur chemicals industry, in particular, is provided in Sections 4.1 and 4.2, below.

4.1 Water Use

Water use and wastewater generation are reported by USEPA (1987) to occur primarily in the following areas at an organic chemical manufacturing facility:

- Direct and indirect contact process water - Uses include the direct use of water as the reaction medium for the chemical process and indirect contact through vacuum jets or sprays to recover solvents and volatile organics from the reaction vessel.

- Contact and non-contact cooling water - Cooling of reactors, distillation units and other equipment results in the highest volume of water use at chemical manufacturing facilities. Contact cooling water is usually directly integrated in the reaction process, such as in a barometric condenser. Non-contact cooling water does not come into direct contact with process chemicals, and is generally uncontaminated.

- Utilities, maintenance and housekeeping - Ancillary water uses at chemical manufacturers can also consume significant quantities of water. Uses include cleaning of reactors and conduits, process area washdown, and flushing of tanks and storage vessels.

- Waters from air pollution equipment such as Venturi scrubbers - Many organic chemicals manufacturers generate significant volumes of airborne contaminants. Scrubbers used to remove these airborne pollutants utilize large volumes of water.

Although inorganic chemicals manufacturers utilize significantly different raw materials and processes to produce their chemical products, the areas of water use are quite similar to those in the organic chemicals industry.

Water is used extensively in the sulfur chemicals and soap and detergent manufacturing industries. In a comprehensive review of the soap and detergent manufacturing industry in the United States, USEPA (1974) identified water use practices for the following industry processes:

Soap Manufacture:

Steam is widely used in the heating and processing of fats; thus, cooling water is required for this process. In the kettle batch process, water use and discharge may range from 623 to 2080 l/kkg. Wastewater can be generated from leaks, spills, and rainwater runoff from processing areas. Wastewaters are also generated by the fat skimmers during the manufacturing process. Depending on the process used, a wastestream may also be generated by the saponification process through the sewering of waste nigre.

If a facility practices waste soap reclaiming, an additional wastestream referred to as "sewer lyes" may also be generated. Sewer lyes are usually low volume; however, they contain highly concentrated pollutants.

Where soaps are manufactured by the fatty acid neutralization process, there is little or no wastewater produced.

Fatty Acid Manufacture:

In the United States, USEPA determined that the majority of water used for fatty acid splitting was recycled. The small amount of water discharged results from blowdown from the cooling system and generates flows in the range of 3.2 to 12.6 l/sec. The other main source of waste water from this process is generated in the processing of still bottoms. The flow from this process is low; however the wastestream is highly concentrated.

Glycerine Recovery:

The crude glycerines generated during the soap manufacturing process contain approximately 90 percent water. The majority of wastewater generated by this process comes from the cooling water condensers. Where recycling is practiced, water use is relatively low; however, without recycling, flows may approach 1,000,000 l/kkg of glycerine produced. Smaller flows are also generated by still washout, steam generation, and ion exchange media regeneration.

Oleum Sulfonation and Sulfation:

The processes of sulfonation and sulfation are used to manufacture synthetic detergents from akylbenzenes, fatty alcohols, and alcohol ethoxylates. These manufacturing processes generate no process wastewater; however, water is used for clean-up and wastewater and may be generated by leaks and spills.

Spray Dried Detergents:

Cooling water is not used for this process. The majority of the wastewater generated by this process is from clean-up activities. In particular, if scrubbers are used to remove organic contaminants from the spray tower vent gasses, large volumes of scrubber water will be generated.

4.2 Waste Generation

Wastewaters generated at organic chemicals manufacturing facilities are somewhat more easily classified than those at inorganic chemicals manufacturing facilities due to the common feedstocks and processes. The pollutants introduced by inorganic chemicals manufacturers are directly related to the specific raw materials and processes utilized by a given facility. It is, therefore, beyond the scope of this paper to include an a comprehensive inventory of the types of wastes generated by the inorganic chemicals industry segment; thus, the majority of this section of the background paper will focus on the organic chemical industry.

The types of pollutants generated by an organic chemical manufacturer can be grouped into three general categories, and several additional subcategories as follow:

- **Conventional Pollutants** (Treatable by conventional biological methods)
  - Biochemical Oxygen Demand (BOD)
  - Total Suspended Solids (TSS)
  - pH
  - Chemical Oxygen Demand (COD)
  - Total Organic Carbon (TOC)
  - Oil and grease.

- **Toxic Pollutants** (Requiring specific physical, chemical or biological treatment)
  - Toxic Organic Pollutants
    - Wide variety of pollutants related to raw materials, intermediates, reaction media, and final products.
  - Toxic Inorganic Pollutants
    - Metallic elements and compounds related to raw materials, intermediates, reaction media, and final products.

- **Non-Conventional Pollutants** (Not highly toxic, but requiring special treatment)

  - Nutrients (e.g., nitrogen, phosphorus)
  - Sulfur Compounds
  - Chlorides

The sulfur chemicals and soaps and detergents industries generate wastewaters that contain primarily conventional and non-conventional pollutants. In particular, process wastestreams, contact cooling water, leaks, spills, and cleaning activities introduce raw materials, intermediates, and final product, lost through processing and clean-up, to the wastestreams. Production processes typically result in wastewaters that have high alkalinity, high suspended solids, high salt, and high oxygen demand, as well as fats an oils, surfactants and foaming agents. In addition to these parameters, the pH of the wastestreams can vary widely due to large volumes of acids and alkali materials used by this industry. USEPA's survey of the soap and detergent manufacturing industry (USEPA 1974) identified specific pollutants generated by the following processes.

Soap Manufacture:

Pollutants generated by the soap manufacturing processing include; fats and oils (raw materials); unrecovered sodium chloride, sodium sulfate and sodium hydroxide; and waste soap materials. These pollutants result in high BOD and COD, high suspended solids, and pH fluctuations.

Fatty Acid Manufacture:

This manufacturing process generates waste organic material in the form of waste fats and oils, and unrecovered glycerine, and inorganic wastes such as sodium hydroxide and sodium sulfate.

Glycerine Recovery:

Pollutants include glycerine and glycerine polymers, sodium chloride and sodium sulfate.

Oleum Sulfonation and Sulfation:

Wastes generated by these processes include waste oils, sulfuric acid, and surfactant sulfonic acids.

Spray Dried Detergents:

Pollutants include the raw materials used in the production of spray dried detergents such as LAS, amides, non-ionic and alcohol surfactants, sodium silicates, and other builders and additives.

USEPA reported pollutant concentrations in the wastestreams from the manufacturing processes in the soap and detergents industry in its 1974 study of this industrial sector. The findings of this study are presented in Exhibit 4-1.

Pollutant	Reported Concentration
Oils and greases	0-3,400 mg/l
Suspended organics	0-30,000 mg/l
Dissolved and colloidal organics	100-12,000 mg/l
Surfactant organics	0-1,700 mg/l
Boron and borates	less than 1 mg/l
Phosphates	25-1,000 mg/l
Dissolved inorganics	0-250,000 mg/l
Zinc and barium	less than 1 mg/l

Exhibit 4-1 Typical Pollutant Concentrations for the Soap and Detergent Manufacturing Industry
(From: USEPA. *Development Document for Soap and Detergent Manufacturing*. 1974)

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5.0 POLLUTION PREVENTION AND WASTE MINIMIZATION TECHNIQUES USED BY THE CHEMICAL MANUFACTURING INDUSTRY

Due to the distinctive manufacturing processes at individual chemical facilities, PP/WM techniques practiced at one facility may not apply to all others. However, there are similarities in water use practices and types of wastes generated that may allow the sharing of successful technologies. Since no one set of PP/WM practices will apply to all facilities, decisions regarding water reuse and PP/WM will depend on site-specific characteristics, as well as well as water supply and environmental factors. This section, therefore, will present several alternatives that have proved successful in specific applications.

5.1 Water Conservation and PP/WM Techniques

The wastes generated by chemical manufacturing industries, excluding atmospheric discharges, are most often directly related to the contamination of the water used at the facility. It follows, therefore, that water conservation practices and control of water use at a chemical manufacturing facility will reduce chemical loss and waste generation. In addition to control of water use, many chemical manufacturers have identified wastestreams that contain unused raw materials, product, or by-products. Instead of discharging these materials as wastes, prudent companies have developed techniques for further processing and recovery of these former waste materials.

As noted in Section 4, many of the wastes generated by the chemicals manufacturing industry can be highly toxic to humans and wildlife. To address the reduction of discharges containing these toxic materials, a facility may wish to consider raw material or product substitution. The literature cites many examples of facilities that have found less toxic substitutes for existing chemical reagents. Examples are also provided of facilities that have identified less hazardous processes for producing equivalent final products.

For the organic chemicals industry, USEPA (1987) notes that the following water conservation techniques have been utilized:

- Recovery and reuse of steam condensates and process condensates
- Process modifications to recover more product solvents
- Effective control of cooling tower treatment and blowdown to optimize cycles of concentration
- Elimination of contact cooling for off-vapors
- Monitoring of water uses and prompt attention to faulty equipment, leaks, etc.
- Installation of automatic monitoring and alarm systems on in plant discharges.

These techniques may prove useful in conserving water and in minimizing pollutant losses to the wastestream.

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Pollution prevention and waste minimization at sulfur chemicals and soap and detergent manufacturing facilities is directly related to control of water use and wastewater generation. Studies of this industry sector have determined that significant reduction in pollutant loadings can be achieved through efficient water use. In addition, many materials ordinarily discharged in soap and detergent manufacturing wastewater can be effectively recovered as saleable products (USEPA 1974).

In addition to the specific practices noted below, all chemical industries should perform complete water balances. Due the age and complexity of many manufacturing facilities, plumbing and piping diagrams are often incomplete. A complete and comprehensive inventory and assessment of water use and disposal, therefore, is a critical first step in any PP/WM effort. Many inefficient water use practices, and opportunities for potential recycling can be identified through these studies.

In its evaluation of this industrial sector, USEPA grouped PP/WM techniques in three broad categories based on the source of the pollutant introduction: 1) impurities removal; 2) by-product/degradation product control; and 3) dilute product from cleanouts, leaks and spills. The following PP/WM techniques, organized by pollutant source, have been demonstrated successfully by this industry:

Impurities Removal

In many applications, the barometric condensers can be replaced by surface condensers that can reduce water use by several orders of magnitude and reduce the amount of organic contamination by up to 80 percent.

Alternatively, the operation of barometric condensers can be modified for more efficient operation. If water from the barometric condensers is recycled through fat skimmers, organic material ordinarily discharged from these processes can be recovered and reclaimed. Reductions in waste of raw materials can be expected in the range of 75 percent. The removal efficiency of the oil and grease removal can also be enhanced by the installation of chemically assisted flocculation systems.

Glycerine removal can also be achieved by installation of surface condensers and vacuum extraction equipment. While this the initial capital cost for this type of system is high, glycerine recovery of up to 90 percent can be achieved. The pay back period for this system is reported to be approximately 10 years.

By-product/degradation Product Control

Where batch kettle soap making is practiced, the waste nigre can be recovered and reclaimed for products such as pet soap or industrial lubricants. The capital costs would include construction of an accumulator tank for material storage and treatment for fat recovery. These systems can achieve a reduction in raw waste load of 75 to 80 percent.

The degradation of product in the sulfonation process can result in a large volume wastestream. This problem occurs in all sulfonation processes; however, it is more serious in smaller volume operations. Installation of a batch countercurrent process with enhanced agitation for improved heat transfer and improved mixing can reduce waste generation. Costs are reportedly minimal for these systems.

Dilute Product from Cleanouts, Leaks and Spills

In the manufacture of liquid detergents, large volumes of water are used to clean reaction tanks and feedlines during product changeover and cleanup operations. Substituting "dry" cleaning operations can significantly reduce water use and waste generation. For example, air or steam can be used instead of water to empty feed lines. It may also be possible to reconfigure plumbing to utilize relatively uncontaminated wastestreams.

Facilities that operate detergent spray towers can minimize water use by utilizing water recycling practices. One possible arrangement involves the use of vent gas scrubber streams in series. The more contaminated streams from the "first stage" scrubber can be recycled to the crutcher and the less contaminated second stage wastestream would be cooled and returned to the first stage scrubber. Capital costs are reportedly moderate and raw wastes can be reduced up to 65 percent.

Many additional PP/WM techniques have been reported in the literature for specific chemical industry applications. A recent publication by Dorfman, et al., (1992) provides over 100 PP/WM techniques practiced by organic and inorganic chemicals manufacturers in the United States. While not all of these examples will apply to this industrial sector, certain technologies may provide ideas or inspiration for additional applications. Excerpts from this document (reprinted by permission from the author), as well as case studies from several other literature sources, are provided in Appendix B of this paper.

5.2 Effluent Control and Treatment Technologies

Treatment technologies for the chemical manufacturing industry vary widely depending on the type of waste being treated. A complete review of the types of technologies used by the industry is, therefore, beyond the scope of this paper. A brief overview of the general types of technologies, however, is provided to identify commonly used processes. Processes utilized by the industry consist of physical/chemical in-plant controls, and "end-of-pipe" physical/chemical and/or biological treatment units (USEPA 1987, USEPA 1980). Treatment processes described in USEPA chemical industry studies are provided below.

Chemical manufacturing facilities often utilize physical/chemical "in-plant" control technologies. These operations are designed to recover products or solvents, to reduce pollutant loadings on subsequent biological treatment units and to remove pollutants that subsequent treatment may be unable to adequately treat. In plant treatment can include:

- Process modifications
- Addition of control instrumentation
- Installation of solvent recovery units
- Water control and reuse technologies (See Section 5-1)

End of pipe treatment technologies include physical, chemical and or biological treatment units. Treatment for the organic chemicals industry typically consists of a combination of primary (neutralization and settling), secondary (biological high-rate aeration and clarification), polishing, and/or tertiary (polishing ponds, filtration, or carbon adsorption) operations. End of pipe treatment for inorganic chemicals manufacturers is designed specifically to remove the pollutants generated at a given facility. Treatment generally consists of physical and chemical unit operations such as: primary settling and neutralization, chemical precipitation and clarification, ion exchange, and filtration. Depending on the products and raw materials used at facility, other more chemical specific treatment units may be utilized on a site-specific basis.

The sulfur chemicals and soap and detergent manufacturing industry generally utilize well established physical, chemical and biological treatment systems for pollutant control. As described in Section 4 of this paper, the majority of the pollutants generated by this industrial sector are not highly toxic and can be treated by relatively uncomplicated treatment technologies. A list of the treatment processes commonly used for removal of various pollutants is provided in Exhibit 5-1.

The treatment and removal of free and emulsified oils and greases is typically accomplished by gravity separation, physical filtration and/or floatation. These treatment processes may be used alone or in combination depending on the nature of the oils and greases to be treated and the strength of the wastestream. Where oils are highly dispersed, or where organic solvents are present, activated carbon filters may also be used. The removal efficiency of these systems is provided in Exhibit 5-2.

Suspended solids may be removed through coagulation and settling and/or mixed media filtration. These types of treatment systems are highly effective on the suspended solids generated by the soap and detergent manufacturing processes. Typical removals are provided in Exhibit 5-2.

Suspended and dissolved biodegradable organics are effectively removed using biological treatment systems such as aerated lagoons, activated sludge basins, contact stabilization and/or trickling filters. Since most organic contaminants generated by facilities in this category are biodegradable, these types of systems are frequently utilized. Where organic contaminants are not readily biodegradable, carbon adsorption systems may be utilized. These systems may use activated carbon towers, or may add powdered carbon to the wastestream for subsequent removal. The efficiency of these treatment units in treating wastes from this industry are provided in Exhibit 5-2.

Pollutants	Treatments
Free and emulsified oils and greases	1. Gravity separation 2. Coagulation and sedimentation 3. Carbon adsorption 4. Mixed media filtration 5. Flotation
Suspended Solids	1. Plain sedimentation 2. Coagulation-sedimentation 3. Mixed media filtration
Dispersed Organics	1. Bioconversion 2. Carbon adsorption
Dissolved Solids (Inorganic)	1. Reverse osmosis 2. Ion exchange 3. Sedimentation 4. Evaporation
Unacceptable Acidity or Alkalinity	1. Neutralization
Sludge obtained from or produced in process	1. Digestion 2. Incineration 3. Lagooning 4. Thickening 5. Centrifuging 6. Wet oxidation 7. Vacuum filtration

Exhibit 5-1 Treatment Methods Used by the Soap and Detergent Manufacturing Industry
(From: USEPA. *Development Document for Soap and Detergent Manufacturing*. 1974)

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Pollutant and Method	Efficiency (Percentage of Pollutant Removed
Oil and Grease	
API type separation	Up to 90 percent of free oils and greases. Variable on emulsified oil.
Carbon adsorption	Up to 95 percent of both free and emulsified oils.
Flotation	Without the addition of solid phase, alum or iron, 70-80 percent of both free and emulsified oil. With the addition of chemicals, 90 percent
Mixed media filtration	Up to 95 percent of free oils. Efficiency in removing emulsified oils unknown.
Coagulation-sedimentation with iron, alum or solid phase (bentonite, etc.)	Up to 95 percent of free oil. Up to 90 percent of emulsified oil.
Suspended Solids	
Mixed media filtration	70-80 percent
Coagulation-sedimentation	50-80 percent
Chemical Oxygen Demand	
Bioconversions (with final clarifier)	60-95 percent or more
Carbon adsorption	Up to 90 percent
Residual Suspended Solids	
Sand or mixed media filtration	50-95 percent
Dissolved Solids	
Ion exchange or reverse osmosis	Up to 99 percent

Exhibit 5-2 Relative Efficiency of Several Methods Used to Remove Pollutants
(From: USEPA. *Development Document for Soap and Detergent Manufacturing*. 1974)

As indicated in the discussion of industry processes in Section 3, the sulfur chemicals and soap and detergent manufacturing industry may operate several very different unit processes using many raw materials to produce intermediates and final products. The treatment systems for these facilities, therefore, must be tailored to the specific unit processes and the types of wastes generated by each facility. In addition, the proximity of each of the unit processes to each other may determine whether treatment processes can be centralized, treating a variety of wastestreams, or whether each wastestream will require individual treatment. An example of an integrated treatment flow sheet for the soap and detergent manufacturing industry is provided in Exhibit 5-3. While this treatment scheme will not apply to all facilities, it provides a useful schematic describing the placement and configuration of the various treatment units.

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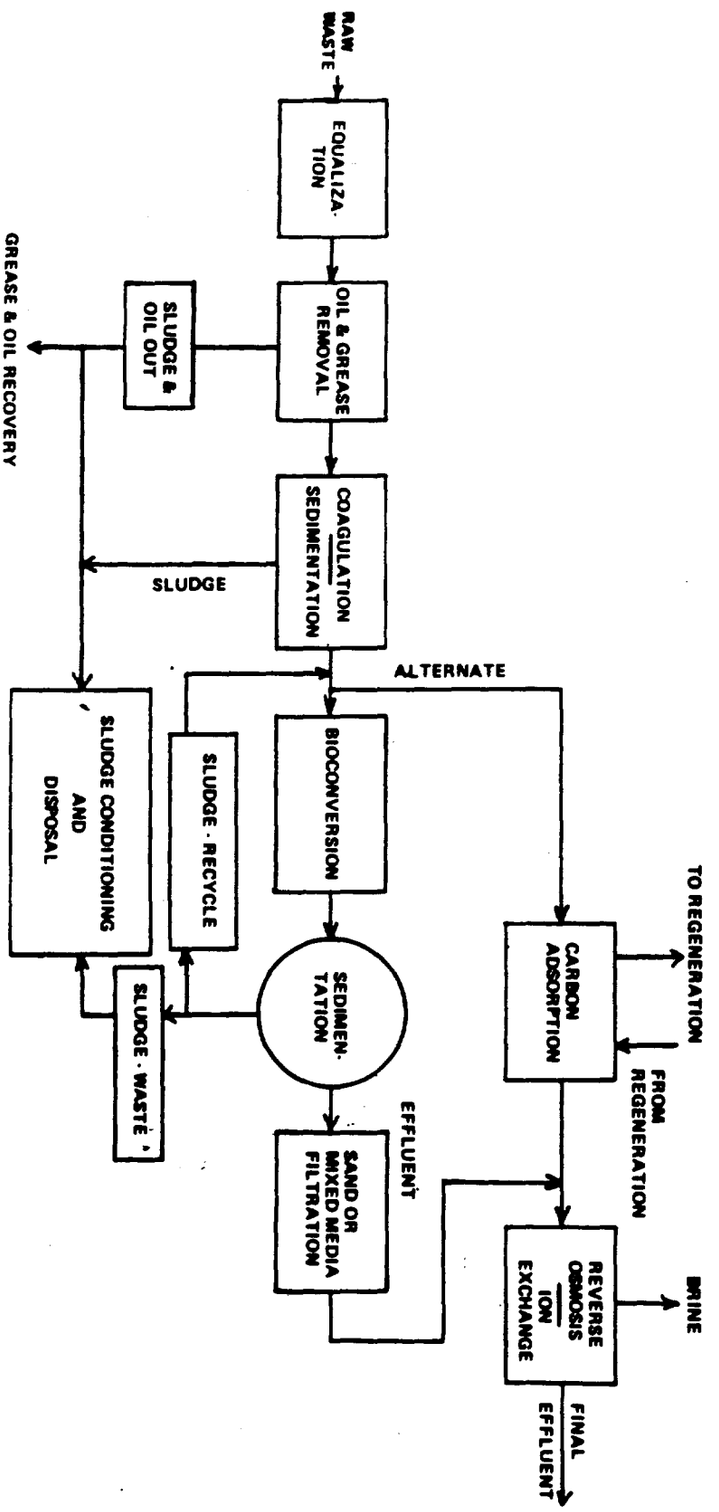

Exhibit 5-3 Composite Flow Sheet for Waste Treatment
(From: USEPA. *Development Document for Soap and Detergent Manufacturing*. 1974)

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6.0 REFERENCES

Appendix A Selected PP/WM Guidance and Fact Sheets for the Chemical Manufacturing Industry

Appendix B Selected PP/WM Case Studies for Chemical Manufacturing Industries

Appendix C Bibliography

Appendix A

Selected PP/WM Fact Sheets for the Chemical Manufacturing Industry

Selected Fact Sheets:

1. "Eliminating Hexavalent Chromium from Cooling Towers." (Source: Board of Public Works, City of Los Angeles, CA)

2. "Reducing Water Usage with Cooling Towers." (Source: Minnesota Technical Assistance Program)

3. "Water and Chemicals Reduction for Cooling Towers." (Source: North Carolina Department of Environment, Health, and Natural Resources)

FACL-6

Board of Public Works
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FACT SHEET

Eliminating Hexavalent Chromium From Cooling Towers

Cooling towers are used by office buildings and manufacturing plants throughout the Los Angeles area to dissipate waste heat from air conditioning, industrial and power generation processes. Recirculating water transfers thermal energy from the building or industrial process to the atmosphere. Atmospheric air blown through the cooling tower carries away the heat.

Environmental problems arise when water escapes from the system in the form of droplets. Such water droplets carry with them various chemicals that are used in the system. Some of these chemicals are environmentally harmful. Hexavalent chromium is the one that is of the most concern and warrants immediate attention.

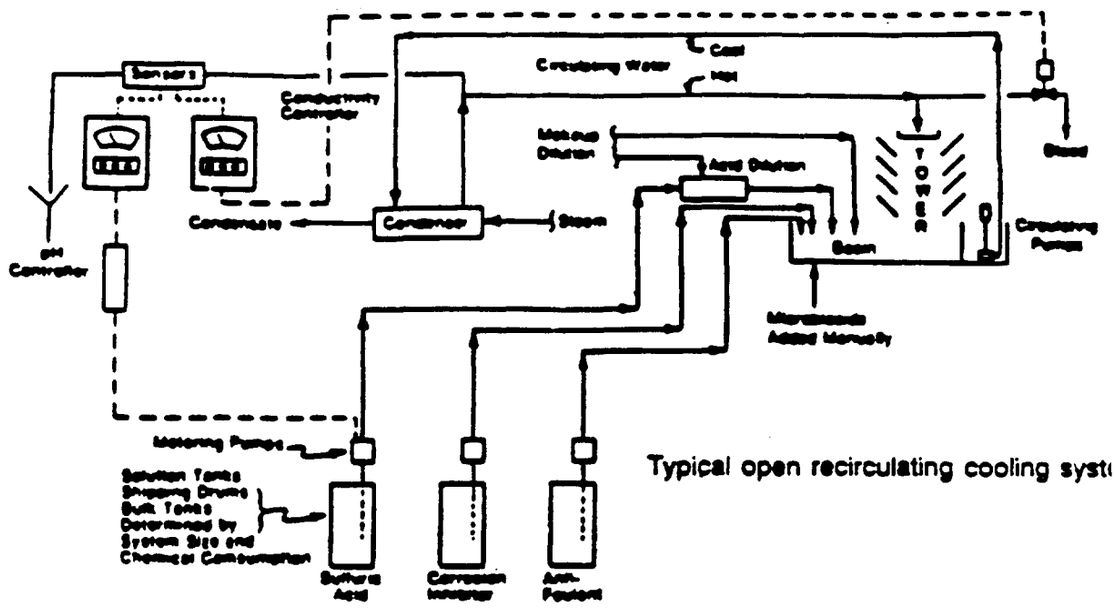
Hexavalent chromium-based ("chrome") compounds are among the most efficient and cheapest corrosion inhibitors available. The trouble is, hexavalent chromium is a suspected carcinogen, and is highly toxic. Chrome emissions from cooling towers in the South Coast Air Quality Management District (SCAQMD) alone could cause as many as 700 cancer cases over a 70 year exposure period.

SCAQMD has banned the use of hexavalent chromium water treatment chemicals in open water circulating systems that are potentially capable of emitting respirable hexavalent chrome. This prohibition is expected to reduce the risk of cancer cases due to cooling tower emissions to virtually zero. Additionally, elimination of hexavalent chromium-based treatment chemicals will eliminate the amount of hazardous and toxic wastes discharged through blowdown.

COOLING TOWER DESIGN

Most cooling towers are designed with recirculating water systems to conserve water resources and reduce costs of purchasing water. Cooling towers generally use open recirculating systems, although some employ closed systems. In open (wet) recirculating systems, warm water is brought into contact with air. Cooling takes place through evaporation. A simplified flow diagram of a typical open recirculating cooling tower system is shown in Figure 1. In closed (dry) recirculating systems, the warm water and air are separated by a solid surface, usually steel, which conducts heat from the warm water to the cooler air. Such systems require very large heat transfer areas. The cost of constructing such closed recirculating systems is about ten times that of wet direct contact systems (Kirk and Othmer 1979). They are thus not constructed unless there is an extreme scarcity of water. It is the more common open systems that are responsible for hazardous air emissions.

Figure 1



Typical open recirculating cooling syst

Source: Drew (1977), Principles of Industrial Water Treatment

Cooling towers use either forced drafts or natural drafts to circulate water. The forced draft to uses fans to move air. The difference in buoyancy of the air column in a very tall stack provi the driving force in a natural draft tower. Both towers employ a set of louvers and baffles (cal the "fill") over which warm water passes. The internal grid work of the fill material is designec enhance splashing and film formation in order to give a large water-air interface. Depending the tower characteristics, air may flow across this cascading liquid or counter current to it. M cooling towers are equipped with drift eliminators that prevent water bubbles and droplets fr leaving the water distribution portion of the tower. Several designs are in current use, most of wh prevent water losses by redirecting the escaping bubbles and droplets back into the tower's ba (Drew 1977).

WATER LOSS AND COOLING TOWER EMISSIONS

Although water is recirculated in open cooling systems, losses are considerable. They occ mainly through :

a) evaporation into the exhaust air stream. Evaporation provides for 80 percent of the coolin Evaporated water does not contain chemicals, and so is not environmentally hazardou (SCAQMD 1989).

b) cooling water blowdown. Cooling water blowdown is a purge stream, which is necessar to prevent excessive build up of dissolved solids in the circulating water inventory. Th makeup water to the cooling tower contains dissolved solids. Without the blowdown, thes solids would quickly build up to the levels resulting in excessive scaling of heat transfe surfaces. Cooling water blowdown is treated to remove chrome before being discharged

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c) drift. Water droplets and bubbles that escape from cooling tower stacks are referred to as drift. Drift is estimated to be in the range of 0.003% to 0.005% of circulating water (in gpm). Drift emissions are made up of large and small water droplets and bubbles. Large drops and bubbles are relatively heavy and may settle or condense in the vicinity of the cooling towers. Small bubbles and droplets travel further and can find their way into the human respiratory system. It is such respirable emissions that present a danger to human health and the environment.

THE NEED FOR COOLING WATER TREATMENT

Circulating water chemical treatment is practiced to control scaling, erosion, corrosion and biological growth within the cooling towers, heat transfer units and associated piping. These phenomena are caused by dissolved and suspended solids and nutrients that promote the growth of microorganisms in the circulating water.

Scaling and fouling of heat exchange surfaces drastically reduce the heat transfer efficiency, resulting in sharp rises in energy transfer costs. Deposition of scale in heat exchanger tubes, on fill and in drift eliminator ports results in clogging, higher pressure drops and alteration of fluid flow characteristics. This can lead to frequent shutdowns and increases in the generation of system cleaning wastes, maintenance and operating costs. Aeration of water in the cooling tower generates a highly corrosive environment for the tower components and associated equipment in contact with the water. Excessive corrosion causes additional maintenance and premature replacements of capital equipment. These operational problems cannot be controlled unless corrosion inhibitors, antiscalants, antifoulants, dispersants, surfactants, biocides and pH control chemicals are added to the circulating water (Table 1).

Table 1

Water Quality Problems and Possible Chemical Treatment

Problems	Chemical Additives Employed To Solve The Problem
Corrosion	Chromate, Zinc, Molybdate, Silicate, Polyphosphate, Aromatic azole, Carboxylate.
Scaling	Polyphosphates, Polyester, Phosphates, Polyacrylates.
Fouling	Polyester, Phosphates, Polyacrylates, non-oxidizing biocides.
Biological Growth	Non-oxidizing biocides, Chlorine, Bromine.

Chromate compounds are among the most efficient and cheapest corrosion inhibitors available. However, they are highly toxic and suspected to cause cancer in human beings. Hence they must be replaced with non-chromate-based chemicals. Some that have proved useful are polyphosphates, organophosphates, zinc, molybdates and aromatic azoles. Unlike chromate inhibitors, these substitutes perform well only under specific conditions. This disadvantage can be overcome by employing blends of two or more inhibitors that can take advantage of the strengths of each. Table 2 compares the performance of some of these blends to that of a chromate-zinc blend. Note that while the chromate-zinc combination offers the best corrosion inhibition in most cases, other blends are close. To obtain the best results, several blends must be tested (for a

specific water quality) and the one that best satisfies all performance requirements sho chosen.

Table 2

Comparison of Several Inhibitor Blends (Roti and Soeder 1988)

Treatment chemical blends[2]	Concentration (mg/l)	Corrosion Rate (mpy)[1] LISCW[3]	HISCW[4]	HISAW[5]
Molybdate-HEDP-Azole	8.0	6.2	36.0	2.9
Molybdate-HEDP-Azole-Zinc	6.0	4.8	3.8	1.3
Molybdate-Orthophosphate-Azole	6.0	2.0	1.2	1.8
Molybdate-Phosphonate-Azole	6.0	8.3	42.0	2.0
High phosphate	15.0	2.0	1.2	2.9
Zinc-chromate	20.0	0.8	0.8	1.4

Table 2 (continued)
Water Quality

Criteria	LISCW	HISCW	HISAW
pH	7.7	7.0-7.5	8.0-8.5
Calcium as $CaCO_3$	64	300	300
Magnesium as $CaCO_3$	32	100	100
Chloride as Cl	17	500	210
Sulfate as SO_4	21	500	95
Silica as SiO_2	15	20	20
Total alkalinity as $CaCO_3$	72	20	120
Conductivity as mhos/cm	269	1710	1100
Langelier Saturation Index	0	-0.7	+1.1
Ryzner stability index	7.7	8.4	5.8

[1] mils of mild steel per year.
[2] based on proprietary chemical data.
[3] Low ionic strength corrosive water.
[4] High ionic strength corrosive water.
[5] High ionic strength alkaline water.

Non-chromate chemicals may have some adverse impacts on the environment. For examp while zinc based chemicals are not particularly dangerous to humans, they are highly toxic marine life. Similarly, phosphates discharged into lakes and ponds may cause excessive al growth leading to eutrophication problems. But in comparison to the highly toxic chroma inhibitors, the substitute chemicals are relatively innocuous and do not present the san environmental problems that chromates do. Nevertheless, the impact of substitute chemicals the environment must be carefully analyzed before actually using them.

It is encouraging to note that before the Rule went into effect, 85% of the cooling towers operatin in the South Coast Air Quality Management District had already changed to non-chromat systems. The remaining 15%, however, have the potential to cause as many as 700 cancer case in the years ahead if they are not modified (SCAQMD).

ECONOMIC CONSIDERATIONS

No major modifications to the cooling tower are required for changing from chrome to non-chrome systems although new test kits for analyzing and sampling will have to be used. Non-chrome chemicals, such as phosphates, react with metal surfaces and tend to remove existing chrome coatings from metal parts. This can lead to severe localized pitting. Therefore existing chrome coatings on cooling tower and downstream components must be completely removed before chromate systems with cooling capacities of 500 and 3000 tons (T) are shown in Table 3. The costs shown in Table 3 include capital and maintenance costs, but do not include regulatory and operating costs. The capital cost includes new equipment and shortened life of towers using non-chromate chemicals. Non-chromate treatment costs can significantly vary depending upon the type of treatment used. The treatment costs shown in the table are average values and can vary as much as ±50%. Presently, non-chromate chemical treatment costs are far more expensive than chromate treatment costs. However, with the increased consumption of non-chromate chemicals, the cost is bound to reduce significantly.

Table 3

Cost Estimates*

Parameters	Chromate		Non-chromate	
Tower life in years**	20		15	
Cooling Load in tons (T)	500	3000	500	3000
Tower cost in $/yr	3500	18000	4300	22000
Treatment cost in $/yr	1000	6000	5000	30000
Maintenance cost in $/yr	1500	9000	25000	13000
Total annual cost	6000	33000	11800	65000

* Does not include down stream piping and equipment (such as coolers).
** Source: SCAQMD 1989.

OTHER OPTIONS

Currently, the best possible solution to the chromate problems appears to be replacement with non-chromate chemicals. However, in view of the potential hazards of many of the alternate chemicals, it may be wise to eliminate or reduce the emission of any treatment chemicals into the environment. This could be accomplished by :

a) Makeup water pretreatment. Pretreatment of makeup water to cooling towers reduces the chemical treatment requirements for scale and corrosion control and can increase the number of times cooling water may be recycled before blowdown. Pretreatment reduces dissolved solids in the makeup water through precipitation and flocculation, softening and ion-exchange. Suspended solids are removed by clarification and filtration. Pretreatment may not be economical for "comfort" cooling towers (those used in office building air conditioning systems) but is advantageous for large industrial cooling towers.

b) using inert construction materials. Polyethylene (PE) and stainless steel (SS) are rela non-reactive compared to carbon steel. Therefore PE and SS towers would re relatively lesser quantities of scale and corrosion inhibitors.

c) increasing the heat and mass transfer efficiency of cooling towers. Efficiency ca enhanced by improving the design of cooling towers. One example is to avoid des where sunlight can shine directly on the water; adding to the cooling load and prom biological growth. Increasing the efficiency will result in the usage of smaller towers need less treatment chemicals.

d) increasing the efficiency of pollution control devices. Cooling tower emissions ma reduced by installing high efficiency drift (HED) eliminators (such as waveform advanced interlaced monofilament eliminators) claim to reduce drift by 80%. Howe even these eliminators are not capable of capturing most of the smaller respirable drop and bubbles, which are the main source of health concerns.

e) use of wet-dry forced draft cooling towers (WDCT). In this type of tower, a dry coo section is added to a conventional evaporative cooling tower. WDCT's combine advantages of lower consumption of water and water treatment chemicals, reduced fogg problems in winter, and economical cooling during summer. WDCT's are larger in size cost about 25% to 100% more than wet forced draft cooling towers. The economics of us such systems largely depends on the geographic location of the cooling tower, and may be a viable alternative in the case of comfort cooling towers.

REGULATORY CONSIDERATIONS

The SCAQMD has declared Rule 1404 to be effective starting January 1st 1990. This n prohibits the use of hexavalent chrome-containing water treatment chemicals in open circulati waters of cooling towers. According to the rule, the concentration of hexavalent chrome in t cooling tower water of non-wooden towers is not to exceed 0.15 mg/l. The rule also requir biannual testing of the circulating water and accurate record keeping of test results.

Residual chromate chemicals may slowly desorb from wooden towers that were using chromi chemicals in the past. To account for this phenomenon, the law allows chrome concentratio up to 8 mg/l in wooden tower circulating waters until July 1st 1990. Thereafter, wooden towe must also comply with the 0.15 mg/l chrome concentration limit. The chromium chemicals can b desorbed quickly from the wooden towers using high pressure water flushing in combination wi alkali/acid treatment techniques. Cooling tower chemical treatment suppliers claim that aft appropriate treatment, the chromium concentration in the replaced systems can be reduced t less than 0.15 mg/l in less than six months (Atwater, 1990).

In addition to SCAQMD, other regulatory agencies such as EPA, Bureau of Sanitation an Occupational Health and Safety Administration (OSHA) can regulate use of various consume and industrial hazardous chemicals. For example, cooling tower operators require Nationa Pollution Discharge and Elimination System (NPDES) and Industrial Waste Water permits befor discharging cooling tower blowdown.

DISPOSAL OF HEXAVALENT CHROMIUM-BEARING WATERS

Hexavalent chromium bearing recirculating waters and cooling tower sludges must be disposed of appropriately before changing to non-chromium based systems. Recirculating waters are currently disposed of in the same way as blowdown, by mixing with other building sanitary sewer waters. However, permission must be obtained from the local sanitation district before disposing of recirculating waters in this way. While disposing the chromium bearing recirculating water into the sanitary sewer, care must be taken not to exceed the hydraulic loading capacity of the existing sewer system and the discharge chromium concentrations permitted by the local sanitation district. Sludge that has collected in the cooling tower basin while operating the chromium system must be analyzed for chromium-concentrations. If the concentrations exceed State of Federal toxicity criteria, the sludge must be disposed of appropriately as a hazardous waste.

CONCLUSION

Open recirculating cooling towers emit droplets of water into the air that carry chemicals used for treating recirculating waters along with them. Treatment is performed to control scaling, erosion, corrosion and biological growth within the cooling tower, heat transfer units and associated piping. Hexavalent chromium based treatment chemicals have traditionally been used for this purpose because they are the most efficient and cheapest among commercially available treatment chemicals. But the problem is, hexavalent chromium is a suspected carcinogen. Chrome emissions from cooling towers in the SCAQMD alone could cause as many as 700 cancer cases over a 70 year exposure period.

In view of the environmentally harmful effects, SCAQMD has banned the use of hexavalent chromium based chemicals in open recirculating cooling towers. The ban is effective starting January 1st 1990. Many other alternates to hexavalent chromium based chemicals are commercially available. These products are currently comparatively expensive and somewhat less effective than chromium chemicals. With the increased consumption of non-chromate based treatment chemicals, however, the cost of such treatment is bound to be reduced.

REFERENCES

Atwater, Ed. 1990 Aqua Serve Inc. Personal Communication.

Roti, Joseph and Soeder, Kenneth. (1988) Technical Paper Number TP 88-03, Cooling Tower Institute 1988 Annual Meeting.

Drew. (1977) Principles of Industrial Water Treatment. Published by Drew Chemical Corporation, Boonton, New Jersey.

Popejoy, Cliff. 1990 California Air Resources Board. Personal Communications.

South Coast Air Quality Management District (SCAQMD). 1989 Agenda #34 - Adopt Proposed Rule 1404. El Monte, California.

ADDITIONAL PUBLICATIONS

Several articles on various aspects of cooling tower chemical treatment have been published by the Cooling Tower Institute. A bibliography and price list of all these papers are available from the cooling tower institute. PHONE: (713) 583-4087.

FURTHER INFORMATION

For more regulatory information on Rule 1404 contact :
South Coast Air Quality Management District Board (SCAQMD)
PHONE : (818) 572-6200
California Air Resources Board (CARB)
PHONE: (916) 322-8521.

FURTHER INFORMATION

For further information and assistance or quest additional publications please cont HTM Office at:

City of Los Angeles
Board of Public Works
Hazardous and Toxic Materials Office
200 N. Spring Street, Room 353
Los Angeles, California 90012
(213) 237-1209

The Board of Public Works Hazardous and T Materials Office was established by the Los geles City Council in 1988. The purpose o program is to promote the National policy of mizing hazardous waste generation and en citywide compliance with hazardous mate and waste requirements. Technical assista is provided to City agencies and industry thro on-site consultation, information disseminat and waste assessments.

TechnicalAssistance for this publication provided by Jacobs Engineering Group

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200 N. Spring Street, Room 353
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Reducing Water Usage With Cooling Towers

MnTAP
Minnesota
Technical
Assistance
Program

You may benefit from using a cooling tower if you are using water for cooling in the following v

- Cooling heavy machines
- Quenching hot metals and other materials
- Air conditioning units
- Molding processes
- Condensers
- Cooling computers

BENEFITS

Limited water supplies and rinsing water costs have driven companies to look at water conservation measures. Cooling towers replace the single use cooling system where water is used once to cool and then discharged. Using a cooling tower can have the following benefit

- May reduce cooling water usage and wastewater discharge by as much as 97% when contrasted with flow-through systems.
- May reduce scaling problems on heat transfer systems, particularly where cooling water is considered hard.

INITIAL CONSIDERATIONS

The items listed below are to assist you in determining whether you should further explore th possibility of a cooling tower for your company. Keep in mind - - -

- The water quality will require checking periodically, unless the system is totally automated.
- Special handling procedures may be required since chemicals used may be toxic or hazardous.
- Routine maintenance of the system is required. Although automatic controls add to the cost of the system, they will reduce the amount of time required for maintenance.
- The payback period may be as low as 6 months or greater than 5 years.

BACKGROUND

Cooling towers take advantage of the process of evaporation. When water evaporates, the energy to vaporize the water comes from the water itself. The energy required to vaporize water is very high and so only a little water has to be vaporized to cool the water extensively. Cooling towers take advantage of this natural process of evaporation and the cooling the evaporation provides.

Towers are designed to expose the maximum moving water surface to the maximum flow of ai for the longest possible period of time. This then increases the tower's cooling ability. Some towers may have a pressure-spray type water distribution system while others use mechanica devices to force air into contact with the water. Each has advantages and disadvantages whic must be considered in meeting a specific cooling need. Units can be purchased which are factory-assembled, and easy to set up on-site. Larger towers may involve fabrication on-site.

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FACT SHEET

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OPERATION

One of the consequences of water evaporation, is that the solids from the water evaporated are ther concentrated in the water left behind. In addition, during the evaporative phase, contaminants form the air are also washed out into the water. The more effective the cooling operation, the more effective is the transfer of air contaminants to the water.

Controlling the level of dissolved solids becomes a very important requirement in operating a cooling tower satisfactorily. This is done by discharging a percentage of the water continuously ("blow down") and replenishing this with relatively pure make-up water and by chemical treatment. "Blowdown" is often expressed as a percentage of the total water volume of cooling tower or as gallons per minute (gpm). The discharge volume is affected by the quality of the incoming water, of the air with which the water comes in contact, the evaporation rate and the effectiveness of the water treatment chemicals. "Blowdown" or "bleed off" may also be used to eliminate or reduce water treatment requirements. Maintaining the proper chemical composition is important for two reasons; the protection of the equipment itself and the efficient operation of the system.

Along with the "blowdown," chemicals are added to control scale, corrosion and microbial growth. Reducing dissolved solids is effective both in reducing potential for scale build up and corrosion. If scale builds up, as salts and solids increase and precipitate out on the heat exchange surfaces, the efficiency of the unit is reduced. Mold, bacteria or fungus growth can also effect the operating efficiency of the unit.

EQUIPMENT

Needed Equipment

- A tower, which includes packing material to increase heat transfer rates and a fan to force air past the water. Metal tower components corrode faster than wood or plastic. Wood towers are more resistant than metal towers to corrosion and microbial growth, but harsh chemicals may leach out the wood's natural strengthening components. Plastic towers are resistant to acids, bases, salts, rust and microbial attack. Metal towers have an operation life of 12-15 years, while plastic or wood towers may last 20 years. The prices are roughly comparable. When making price comparisons, make sure the features and expected life of the compared towers are similar.

- A reservoir will be needed to prevent fluctuations in the system and for storing the water at night. If the system is only used in the summer then the reservoir may be located beneath the tower rather than inside the building. The water will freeze in the winter if it is not indoors. The reservoir size (in gallons) is roughly three times the water rate (in gal/min). Reservoirs can also be constructed from wood, metal or plastic.

- A pump will be required to force the water throughout the system. The pressure required to distribute the water through out the system should be known in order to size the pump. Size and length of piping, and the height that the water must be raised are also factors that need to be known. A good distributor will be able to help you find the needed information.

Optional Equipment

- A control panel may be desired for ease of operation. It is usually used when several towers are connected together and any number of them may be turned on or off depending upon the heating load at the time. One advantage of a control panel is that it centralizes the controls and allows start up and shut down of any of the towers.

- Automatic controllers that monitor the concentration of dissolved solids, pH, and temperature. This allows for adjustments in rate of bleed off, or automatic addition of treatment chemicals. Automatic monitoring and control can contribute to cost savings in chemical usage, and water usage along with reduced labor associated with manual adjustments and cleaning.

- Fire protection equipment may reduce insurance premiums.

SELECTING A COOLING TOWER

Primary considerations

- Determine the heat load from the process. This is critical in making certain the cooling tower is correctly sized. This should be available from the manufacturers of the equipment requiring cooling. If not, it can be obtained by measuring the flow rate, the entrance and the exit temperature of the current cooling streams at maximum operation.

- Cooling water temperatures must not exceed temperature limits for materials in the operation. Systems can be designed where water which exits from the process has a temperature of 95° F or greater than 140° F. Will 140° F be too hot for your process?

- Towers in Minnesota are designed to cool water to 85° during summer heat. A water chiller may be needed to meet your cooling needs for this period of the year.

- Determine whether additional structural support is required for mounting a tower on top of a building.

Water Treatment Considerations

- High priority should be given to selecting chemicals that will allow the cooling water to be discharge directly to the sanitary or storm sewer without further treatment. While this may raise costs for treatment to the cooling water, overall it will reduce costs.

- Select chemicals that will work together effectively as one package by working with one supplier. Make certain that the physical and chemical characteristics of your company's water have been taken into consideration.

- Consider using deionized water for make up as this will lower requirements for chemical treatment an may also reduce the rate of "blowdown."

- Consider advantages of automatic additions of chemicals. For a small tower, manual addition may be reasonable. This might simply mean adding a bag of chemicals to the reservoir every few months. However, for larger systems, automation is preferred. This means monitoring would occur prior to addition, thus likely resulting in chemical cost savings from unnecessary chemical addition.

Other Considerations

- Safety features must also be considered. The system should revert to a once through, non-recycling system when any of these occur: blower, fan or water pump break-down, electricity outage, high water temperature.

- The tower should be designed to prevent freezing in the winter.

- For a tower with a fan, make certain a mechanism exists to signal if the fan has become inbalanced during operation. This could result in tower damage.

ASSOCIATED COSTS

- At a cost of $2.80/1000 gallons (water and sewer cost in the Minneapolis-St. Paul area), reducing water usage by just 2 gallon per minute can save approximately $2500 per year.

- A cost estimate for a small tower (5-10 gpm capacity) ranges from $3300-$8000.

- A cost estimate for a large tower (over 200 gpm capacity) ranges from $15,000-$42,000.

The following resources are acknowledged for much of the information included in the development of this fact sheet. Should you want more information, either of these resources are available from our office.

Cooling Tower Fundamentals edited by John Hensley, The Marley Cooling Tower Company, Mission, Kansas.

Water and Chemical Reduction for Cooling Towers, Pollution Prevention Pays Program, N.C. Dept. of Natural Resources and Community Development.

WATER AND CHEMICALS REDUCTION FOR COOLING TOWERS

Are you pouring money down the drain? Are you operating a cooling tower in the once-through mode or relying on manual control of air-conditioner bleed-off rates? This may result in undue expenses in the form of unnecessary chemical, energy, labor, and water costs. A once-through system employs no conservation practices and is the most expensive alternative in most instances. The manual bleed/feed approach is at best a calculated gamble, and it may lead to water pollution or operational problems. Random manual bleeding of the system to control the dissolved solids and manual addition of chemicals does not take into account the variability of the loading on a system from day to day. Instead the bleed/feed approach is usually based on "average" conditions. When the loading exceeds this average an insufficient volume is bled off and the solids level becomes too high. The converse is true as well; below average loading results in excessive bleed off of water.

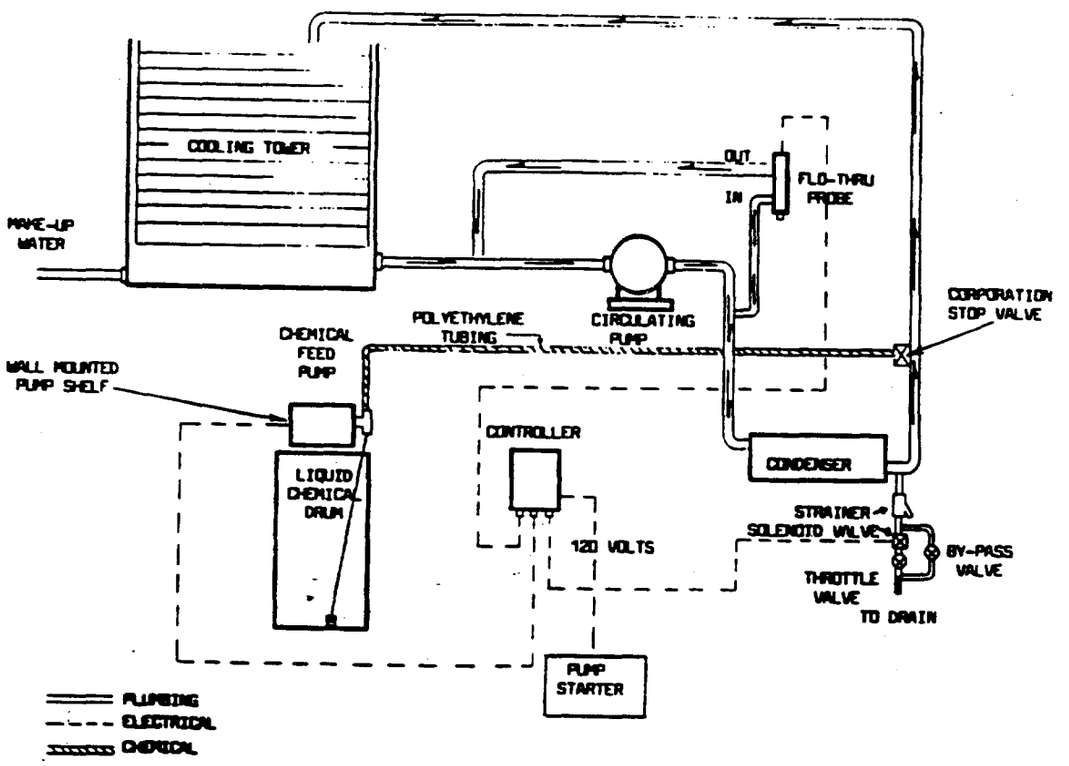
An automated bleed/feed system can reduce water consumption by as much as 60 percent. The cost savings can pay for the controls in a very short period of time. As an example, with combined water and sewer rates of $2/1000 gallons, reducing the water usage by just 1 gpm can save $1000 annually. With a large system, the savings can add up to thousands of dollars annually. When this is added to the reduced operating costs (chemical and energy) the savings are even greater.

The chemical composition of the cooling water must be maintained at the proper level for the system to operate efficiently. Proper control is also necessary to protect the air conditioning equipment. Maintaining cooling water composition is accomplished by: (1) bleeding tower water from the system to overcome the concentrating effects of evaporation and (2) pumping the appropriate quantity of chemicals into the cooling water. Excessive bleeding or chemical addition to the system will result in the discharge of excess chemical conditioners and/or active biocides thereby causing or contributing to water pollution or toxicity problems. Using automatic bleed/feed controllers is a practical approach to reducing the operating costs and minimizing waste from a cooling tower. A diagram of an automated system is shown in Figure 1.

Automatic controllers continuously monitor the concentration of dissolved material in the cooling water. When the concentration

exceeds a preset level, the controller opens the bleed valve an activates the chemical feed pump. Thus the tower is kept at th optimum concentration at all times and unintentional discharge active chemicals is eliminated. This results in a cost savings in many areas. Labor costs for cleaning and manually adjusting chemical feed rates are reduced. Energy consumption is lowered by minimizing scale build up on the heat exchanger surfaces (scale acts as an insulator, thereby reducing the efficiency of the unit). The consumption of both chemicals and water is reduced by avoiding excessive bleeding during periods of lower air conditioning load.

FIGURE 1. AUTOMATIC FEED AND BLEED-OFF SYSTEM FOR COOLING TOWER



(Provided by the N.C. Department of Administration)

Capital and Operational Costs

Automatic bleed/feed controllers and by-pass feeders are not expensive to install or operate. The typical costs for these controls are detailed below.

- Controller: A commercially available controller complete with conductivity probe can be obtained for $325. Installation for the controller will add and additional $75. Several systems are available. The Pollution Prevention Program can provide a list of vendors if desired.

- Chemical Feed Pump: A chemical feed pump and associated appurtenances can be obtained for about $150.

- By-Pass Feeder: A by-pass feeder for adding biological control agents in the cooling system can be obtained for about $150.

The total cost for installing an automatic bleed/feed system and the equipment to introduce biological control agents into the system would be about $1000.

There are no direct operational costs associated with the automatic bleed/feed system. However, the units must be included in the facility's routine inspection and maintenance programs.

Pay Back

The pay back period for installing automatic bleed/feed controls will depend on several factors such as the quantity of water saved, including both water and sewer costs; savings resulting from reduced chemical costs; energy savings; and reduced labor costs. As an example, the North Carolina Department of Administration has installed automatic bleed/feed systems on fifteen air conditioning systems in government office buildings at a total investment of $15,000. The Department has reported a payback period of five (5) weeds and total annual savings of $149,000 as a result of the automated system. The Department of Administration is now recommending that all State owned cooling towers and air conditioners by fitted with bleed/feed controllers.

Specific water, energy, chemical, and labor cost savings experienced by the Department of Administration are as follows:

- Chemicals The chemical costs have been cut from $17,300/yr to $5,445/yr. (Savings = $11,855).

- Energy — The energy savings as a result of the automation has been determined to be 13 percent. At $0.05/KWH this translates into an annual savings of $68,842.

- Labor — All chillers require cleaning and rodding at least annually. Assuming an hourly wage of $8.00, the labor costs for cleaning and rodding were reduced by $2,400/yr due to less frequent need for cleaning. Labor costs for daily manual adjustments of the chemical feed and tower bleed rates were $2,826. (Total savings = $5,226).

- Water — Since the installation of automatic bleed/feed controllers cooling water is now used for 4.5 cycles as opposed to 1.5 cycles before. This saves 34,900,000 gallons of water annually. Based on a combined water and sewer rate of $1.83/1000 gallons, the annual savings is $63,900.

Additional Information

For additional information on automatic bleed/feed systems for cooling towers, contact:

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P.O. Box 27687
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Pollution Prevention Program
N.C. Department of Environment, Health, and Natural Resources

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Appendix B

Selected PP/WM Case Studies for Chemical Manufacturing Industries

Selected Case Studies:

1. "E.I Du Pont De Nemours and Company - Chambers Works, Deepwater New Jersey." (Excerpted from Mark H. Dorfman e al., Environmental Dividends: Cutting More Chemical Wastes. New York, INFORM, 1992., pp 154-163. Reprinted by permission.)

2. "Exxon Chemicals Americas - Bayway Plant, Linden, New Jersey." (Excerpted from Mark H. Dorfman e al., Environmental Dividends: Cutting More Chemical Wastes. New York, INFORM, 1992., pp 164-170. Reprinted by permission.)

3. "International Flavors and Fragrances, Inc. - Fragrance Ingredients Plant, Union Beach, New Jersey." (Excerpted from Mark H. Dorfman e al., Environmental Dividends: Cutting More Chemical Wastes. New York, INFORM, 1992., pp 193-199. Reprinted by permission.)

4. "Monsanto Company." (Excerpted from Mark H. Dorfman e al., Environmental Dividends: Cutting More Chemical Wastes. New York, INFORM, 1992., pp 210-216. Reprinted by permission.)

5. "Waste Reduction Activities and Options for a Manufacturer of Fine Chemicals Using Batch Processes." (P. Eyraud and D.Watts., U.S. EPA Environmental Research Brief, EPA/600/S-92/055, October 1992.)

6. "Waste Minimization Assessment for a Manufacturer of Chemicals." (G. Looby and P. Miller., U.S. EPA Environmental Research Brief, EPA/600/S-92/004, May 1992.)

7. "Reduction of Waste Oil is Achieved by Filtering and Recirculating Lubricating Oil." (Environmental Resources Management, Inc., A Study of Hazardous Waste Reduction and Recycling in Four Industrial Groups in New Jersey. April 1987.)

8. "DuPont Incorporates Pollution Prevention Measures." (G. Hollod and R. McCartney. Waste Management in the Chemical Industry: Du Pont's Approach. Journal of the Air Pollution Control Association. February 1988.)

9. "Source Reduction Alternatives were Investigated for those Wastes Shipped Off-site for Treatment." (Environmental Resources Management, Inc., A Study of Hazardous Waste Reduction and Recycling in Four Industrial Groups in New Jersey. April 1987.)

10. "Tank Cleanout Reuse Eliminates Generation of Corrosive Waste." (Environmenta Resources Management, Inc., A Study of Hazardous Waste Reduction and Recycling ii Four Industrial Groups in New Jersey. April 1987.)

11. "Better Housekeeping Practices and Building Renovation Reduced the Volume oi Wastewater Shipped Off-site for Treatment." (Environmental Resources Management, Inc., A Study of Hazardous Waste Reduction and Recycling in Four Industrial Groups in New Jersey. April 1987.)

12. "Sodium Phosphate Made from Phosphorus Sludge." (Compendium on Low and Non-Waste Technology, United Nations Economic and Social Counsel, Monograph ENV/WP.2/5/Add74)

13. "Production of Ammonium Nitrate with Continuous Control of the Reaction and Degassing of the Resulting Water Vapors." (Compendium on Low and Non-Waste Technology, United Nations Economic and Social Counsel, Monograph ENV/WP.2/5/Add40)

14. "Production of Aluminum Fluoride with Utilization of Waste Silica." (Compendium on Low and Non-Waste Technology, United Nations Economic and Social Counsel, Monograph ENV/WP.2/5/Add112)

15. "Manufacturing of Soda Chlorate by Electrolysis of Sodium Chloride with Graphite Anodes." (Compendium on Low and Non-Waste Technology, United Nations Economic and Social Counsel, Monograph ENV/WP.2/5/Add92)

16. "Use of Anhydrite Formed in the Hydrogen Fluoride Production Process." (Compendium on Low and Non-Waste Technology, United Nations Economic and Social Counsel, Monograph ENV/WP.2/5/Add123)

17. "New Sodium Chlorate Factory Triples Production and Employs Source Reduction Techniques to Avoid Treatment Costs." (Secteur Chimie Enorganique, Technologies Propres, Production du Chlorate de Sodium. Gouvernement du Quebec, Ministere de l'Environnement, Gestion et Assainissement des Eaux, Revised June 1988. Source document is in French.)

E. I. DU PONT DE NEMOURS AND COMPANY
Chambers Works
Deepwater, New Jersey

Summary

Du Pont's Chambers Works plant, built in 1917 and located in southern New Jersey, across the river from Wilmington, Delaware, is one of the oldest and largest chemical plants in the United States. There are 3,500 employees and 500 contractors working at the site which has 45 buildings housing five to six separate business operating units manufacturing close to 750 different products and shipping over 1 billion pounds of product per year.

Du Pont established an official company policy "minimizing waste to the extent technologically and economically feasible" in 1980. A primary incentive for this policy at that time was that the on-site wastewater treatment plant's capacity had proven too small to treat all the waste generated when the Chambers Works plant changed from producing solvent-based dyes to producing water-based dyes. This policy has developed into a program which includes a corporate Waste Minimization and Internalization Committee, overseeing the corporate database, policies, and progress reports, as well as a "waste minimization coordinator" at the Chambers Works site, who is responsible for developing, coordinating, and implementing the site's "waste minimization plans." At Du Pont, "waste minimization" includes source reduction and recycling; waste treatment is a separate (and significant) operation at the Chambers Works plant.

Du Pont has a corporate-wide database on the generation of wastewaters and solid waste dating from 1982. The database includes process wastewaters and recycled materials in addition to RCRA-regulated waste, but does not include air emissions. However, its tracking system does not allow monitoring of waste at the process level.

The Chambers Works source reduction program is overseen by a team of plant personnel from plant management, research and development, engineering management, and Environmental Treatment Services. This team reviews major wastestreams at the plant, performance of the different operating areas, and employee awareness of source reduction opportunities. Du Pont has set goals for every plant to meet; the Chambers Works plant reports progress in meeting the goals as the amount of waste reduced per pound of product. The current goals are to reduce hazardous solid and liquid waste by 35 percent from 1990 to 2000 and reduce toxic air emissions 50 percent from 1987 to 1993.

The company did not grant an interview for INFORM's 1985 study. However, for this report, Du Pont did grant an on-site interview to INFORM and conducted a tour of its Chambers Works facility. The plant reported 13 source reduction activities, mostly involving in-process recycling. They reduce 39,290,000 pounds of waste and save the company $3,755,000 each year.

Products and Operations

Du Pont's Chambers Works plant in Deepwater, New Jersey, one of the oldest and largest chemical plants in the United States, now occupies 619 acres. More than 1,200 products — including Teflon, Freon, neoprene, and Orlon — have been invented or developed at the Chambers Works site. Today, it is a highly technical complex using 3,400 raw materials and over 1,000 intermediates to produce 750 products. There are 45 buildings, 3,500 employees, and about 500 contractors at the plant. Over 75 percent of the 2,000 complex operations at the Chambers Works plant are batch processes, making up about 50 percent of the volume of chemicals produced. Continuous operations produce tetraethyl lead, Freon, and some nitrations.

Du Pont's Chambers Works plant is organized into separate production business units that produce chemicals for textiles, automobiles, agriculture, the building industry, soaps and detergents, and intermediates. Over 1 billion pounds of product are shipped per year from Chambers Works' Deepwater port, in anything from small boxes to tank cars and ships. Forty-two percent of its business is with other Du Pont plants that use materials produced at Chambers Works in other processes.

The site also has a research laboratory which currently concentrates on research for Du Pont's Chemicals and Pigments Department. In addition to products, it develops waste treatment and control technologies.

The Chambers Works plant is a permitted RCRA treatment, storage, and disposal (TSD) facility. More than 600 customers in Delaware and New Jersey send hazardous waste to this facility, which treats over 85 percent of all hazardous aqueous manifested waste (as regulated under RCRA) handled in New Jersey in its on-site wastewater treatment facility. Facility officials also provide assistance to these other waste generators in reducing their hazardous wastes.

Environmental Policy

Du Pont's policy of minimizing waste to the extent technologically and economically feasible, established in 1980, includes a hierarchy of options: source reduction, recycling and recovery of by-products, and detoxification and destruction (treatment and incineration), with containment (landfilling) as a last resort. In 1990, the policy was rephrased as "we will not make, handle, use, sell, transport or dispose of a product unless we can do so safely and in an environmentally sound manner."

The first objective listed in the Chambers Works' mission statement is to operate its facilities emphasizing continued improvement in safety, health, and environmental performance as the highest priority. Techniques for improving yields and consequently reducing waste have been going on for many years at the Chambers Works plant according to Du Pont. In addition, ways to reduce wastes were also being explored during the 1970s as Du Pont changed from solvent-oriented to water-based dye production and the capacity of the site's wastewater treatment plant proved to be too small.

Corporate environmental policy is developed by the Environmental Quality Committee for the Manufacturing Committee. The Manufacturing Committee has a Waste Minimization and Internalization Subcommittee to help develop more specific policies that can then be implemented by the various corporate departments, including the Chambers Works plant.

Each plant site has a "waste minimization coordinator" who is responsible for developing, coordinating, and implementing a written multimedia "waste minimization plan" for the site. The waste minimization coordinator also reports annually on progress made to the corporate database. Du Pont's "waste minimization program" emphasizes reduction, recycling, reclamation, reuse, and detoxification. It does not include waste treatment, which is a separate but significant operation at the Chambers Works plant.

Corporate policy also includes a "waste internalization program" that requires that all wastes be treated on-site or at other Du Pont sites. This program was begun in 1982 in response to a problem of not being able to rely on commercial waste handlers to properly dispose of Du Pont wastes. Further, if the company used a commercial facility that closed down suddenly, the Du Pont plant might also have to close if it could not handle its own wastes.

Plant managers at Du Pont typically come up through the ranks and are moved around to gain a wide range of manufacturing experience. The plant managers' primary responsibility is safety, health, and environmental protection. This includes quality control as well as public relations. The plant manager also works with a business manager at corporate headquarters in Wilmington, Delaware, whose primary responsibility is sales, profits, and product selection.

The plant manager is also responsible for ensuring that hazard reviews are done for any proposed new processes and may make suggestions, such as a different process or safer raw material. A plant manager can also require source reduction measures even if there are resources to treat a waste on-site.

According to a 1986 *Washington Post* article, Du Pont emphasizes both rising treatment and

disposal costs and favorable economics of source reduction as incentives for source reduction. An economic and environmentally acceptable plan for waste management can make Du Pont a low-cost producer and hold the key to the success or failure of many of its businesses.[1]

Materials Data Collection

Du Pont has a corporate-wide (except for Conoco and European operations) database on waste generation which dates from 1982 and currently includes data on solid and liquid waste. Air emissions are quantified through engineering calculations based on the number of valves and flanges, rather then on direct measurement. Wastes are tabulated for the following categories: RCRA wastes, on- and off-site disposal of solid waste, ocean disposal, deep-well injection of wastes, process wastewaters (influent to the on-site wastewater treatment plant), waste fuels (RCRA), and recycled materials. Thus, while most of the wastes tabulated in Du Pont's database are RCRA wastes, it does include non-RCRA categories such as process wastewaters and recycled materials. Du Pont officials state that while air emissions are not part the database, plans are underway to include them.

The corporate database took 20 person-years and $5 million to establish. Its primary purpose is for the generation of reports, both corporate and governmental, that can help officials see where and how waste management can be improved. It can, however, also be used to report on source reduction and to identify potential areas for source reduction as data are established on standard measures for waste generation and on waste generation in different years. While waste generation data are initially collected for each process within each business unit at the Chambers Works plant, periodic measurements are then made at a waste collection tank at each of the business units, rather than at each process. The data are specific to wastestreams or to chemical categories and may refer to mixtures of chemicals. Thus, the plant does not do materials balances at a process or chemical-specific level.

Other Source Reduction Program Features

In addition to having a formal source reduction policy and materials accounting (but not materials balance), Du Pont's Chambers Works plant has five other source reduction program features identified by INFORM: an environmental program, environmental goals, cost accounting, leadership, and employee involvement.

The formal source reduction and recycling program began at the Chambers Works plant in 1983 with the formation of a Waste Minimization and Internalization Committee, a year before RCRA's 1984 requirements for a "waste minimization program." Company officials said it was seen as good business: if source reduction was implemented, then Du Pont would be in a good position when the governmental requirements were established while its competitors might not be. The purpose of the committee was to make all the operating departments aware of costs and opportunities for source reduction.

Today, the Chambers Works plant's source reduction program is overseen by a Chambers Works "environmental leadership team" whose membership includes plant management, research and development management, engineering management, and Environmental Treatment Services business management. A subcommittee, the Waste Minimization Task Force, with members from Environmental Services and Environmental Affairs, helped this committee develop a program for 1987-1988 which included: (1) concentration of efforts on the 75 major wastestreams at the plant, (2) development of a "waste minimization culture" for new and updated processes, (3) performance reviews of the operating areas, and (4) efforts to increase employee awareness of source reduction opportunities. The task force meets biweekly .

For the period 1982 to 1990, the Du Pont corporation focused on its solid and liquid hazardous waste. It set goals to reduce these wastes 35 percent on a wet weight basis, or 20 percent on a dry weight basis per pound of product. The goals refer to the total volume or weight

1 *Washington Post*, September 25, 1986.

of the wastestream materials, which include both toxic chemicals and inert constituents such as water and soil. In 1986, a goal of 5 percent per year reduction was added. In 1990, a new goal was set to reduce hazardous (RCRA-regulated) waste by another 35 percent by the year 2000. It has been the plant manager's responsibility to achieve the goals.

Air emissions were not originally included in the above goals. However, in 1990, Du Pont established a new goal of reducing air emissions of chemicals on the Toxics Release Inventory (TRI) list by 50 percent by the year 1993, using 1987 as the base year. In addition, a specific goal was set to reduce carcinogen emissions by 90 percent by the year 2000, with the ultimate goal of totally eliminating these emissions.

The Chambers Works plant reports progress toward the goals as the amount of wastes reduced per pound of product. From 1982 to 1986, the plant reduced the stream going to the wastewater treatment plant and the volume of landfilled solids by 16.9 percent. This overall reduction included a 16.8 percent reduction in aqueous wastes per pound of product, a 56.5 percent reduction in solids from the wastewater treatment plant per pound of product, and other reductions in other parts of the plant. These figures are on a wet weight basis and may include some water conservation efforts.

While Du Pont does provide an allocation of capital funds for source reduction projects each year, waste treatment costs are allocated to each process on the basis of wastes generated. These costs include costs of wastewater, landfilled solids, and air emissions and are based on chemical categories such as total organic carbon (TOC), acids, or solvents per 100 pounds of product. Wastes are estimated based on defined waste "standards"; that is, the amount of waste, such as TOC or solvents, generated for a certain product/process per 100 pounds of product. This "standard" amount of waste is used to assign costs to the product. At first, the standards may be estimates of waste generated but, as the process is improved and measurements refined, the standards are redefined. Waste standards were first used in 1974 or 1975 at the Chambers Works plant.

Allocated costs include capital and operating costs as well as the costs of the environmental staff. Specific costs included are costs of lost raw materials, operating expenses for the on-site treatment plants, transportation costs, costs associated with accidents and waste clean-up, costs for regulatory compliance, and costs for dealing with the public and customers regarding waste issues.

The corporation's cost reduction program gives Quality Achievement Awards, including monetary awards, to about 20 employees a month. These awards have included awards for source reduction projects. However, Du Pont officials say they are establishing an award program specifically for source reduction, since, in the long term, economics is a driving force for source reduction. According to Du Pont, the company's less profitable plants, with high waste treatment and disposal costs, already have the greatest economic justification for source reduction. Corporate goals and award programs can provide incentives for plants operating at higher profit margins where the economic incentives for source reduction might not be as strong.

Monthly meetings of all employees are held at Chambers Works to publicize source reduction ideas and emphasize that every employee can make an impact. A Waste Minimization Committee, composed of environmental coordinators from all business units, acts as an information network and makes recommendations. It is used as a resource by the line organizations and also conducts reviews, tracking progress toward meeting the site's waste minimization plan.

As part of the company's overall training program, the Personal Effectiveness Process (PEP) includes sending employees off-site for two weeks every year for problem solving and communication training. Du Pont officials feel that this helps them take advantage of new technologies and changes, including those in the source reduction area.

Every new plant process must undergo a hazard analysis, which is often a fault tree analysis identifying potential problems and solutions. Other procedures for new process approval, including trial manufacturing requests and test authorizations, are used as reviewing mechanisms for proposed source reduction projects.

Chambers Works has a central safety/health/environmental committee that has to approve any chemical brought on-site. It operates independently of any business unit. Any operator can shut down an operation if he feels there is a safety hazard. Set rules must be followed to resolve the safety issue before the operation can be started up again. Further, there are employee safety awareness meetings, quality control measures, and evaluation of existing as well as new processes.

The Chambers Works plant has a computerized quality management program, available company-wide, that tracks quality beginning with the raw materials. Insisting that suppliers supply high-quality raw materials, plant officials assert, contributes to source reduction. Manufacturing personnel with line responsibilities within each business unit are responsible for maintaining this database, rather than staff, since they are the ones who can take actions to solve the problems.

The Du Pont corporation is conducting a "waste minimization survey" in all its plants to give plant operators a tool for identifying source reduction opportunities. The survey, which is over 100 pages long, lists the questions and data needed to classify sources of wastes and identify technologies to reduce them. It gives the operators a tool for walking through their facility and identifying problems. It also requests information on source reduction projects already done in order to recognize achievements and INFORM others.

Du Pont's policy on waste internalization also provides an incentive for source reduction. To the extent that the Chambers Works plant can reduce its own wastes, its treatment capacity is available for sale to others. The Chambers Works plant charges other Du Pont plants market prices for treating their wastes.

Source Reduction Activities

Du Pont described 13 source reduction activities to INFORM for this study; these are summarized in Table II-13 and detailed below. The company did not report any source reduction activities to INFORM for the 1985 report, *Cutting Chemical Wastes*.

The first source reduction activity, begun in 1983, and motivated by a desire to improve product quality and reduce waste generation, involves insisting that suppliers provide high-quality raw materials.

Du Pont officials discussed eight in-process recovery/reuse source reduction initiatives at Chambers Works with INFORM. In-process solvent recovery has been a part of process design at the Chambers Works plant for more than 20 years. In more recent years, according to plant officials, a major factor motivating maximum solvent recovery has been the increasing costs of incineration, currently $500 to $1,500 per drum.

At the oxyamines building, in the early 1960s, 10 million pounds per year of 1-butanol were being recovered in a closed-loop process and reused at a savings of $2.75 million. Then, in 1980, 75,000 pounds per year of "still bottoms," a solid waste that used to be landfilled, began to be used as a raw material for producing another product.

At the dimethylaniline building, before 1970, 4 million pounds per year of methanol began to be recovered at a savings of $350,000. Most of the methanol is returned to the same process; the rest is used as a raw material in another part of the plant.

At the speciality intermediates building, in 1985, clean-out solvent recovery began to be used to obtain 750,000 pounds per year of ortho-dichlorobenzene for reuse in the same process, at a savings of $260,000.

In 1985, as part of its program to reduce landfilled wastes and to obtain a cheaper source of chlorine, Du Pont began to redistill still bottom purge streams from its chloroamines process. Twenty-two million pounds per year from this stream are now recycled back into the process at Chambers Works.

Also in 1986, in order to reduce operating costs, an in-process iodine recovery unit costing $1 million was installed at the Chambers Works plant. Eighty to eighty-five percent of the iodine, or 200,000 pounds per year, are now sold as product. Du Pont expects to recoup the capital costs of this project within 3 to 4 years.

Another in-process recovery/reuse effort was initiated in 1985 because New Jersey banned landfilling of material with para-chloroaniline. Du Pont began to reintroduce any off-quality para-chloroaniline flakes back into the production process, using distillation. Du Pont found that minor capital expenses, mainly equipment to unload drums, were needed; 65,000 pounds per year were recycled back to the process. In 1990, this process was no longer in use at Chambers Works.

Since 1988, 250,000 pounds per year of waste methyl ethyl ketone have been recycled back into the process with overall savings of $120,000 a year. The process improvements were taken to reduce the costs of raw materials and avoid the increasing costs of incinerating the waste. Other process improvements at the hydrogen reduction building cut by 50 percent the use of methyl ethyl ketone (MEK) as a reactant and solvent and reduced MEK wastes by 200,000 pounds per year.

In 1986, the Chambers Works plant reduced a source of nonhazardous solid waste that was landfilled. The plant replaced the filter aid at the wastewater treatment plant with perlite, which improved the filter operation, reducing the waste generated by 50 percent or 1 million pounds a year. While the cost per pound of perlite is higher than the former filter aid, the improved performance has reduced operating costs of the treatment plant as a whole.

Process control improvements to reduce operating costs in the Monastral manufacturing unit, implemented from 1979 to 1982, resulted in savings in the use and disposal of nitrochlorobenzene. The improvements have reduced waste purged from the process by 750,000 pounds per year, or 65 percent.

In 1985, Du Pont began a vent abatement program to reduce process emissions, prevent accidental releases, and lower plant operating costs. The Freon plant operator did some mass balance calculations for the entire plant's Freon production process and discovered significant losses through evaporation of this gas from the tank trucks in which Freon was delivered to customers. By installing compressors, the company reduced vapor emissions while saving its customers vapor lost from the trucks.

A 1982 assessment of the plant site revealed that the wastewater collection system, then an in-ground open ditch, was a possible source of soil and groundwater contamination and of evaporative losses. All ditches were scheduled to be closed by 1991 and a new collection system, consisting of an above-ground closed pipe, was planned to replace the open ditches and conform to environmental regulations. The cost of closing the ditches was over $10 million. With the new collection system in place, Du Pont expects further source reduction projects to be identified because, for the first time, it will be possible to measure and confirm wastewater generation from specific plant areas.

Other Waste Management Practices

In addition to its source reduction activities, Du Pont reported employing a variety of other waste management procedures. For example, in the production of Freon, which is used in the silicone industry, Du Pont recovers both Freon and hydrochloric acid from the wastestream for reuse. Some 70 million pounds (80 to 85 percent) of hydrochloric acid are now recovered per year. Half is sold and the remainder is used in the ethyl chloride manufacturing process at the plant. The dollar savings are estimated at $6.5 million a year. In 1985, Du Pont spent about $2 million to improve the quality of the hydrochloric acid by-product, enabling the company to provide a higher quality product to its customers. While this did not result in increased reuse or sale of hydrochloric acid, the higher quality product was a key to staying competitive in the production of Freon.

Du Pont built a wastewater treatment plant at the Chambers Works site in 1974. At the time, Du Pont did not concentrate on ways to reduce the wastewater flow but developed a new technology for treating industrial wastes called PACT (powdered activated carbon treatment). PACT removes more than 90 percent of the EPA's organic "priority pollutants" for wastewater. In 1979, when the dye business at this plant was closed down, Du Pont began to market its wastewater treatment capacity (40 million gallons per day) to others. It now handles about 85

Table II-13 Du Pont (Deepwater, NJ): Source Reduction Activities

Waste Medium (SR Type) Year	Source Reduction Activity	Specific Waste Reduced (Hazardous or Nonhazardous)	Percent Waste Reduced	Amount Waste Reduced	Change in Yield	Dollars Saved	Dollars Spent	Motivation	Comments	Time Needed for Implementation
Various (OP) 1983	Du Pont insists that suppliers supply high-quality raw materials.	Various (H, N)	Not quantified					Higher product quality and lower waste generation.		
Water (PS) early 1960s	Butanol used as a solvent in oxyamines building is closed-loop recovered and reused.	1-Butanol (H)		10,000,000 lb/yr		$2,750,000/yr		Cost reduction.		
Solid (PS) 1980	Still bottoms from oxyamines building are used as a raw material in another product.			75,000 lb/yr				Increased costs of landfilling and process yield improvement.		
Water (PS) pre-1970	Methanol, a solvent used in the dimethylaniline building, is recovered and reused.	Methanol (H)		4,000,000 lb/yr		$350,000/yr		Operating costs reduction.		
Water (PS) 1985	In the specialty intermediates building, cleanout solvent recovery is used to recover ortho-dichlorobenzene.	ortho-Dichlorobenzene (H)		750,000 lb/yr		$260,000/yr		Operating costs reduction.		
Solid (PS) 1985	Still bottom purge streams are redistilled from the chloroamines process and recycled.			22,000,000 lb/yr				As part of program to reduce landfilled waste banned in New Jersey.		
Water (EQ) 1986	An iodine recovery unit installed in the process. Recovered iodine is sold as product.	Iodine (N)	80-85%	200,000 lb/yr		$275,000/yr	$1,000,000	Operating cost reduction.	Expect to pay back costs within 3-4 years.	
Solid (PS) 1986	Off-quality parachloroaniline flakes are distilled and reused in the same process.	Parachloroaniline flakes (H)		65,000 lb/yr				New Jersey banned landfilling of this material.	Minor capital expenses, mainly for equipment to unload drums.	
Water (PS) 1988	(1) Process improvements reduced use of methyl ethyl ketone (MEK); (2) waste MEK recycled back to process.	MEK (H)	50%	1) 200,000 lb/yr reduced 2) 250,000 lb/yr recycled to process	None	$120,000/yr		Operating cost reduction (raw material costs plus reduced cost of incineration).		
Solid (CH) 1986	Perlite replaced another filter aid, improving filter performance of wastewater treatment plant.	Filter aid (N)	50%	1,000,000 lb/yr				Operating cost savings plus improved filter performance.	Cost per pound of perlite is higher than former filter aid.	3 mo
Water (PS) 1979-1982	Process control improvements in Monastral process reduced use of nitrochlorobenzene.	Nitrochlorobenzene	65%	750,000 lb/yr				Operating cost reduction.		
Air (EQ) 1985	Compressors installed in tank trucks reduce vapor losses.	Various (H, N)	Not quantified					Reduced air emissions and operating cost reduction.	Done as part of Du Pont's vent abatement program, result of mass balance calculations.	
Solid/water/air (EQ) 1982-1991	Wastewater collection system (closed, above-ground pipe) being built to replace open ditch system.						More than $10,000,000 (projected)	Environmental regulations.	Will eliminate evaporative losses and possible soil or groundwater contamination.	

Key to source reduction types: CH, chemical substitution; EQ, equipment change; OP, operational change; PR, product change; PS, process change.
A blank indicates that the plant did not provide information.

percent of the manifested aqueous hazardous wastes sent to treatment, storage, and disposal (TSD) facilities in New Jersey. Up to 50 percent of the total organic carbon (TOC) load at the treatment plant comes from outside, while 4 to 10 percent of the acid load does. The charge is $1.90 per pound of TOC, $0.34 per pound of total suspended solids (TSS), and $0.33 per pound of acids.

The Chambers Works plant has an on-site landfill that is designated "secure." Its leachate is collected. There is also a decontamination furnace that detoxifies scrap metal for recycling. The plant rinses chemical shipment drums and sends them to a commercial barrel recovery facility.

Chambers Works recovers some chemicals and ships them for use at other Du Pont plants, while it buys chemicals from other company plants. A 2,3-dichloroaniline by-product (1,250,000 pounds per year) is shipped as a co-product to another Du Pont site where it is used as a heat and chlorine source in the manufacture of titanium oxide. The company had to run a year of tests to obtain the government permits to use this material.

Technical Assistance

In recent years, Du Pont has changed its practices with regard to the public. Company officials cite community right-to-know laws as one important reason for this change. Since these laws were enacted, they say, visitors are welcomed and more information is shared with the community and plant workers.

Over 13,000 visitors come to Chambers Works each year. Some are local community residents, but many are others who seek technical assistance on hazardous waste management. The Chambers Works plant's Environmental Products and Services Committee is set up to provide technical expertise on source reduction and waste management to outsiders, in particular to customers in the automobile and plastics industries, but also, for example, to municipal officials seeking information on the storage and handling of hazardous wastes. Also, because this plant is the single available place for disposing of aqueous hazardous wastes for many facilities and communities in New Jersey and Delaware, Du Pont gives assistance and advice on source reduction to these customers.

Du Pont's Chambers Works plant has a Transportation and Emergency Response Team with equipment to handle chemical transportation emergencies. The equipment includes a truck with an on-board computer that can access any Materials Safety Data Sheet as well as the SAFER computer system that predicts the spread of a chemical in the case of an accident. This truck is available to go to an emergency site in the case of a chemical spill.

In 1986, the Du Pont corporation sponsored a symposium on waste management for its employees. Twenty-five outside vendors, including many advocating source reduction techniques, presented their technologies. A similar symposium was held in November, 1988. Du Pont does not use waste exchanges with companies that can use the waste as a raw material, citing the difficulty in having the type and quality of chemicals needed available on a timely basis.

Company Comments on State and Federal Regulations

In Du Pont's experience, some regulations discourage source reduction. For example, one of its Toledo facilities found that recovering solvents would require the plant to obtain a permit as a treatment, storage, and disposal site under the new RCRA definition, so the project was not instituted.

Du Pont has also found problems in the area of air permitting. New permits are required for each new source, for each replacement or modification of equipment, and for new processes that emit fewer air pollutants. Each individual stack or vent needs a permit. Company officials believe that the time needed for approval of new air permits (6 months to over a year) is often too long to competitively introduce a new process, one that may achieve source reduction. In particular, Du Pont has found the time it takes to obtain air permits to be a limiting factor for its agricultural chemicals, since it must react quickly to the market. Du Pont officials view the state air program's resources as inadequate, especially since new chemicals (hazardous air pollutants) and new sources (gas stations) are being added, requiring more staff to review permit applications, but the funds needed for increased staff have not been provided. Currently, the Chambers Works plant has 73 air permit applications pending.

Future

Du Pont plans for a computerized waste monitoring system attached to eight holding tanks, each of which holds chemical waste from five or six buildings and about 500 different processes a day. Based on Du Pont's experience with this type of metering for energy conservation, the company believes that, even though this monitoring system will operate on an area-wide basis, rather than tracking wastes to individual processes, the expertise of the operators combined with the monitoring data will allow the company to find the waste sources.

EXXON CHEMICAL AMERICAS
Bayway Plant
Linden, New Jersey

Summary

Exxon Chemical Americas, a division of the Exxon Chemical Company (which is wholly owned by Exxon Corporation), is the fourth largest chemical company in the United States. It operates the Bayway chemical plant on the same site as one of Exxon's petroleum refineries in Linden, New Jersey. The plant makes olefins (used as raw materials for plastics and other chemicals), additives for fuels and lubricating oils, and some speciality chemicals, and employs about 500 people. One of the oldest plants in the industry, operating since 1921, it is situated in a heavily industrialized area of northern New Jersey, within 10 miles of New York City.

Exxon has no formal written policy on source reduction. The corporate management, Exxon Chemical Americas, has an environmental affairs office that coordinates Exxon's response to federal regulations. The focus is on treatment and control of waste as required by federal laws, and directives are developed separately for air, water, and solid waste, also reflecting federal rules.

The Bayway plant has its own environmental department responsible for compliance with the state and federal laws that affect this plant. Waste management at Exxon's Bayway plant is also directed separately for each environmental medium. Source reduction was incorporated into the management of solid waste in 1985 and 1986, but the issue of how to best set up an all-encompassing source reduction program at Exxon is still under debate.

Exxon granted an interview for INFORM's 1985 study and at that time reported four source reduction activities reducing 681,810 pounds of waste and saving the company $205,305 each year. Exxon again granted an interview to INFORM for this report, with corporate officials from Exxon Chemical. For this study, the plant reported five additional source reduction activities, reducing 16,408,000 pounds of waste and saving the company $3,207,000 each year, none of which was implemented after 1984.

Products and Operations

Exxon Chemical Americas' Bayway plant is located next to a larger petroleum refining operation at the same site. The chemical plant currently has 500 employees, a decrease of about 10 percent since 1984.

The plant manufactures three major product lines:

- Olefins, including propylene and butylenes, used as raw materials in the manufacture of other industrial chemicals and plastics.
- Paramins additives, Exxon's trade name for its line of chemicals that, when added to fuels and lubricating oils, inhibit corrosion, improve flow properties, stabilize viscosity, and otherwise enhance their quality. The Paramins operation manufactures dispersant additives (with the raw material maleic anhydride), detergent inhibitor additives (with the raw material phenol), and synthetic lubricating oils.
- Speciality chemicals, including such isobutylene polymers as LM Vistanex, Exxon's trade name for an ingredient in chewing gum and surgical adhesives.

Since 1988, the plant has discontinued the manufacture of organic solvents.

Environmental Policy

Exxon Chemical Americas has no written policy favoring source reduction. Its Solid Waste Management Plan addresses reduced generation of wastes, recycling, treatment, and safe disposal, but does not put source reduction as its highest priority. The company's corporate environmental affairs office in Houston, Texas, sets broad corporate policy and goals and renders assistance to the individual Exxon plants. It also coordinates Exxon's response to federal environmental laws and regulations. Its written directives include air, water, and solid waste management.

The Exxon headquarters office developed the overall corporate Waste Management Plan in 1982 and 1983. With prime attention to solid waste, it has three goals: to decrease land disposal, to increase recycling, and to ensure that the disposal contractors it uses are competent and responsible. The Bayway plant does not have on-site land disposal or incineration and is not a treatment, storage, and disposal (TSD) facility, so the reduction of solid waste and reliability of its contractors are major considerations.

In general, Exxon's corporate structure is decentralized. The Bayway plant has its own environmental department, which is responsible for compliance at the plant. Because each state's laws differ, individual plants must respond to changes in state laws. New Jersey state laws are the controlling regulations for Bayway.

Waste management at Bayway is directed separately for the separate media. Source reduction was overlaid onto the corporation's management of solid wastes in 1985 and 1986. The use of Waste Minimization Committees, primarily concerned with RCRA compliance, is growing at Exxon plants. The Bayway chemical plant and its adjacent refinery used a Waste Minimization Committee to analyze and follow up on joint problems and opportunities during 1986 and 1987. Currently, the plant has an active Waste Minimization Committee and a management level person in charge of solid waste reduction at the plant.

Nevertheless, Exxon does not currently have a company-wide source reduction program. Officials say they are studying what the best structure may be. A multimedia approach is definitely to be included but the company has not determined just how communication with employees would be done, what type of database would be used, what kind of program top management would be comfortable with, and exact definitions and terminology.

Materials Data Collection

With solid waste and RCRA compliance as its main corporate concerns, Exxon has conducted an annual survey of solid waste since 1982. The survey is carried out at Bayway, as at all company facilities, and is done for each wastestream. The survey gathers information about waste generation rates, disposal locations, and costs for each wastestream, and reports units of waste per unit of product.

The Exxon corporate headquarters uses its annual plant survey of waste to highlight the 20 largest wastestreams (in terms of costs and volume). The corporate environmental affairs department then focuses its efforts on these wastes. None of Bayway's wastestreams were among the largest in the 1987 survey.

The Exxon Bayway plant initiated its own additional plant-wide "waste minimization and compliance review" in 1987, using internal reviewers. It inventoried all wastestreams (solid, water, and air) and reviewed government regulations, especially New Jersey's, to monitor plant compliance.

Cost accounting at the Bayway plant includes solid and aqueous wastes and is directly tied back to the production unit. Air emissions are considered direct raw material or product losses. Specific costs allocated include material losses, disposal costs, costs of regulatory compliance, insurance, clean-ups, and costs of public/customer relations dealing with waste issues. The cost accounting system encourages plant operators to focus on costs and to identify ways to reduce the costs of waste management, including source reduction measures.

According to Exxon Chemical Americas, mass balance accounting is not typically used at the Bayway plant for environmental control because the production volumes are so large that, even though the company's instruments can measure product flow to within 0.25 percent error, that small error could still mean large variations in predicted product flow and, hence, in predicted waste volumes, which are very small in relation to overall product volume. Company officials find it much more effective to directly measure or estimate wastestreams

In 1984, Exxon Chemical Americas conducted a risk assessment of solid wastes produced at all its plants. As a result, a prime goal of the company's waste management plan is to significantly reduce untreated waste going to landfills. Source reduction, internal recycling, and incineration were reported as leading options for meeting this goal.

Other Source Reduction Program Features

In addition to having materials accounting and cost accounting (but not a formal source reduction policy or materials balance), the Bayway plant has three of the other four source reduction program features identified by INFORM: leadership, an environmental program, and environmental goals, but no employee involvement.

Prior to the 1980s, source reduction at Bayway was considered a process design function where optimization of processes was concerned with material and product losses and the economics of production. Process engineers at Exxon did not generally see environmental operations as part of their role. Exxon's focus was on the "end of the pipe," with environmental specialists whose duties covered treating wastes in an environmentally sound way. In the 1970s, after the price of crude oil rose dramatically, concern increased regarding losses of raw materials. But in the 1980s, source reduction has been encouraged in the solid waste area because of skyrocketing disposal costs (up to a 500 percent increase for some of Exxon's wastes).

Source Reduction Activities

The Exxon Bayway plant reported five source reduction activities (all affecting RCRA waste) for this study, in addition to four other activities the plant had revealed to INFORM for the 1985 study. The five newly reported activities accomplished a total reduction in solid hazardous waste of 18.1 million pounds a year. They entailed an investment of $18.8 million and have produced annual savings of $3.2 million. These activities are summarized in Table II-14 and are discussed in detail below. All of the five newly reported activities were implemented in 1984 or earlier.

The first activity was a project to reduce acid coke, a residue from many processes at the plant, in order to reduce potential long-term liability and disposal costs of the residue. Acid coke is a by-product of the manufacture of butyl alcohol and is a carbonaceous solid saturated with sulfuric acid. Source reduction was achieved through optimization of operating conditions such as temperature and pressure. The study to optimize the process took 5 years, from 1980 to 1984, and was undertaken by the plant engineers. Waste volume was reduced 90 percent from 175 tons in 1980 to 18 tons in 1986, and unit of waste per unit of production dropped from 83 to 7. Prior to 1984, the waste was landfilled; currently, it is incinerated. This measure saved $340,000 per year in incineration charges from 1984 to 1986.

The second source reduction activity cited by Exxon involves a spent catalyst — an organic resin saturated with phenol and a hydrocarbon. The catalyst is used in a batch alkylation reactor until its activity drops below an acceptable level. It is then emptied from the reactor; prior to 1985, it was disposed of in a landfill, but now it is incinerated. Exxon's goal was to reduce the amount of spent catalyst in order to reduce the downtime for catalyst changes as well as to reduce disposal costs and long-term liability. A study undertaken in 1983 to reduce the catalyst waste considered both substitution of other catalysts and process optimization. No replacement catalyst was found, but continuous process optimization of the alkylation reactor operating conditions has extended the useful lifespan of the catalyst by 200 percent and study of ways to further improve the process is continuing. No capital expenditures were required for implementing this project. The waste has been reduced by 11 tons per year, and disposal cost savings are $14,000 per year. Current costs of disposing of this waste are $9,000 for 7 tons of waste. The unit waste per unit of production has been reduced from 19 in 1983 to 6 in 1986, an approximately 70 percent reduction.

The third source reduction activity involved waste oil containing phenols. Prior to 1984, all safety valve releases from a manufacturing unit that contained phenol and an aliphatic hydrocarbon were directed to a blowdown tank where the release was brought into contact with oil in order to capture the vapor/liquid. When the oil became saturated with phenol, it had to be replaced; the waste oil was sent to fuel reclaimers. In 1984, the unit section supervisor suggested that instead of using oil as the contacting medium in the blowdown tank, one of the hydrocarbon raw materials could be used. When the phenol concentration increased above a certain level in the blowdown tank, the hydrocarbon and phenol mixture could be recycled as feedstock to the unit. By substituting a raw material for oil as the absorbing material, the system became closed and the wastestream was completely eliminated. No capital investment for the change was required and the waste elimination has saved $83,000 per year in disposal costs, while reducing 240 tons of waste oil. This project was undertaken to reduce the amount of waste sent off-site for disposal and to save raw material costs.

The fourth example of source reduction at the Exxon Bayway plant is a long-term project (first begun in 1972 and continuing today) to reduce filter cake and process solids generated from the production of lubricating oil additives. After the additive active ingredients are produced in reactors, they contain low levels of solids that must be removed. This had been accomplished by filtration with diatomaceous earth filter aids. The filtration produced a filter cake waste that was 50 percent solids and 50 percent oil and oil additives. The large volumes of solid waste mixed with product indicated to the plant operators that there were opportunities to reduce product losses and disposal costs.

The project began with the replacement of certain filters with high-speed centrifuges that could remove the solids from the lubricating oil additives without the addition of filter aid. The sludge of solids removed by the centrifuges was then blended into waste oils and used as an alternate liquid fuel in industrial furnaces off-site. A series of full-size centrifuges has been installed since 1972. In 1984, second-stage separation devices were installed to recover the oil and active ingredients that remained in the centrifuge sludge. The sludge from the second-stage separation devices was akin to the original filter cake except that it contained no filter aid and was less than half of the equivalent volume of filter cake. Study of possible process modifications, such as extraction, to eliminate or reduce the amount of solids generated in the reactors continues.

According to plant officials, the project used equipment on the leading edge of technology, and assuring consistently high product quality was a concern. The product had to meet high government specifications and there was concern about haze (decreased transparency of the product) after the process changes. Therefore, research on improving product quality and efforts to assure customer acceptance were necessary. As a result, there was a long period of experimentation in which the separation process and mechanical reliability were optimized. The possibilities of recycling the centrifuge sludge to a raw material supplier are also being explored.

The cost of this project has been $18,700,000 since 1972 and has realized a raw materials savings of $1,300,000 per year and disposal cost savings of $261,000 per year. The remaining wastes continue to be landfilled, but the volume of waste has been reduced to one-third the original level (from 5,574 tons in 1980 to 1,478 tons in 1986), for a reduction of over 4,000 tons per year of solid waste. The unit waste per unit of production has been reduced from 105 in 1980 to 34 in 1986, or by 68 percent.

The final source reduction activity cited by Exxon concerns the Bayway plant's production of additives used in lubricating oils. Waste lubricating oil additives are generated when lines and tanks are flushed to avoid cross-contamination when oil leaks from valves and pump seals and when a batch is off-specification. Most of the waste lubricating oil additives are collected from the plant's wastewater collection system. These wastes were reduced both through a study of the lubricating oil manufacturing process and through increased operator awareness resulting from that study. Some of the source reduction measures included better housekeeping and the scheduling of longer campaigns; that is, producing a larger volume of an individual product at one time so that fewer equipment washings are needed. The volume of this waste has been reduced by 50 percent from 1980 to 1986 (from 7,570 tons to 3,774 tons) and has annually saved $214,000 in disposal charges and $1,000,000 in raw material purchases. Previously, the lubricating oil additive waste had been disposed of through third-party waste fuel reclaimers. Since 1985, the remaining waste oil additives have been used as an alternative fuel in cement

Table II-14 Exxon Chemical Americas (Linden, NJ): Source Reduction Activities

Waste Medium (SR Type) Year	Source Reduction Activity	Specific Waste Reduced (Hazardous or Nonhazardous)	Percent Waste Reduced	Amount Waste Reduced	Change in Yield	Dollars Saved	Dollars Spent	Motivation	Comments	Time Needed for Implementation
Solid (PS) 1984	Continuous process optimization of operating conditions has resulted in reducing generation of acid coke, a process residue.	Acid coke residue (H)	90%	157 tons/yr (314,000 lb/yr)		$340,000/yr		Undertaken to reduce potential long-term liability and disposal costs of waste previously landfilled. Remaining waste now incinerated.	Waste per unit of production dropped from 83 to 7. Savings are in incineration costs.	5 yr
Solid (PS) 1983	Process optimization has reduced waste catalyst from a batch alkylation reactor.	Catalyst (H)	70%	11 tons/yr (22,000 lb/yr)		$14,000/yr	$0	Undertaken to reduce downtime for catalyst changes and to reduce disposal costs and long-term liability. Current disposal costs are $9,000 for 7 tons.	Waste per unit of production dropped from 19 in 1983 to 6 in 1986. Savings are in incineration costs.	
Solid (PS,CH) 1984	A hydrocarbon raw material replaces oil as the phenol-absorbing medium in a manufacturing unit. The hydrocarbon and phenol mixture in the blowdown tank is recycled as feed to the unit.	Waste oil containing phenols (H)	100%	240 tons/yr (480,000 lb/yr)		$83,000/yr	$0	Undertaken to reduce waste disposed of off-site and for raw material savings.	Savings are in disposal costs.	
Solid (PS) 1972	Replaced filters with high-speed centrifuges that remove the solids from lubricating oil additives without the addition of filter aid. Second-stage separation devices installed to recover the oil and active ingredients remaining in the centrifuge sludge.	Filter cake process solids (N)	68%	4,000 tons/yr (8,000,000 lb/yr)		$1,560,000/yr	$18,700,000	The large volumes of solid waste mixed with product made it obvious that there were opportunities to reduce product losses and disposal costs.	Waste per unit of product reduced from 105 in 1980 to 34 in 1986; remaining waste landfilled.	
Solid (OP) 1980	Reduction in waste lubricating oil additives accomplished through better housekeeping practices and scheduling of longer campaigns (larger volumes of an individual product are produced at one time, reducing the number of equipment washings needed).	Waste lubricating oil additives (H, N)	50%	3,796 tons/yr (7,592,000 lb/yr)		$1,210,000/yr		Undertaken to reduce potential long-term liability when disposing of waste through a third party.	Waste lubricating oil additives are generated when lines and tanks are flushed. Savings are from reduced disposal costs and raw material purchases.	

Key to source reduction types: CH, chemical substitution; EQ, equipment change; OP, operational change; PR, product change; PS, process change.
A blank indicates that the plant did not provide information.

kilns, instead of being sold to recyclers or brokers. Exxon does this to reduce potential long-term liability, even though the cost is higher.

Other Waste Management Practices

Besides the source reduction activities, Exxon also described other waste management practices concerning alternatives to land disposal. Exxon's Bayway plant has moved from land disposal to incineration and other treatment where possible. This decision has increased disposal costs in some cases. For example, the decision to incinerate acid coke increased Bayway's disposal costs by over 400 percent from 1984 to 1986 (from $7,000 to $39,000).

Technical Assistance

Within the corporate structure, Exxon has a Research and Engineering Department that provides regulatory advice and environmental design development as internal consultants to all of the company's plants. It also provides assistance to customers and suppliers when asked. Exxon also has a contractor inspection program that inspects contractors, such as the commercial disposal facilities it uses for hazardous waste disposal, to ensure that they are in compliance with regulations. The company sponsors periodic corporate-wide meetings to exchange information about technical advances, considering this to be the best way to disperse ideas on source reduction throughout its plants. However, Exxon's management believes that most technology in the area of source reduction is plant-specific and that other companies or government agencies

probably cannot supply the necessary level of detail or expertise.

The corporation held its first waste reduction conference, which addressed source reduction among other waste management strategies, in September, 1987, at Bayway. Plant managers from throughout the international corporation attended to discuss their problems and solutions.

Company Comments on State and Federal Regulations

Exxon reported that the Toxics Release Inventory (TRI) has been a great additional burden because the company had been tracking wastes by wastestream, as required under RCRA, and not by specific chemicals. Also, materials balance was a driving force for establishing TRI, and Exxon believes that a materials balance approach is not effective when there are small wastestreams from large product flows. If the law were to change to require some sort of materials balance, Exxon's view is that this would be a large waste of resources.

Resources for source reduction and recycling at Exxon were stretched to cover TRI requirements in 1987, but the company hoped to be able to redirect these resources. Because there are already massive incentives for source reduction, Exxon does not believe that TRI will be beneficial in this respect. Also, it does not expect to find any surprises from the data. It sees possible benefits as better federal policy and regulations once a better database is in place.

Exxon officials identified the constant changes in regulations, including definitions of waste, as a serious problem. Each time changes occur, resources that might otherwise be spent studying wastestreams must be diverted to rearrange government reports and continuity of databases used in improving waste controls is lost.

Exxon would like to do more recycling and waste exchanges but believes that RCRA permitting rules are too onerous for most potential recyclers.

One change Exxon has made at Bayway and its other chemical plants is to ensure that technical and communication specialists are on its environmental staff so that, as TRI data become publicly available, Exxon is able to answer questions posed by members of the community where the plant is located.

Future

Exxon reported that the company is in a transition period during which emphasis on treatment technology must give way to a broader, more integrated approach to waste management. Officials believe that this will be difficult because such a large company has many specialists (for example, engineers whose sole duty is to ensure compliance with air permits) who know about treatment technology and their separate media problems but who are now being asked to be health and risk specialists and cross-media experts. Control of chemical wastes does not appear to Exxon to be a problem of technology or numerical incentives for source reduction. Indeed, Exxon reported that requirements such as a given percentage reduction, whether internal or legislated, would more likely reduce the options available, rather than stimulate more source reduction. The company identifies the problem as a management one, involving combining individual expertise and experience in process operations and waste handling in separate media with an expanded view extending beyond treatment and control to the full spectrum of management options.

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Waste Reduction Activities and Options for a Manufacturer of Fine Chemicals Using Batch Processes

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DEPOSITORY DR-242

Abstract

The U.S. Environmental Protection Agency (EPA) funded a project with the New Jersey Department of Environmental Protection and Energy (NJDEPE) to assist in conducting waste minimization assessments at 30 small- to medium-sized businesses in the state of New Jersey. One of the sites selected was a manufacturer of fine chemicals using batch processes. A site visit was made in 1990 during which several opportunities for waste minimization were identified. Options identified for waste reduction included initiation of solvent recycling or reconditioning for reuse and modifying the chemical reaction conditions to improve product quality and reduce the amount of reprocessing which has been necessary. Implementation of the identified waste minimization opportunities was not part of the program. Percent waste reduction, net annual savings, implementation costs and payback periods were estimated.

This Research Brief was developed by the Principal Investigators and EPA's Risk Reduction Engineering Laboratory in Cincinnati, OH, to announce key findings of this completed assessment.

Introduction

The environmental issues facing industry today have expanded considerably beyond traditional concerns. Wastewater, air emissions, potential soil and groundwater contamination, solid waste disposal, and employee health and safety have become increasingly important concerns. The management and disposal of hazardous substances, including both process-related wastes and residues from waste treatment, receive significant attention because of regulation and economics.

As environmental issues have become more complex, the strategies for waste management and control have become more systematic and integrated. The positive role of waste minimization and pollution prevention within industrial operations at each stage of product life is recognized throughout the world. An ideal goal is to manufacture products while generating the least amount of waste possible.

The Hazardous Waste Advisement Program (HWAP) of the Division of Hazardous Waste Management, NJDEPE, is pursuing the goals of waste minimization awareness and program implementation in the state. HWAP, with the help of an EPA grant from the Risk Reduction Engineering Laboratory, conducted an Assessment of Reduction and Recycling Opportunities for Hazardous Waste (ARROW) project. ARROW was designed to assess waste minimization potential across a broad range of New Jersey industries. The project targeted 30 sites to perform waste minimization assessments following the approach outlined in EPA's *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003). Under contract to NJDEPE, the Hazardous Substance Management Research Center at the New Jersey Institute of Technology (NJIT) assisted in conducting the assessments. This research brief presents an assessment of the manufacturing of fine chemicals using batch processes (1 of the 30 assessments performed) and provides recommendations for waste minimization options resulting from the assessment.

Methodology of Assessments

The assessment process was coordinated by a team of technical staff from NJIT with experience in process operations, basic chemistry, and environmental concerns and needs. Because the EPA waste minimization manual is designed to be primarily applied by the inhouse staff of the facility, the degree of involvement of the NJIT team varied according to the ease with which the facility staff could apply the manual. In some cases, NJIT's role was to provide advice. In others, NJIT conducted essentially the entire evaluation.

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The goal of the project was to encourage participation in the assessment process by management and staff at the facility. To do this, the participants were encouraged to proceed through the organizational steps outlined in the manual. These steps can be summarized as follows:

- Obtaining corporate commitment to a waste minimization initiative
- Organizing a task force or similar group to carry out the assessment
- Developing a policy statement regarding waste minimization for issuance by corporate management
- Establishing tentative waste reduction goals to be achieved by the program
- Identifying waste-generating sites and processes
- Conducting a detailed site inspection
- Developing a list of options which may lead to the waste reduction goal
- Formally analyzing the feasibility of the various options
- Measuring the effectiveness of the options and continuing the assessment.

Not every facility was able to follow these steps as presented. In each case, however, the identification of waste-generating sites and processes, detailed site inspections, and development of options was carried out. Frequently, it was necessary for a high degree of involvement by NJIT to accomplish these steps. Two common reasons for needing outside participation were a shortage of technical staff within the company and a need to develop an agenda for technical action before corporate commitment and policy statements could be obtained.

It was not a goal of the ARROW project to participate in the feasibility analysis or implementation steps. However, NJIT offered to provide advice for feasibility analysis if requested.

In each case, the NJIT team made several site visits to the facility. Initially, visits were made to explain the EPA manual and to encourage the facility through the organizational stages. If delays and complications developed, the team offered assistance in the technical review, inspections, and option development.

No sampling or laboratory analysis was undertaken as part of these assessments.

Facility Background

The facility is an integrated chemical production installation which is part of the manufacturing capability of a large chemical production company. The facility which participated in this study houses pilot plant activities for fine chemicals and for chemical intermediates under investigation by the company. In addition, some manufacturing of products, particularly low volume products occurs at this facility. The facility also hosts research activities, packaging operations, and Quality Assurance laboratory activities. The site is approximately 50 years old, although most of the buildings are significantly newer. The equipment in use varies from brand new to over 30 years in age.

Manufacturing Processes

Although many independent operations take place at this installation, it was decided to focus this initial effort on one of the smaller manufacturing operations. Such a focus was expected to provide the technical and operating management of the facility an illustration of the assessment process and provide the information necessary to plan a larger scale assessment process for the entire facility. It was desirable, therefore, to select a discrete process which could thoroughly analyzed and which held potential for measurable significant pollution prevention opportunities.

The process investigated uses relatively uncomplicated chemi requiring formation of a coordination-type complex between organic amine and a volatile halogen-containing solvent. The co plexation is carried out in the presence of a small amount of alcohol co-solvent. The individual components are synthesized eit offsite or in an area separate from the complexation equipment a process. The process involved is a relatively simple three compone mixing and complexation reaction which allows for an in-dept analysis of waste streams and consideration of alternatives.

Typical steps in the manufacturing process include the followin activities:

- A concentrated solution of the organic amine in an alcoh solvent is slowly added to a large volume of vigorous agitated halogen-containing solvent.
- As a result of the mixing, a portion of the resulting amin solvent complex precipitates.
- The product yield is increased by distilling off a portion the halogen-containing solvent in order to induce crystal zation of the product complex.
- The product is recovered by filtration by vacuum.
- Recovered solvent is sent offsite for recycling.

Existing Waste Management Activities

The company has already recognized the advantages and benef of identifying and implementing waste reduction and pollution p vention practices. The current procedure which utilizes offsite recycli for the waste streams from the investigated process illustrates t recognition and commitment.

Waste Minimization Opportunities

For this facility, the initial use of the manual was carried out by t staff of the facility. The NJIT team participated in identification some of the options for waste reduction. During the assessm process, the following waste streams were identified:

- Liquid Solvent Stream
- Vapor Losses

The liquid solvent waste stream results from distillation of solven raise the product concentration to induce crystallization and from recovery of the product by filtration. It has been generated at a r of about 19,000 kg/yr. The waste stream has been managed offsite recycling at an annual cost of about $12,000.

The vapor loss stream results from atmospheric losses during solvent transfer to a receiving vessel. A minor portion of the loss h been estimated to result from leaking connections and esca during vessel openings. More of the vapor loss results from vacuum filtration step which is used to recover the solid product portion of the volatile solvent is lost through the vacuum system a is not easily recovered. It is estimated that about 1200 kg of mixed solvents are lost annually through these routes. The fract which is captured is sent offsite for recycling at an annual cost about $500.

The continuing technical challenge is to reduce further the size of two waste streams resulting from the process. Technically, it may easier to reduce the amount of vapor loss by tighter vapor handl practices. Because the volume of the liquid solvent stream is great

there may be greater opportunities there for high percentage reduction.

From the perspective of pollution prevention, the company may desire to look for options which reduce emissions to the atmosphere, reduce the total amount of chemical usage, encourage onsite recycling or reuse of the materials, or allow use of less hazardous substances in the manufacture and processing of the product. However, it was decided that the performance requirements for the product precluded any changes in the chemistry of the process until a detailed product characterization and performance evaluation could be carried out. Therefore, any changes in the actual substances used to manufacture the product could not be considered to be a viable initial pollution prevention option. Rather, both of the two waste streams were considered individually to identify the reasons for the size of the streams and possible modification of practices which had potential for their reduction.

The liquid solvent stream presented the greatest challenge in terms of volume. The relatively high cost of the solvents/reactants in the process had previously led to consideration of alternative ratios of materials in order to minimize solvent use. The existing process used the minimum volumes required in order to achieve the necessary performance for the product.

The solvent waste stream is sent offsite for recycling because the combination of alcohol co-solvent with the halogen-containing solvent presents some complications with the distillation process which would normally be used for solvent purification. The necessary equipment to carry out this purification does not exist at the site and the relatively small volume of this stream does not justify investment in such equipment at this time. The required distillation equipment does exist at another company-owned site, however, so one of the options identified is to move this process to another company location in order to permit onsite recovery, recycling and reuse of the solvent.

An alternative to this option was also identified which would utilize a two-step purification of the solvent system. The concept proposed was to utilize an adsorbent for the alcohol component which, in a packed bed medium, could selectively remove the alcohol leaving the halogen-containing solvent in a more easily purified state allowing distillation with existing equipment at the site. Alternatively, it may be possible to reuse the halogen-containing solvent directly although this would have to be verified by product quality and performance testing. An appropriate choice of alcohol adsorbent could allow regeneration with recovery and reuse of the alcohol. Such a procedure would be expected to reduce substantially the percentage of this waste stream which needs to be sent for treatment.

Another alternative option addressed the issue of reduction of the volume of raw materials used in the process itself. Although, as indicated previously, it would not be possible to implement a new process using smaller quantities of the materials, examination of the production records indicated that about 10% of the batch runs represented reworking of batches which failed quality standards. Stated another way, this means that a savings of 10% of the waste stream could be realized by identifying and correcting the reasons for the below standard quality of these batches. It was determined that the product complex which is formed is sensitive to the presence of water. In fact, moisture can cause the decomposition of the complex. The presence of high humidity during the complexation process was determined to be the primary cause of the 10% failure rate. It was proposed, therefore, to provide a more controlled temperature/humidity environment for the manufacturing process to eliminate the failures of these batches. An alternative suggestion was to avoid scheduling production runs during times of the year when ambient humidity would be expected to be high.

The vapor loss waste stream presented some additional challenges. As indicated previously, two significant sources for such losses were identified—fugitive emissions and the filtration step in the product recovery phase of the process. These two sources lead to suggestions of different types of options for reduction of vapor loss.

Several applications of modified engineering practices were identified for reduction of fugitive losses. These included improved control over condenser temperature and reaction temperature, use of couplings and connectors with low dead volume, regular inspection and replacement when necessary of seals, valves, and pressure relief devices. Modified practices such as gravity-induced introduction of solvents rather than by pumping to reduce any pressure buildup in the reaction vessel were also suggested.

While it may be difficult to quantify the pollution prevention impact of options such as these, it is clear that they have the potential for reducing fugitive emission.

Addressing the issue of vapor losses during the filtration process required identification of different options. It was determined that the losses occurred because the relatively low-boiling solvent vaporized under the vacuum filtration conditions and was lost through the vacuum system. The option identified to reduce such losses was to utilize existing equipment to carry out pressure filtrations instead of vacuum filtration. The same pressure drop across the filter could be achieved, but because the absolute pressure in the system was higher, volatilization could be reduced substantially. Therefore, solvent loss would be reduced.

The type of waste currently generated by the facility, the source of the waste, the quantity of the waste and the annual treatment and disposal costs are given in Table 1.

Table 2 shows the opportunities for waste minimization recommended for the facility. 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 at the facility and possible waste reduction depend on the level of activity of the facility.

It should be noted that the economic savings of the minimization opportunity, in most cases, results from the need for less raw material and from reduced present and future costs associated with waste treatment and disposal. 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 savings that would result when the opportunities are implemented in a package.

Regulatory Implications

An important regulatory implication in this study is that although the majority of the waste stream from this process is recycled, it is sent offsite for purification and reuse. Therefore, the streams are classified as waste. Even though the company has at a nearby site the technical capability to purify the material and return it to the original process, regulatory barriers prevent the ready implementation of this practice. The regulatory issue is that because the two facilities are considered separately from a regulatory point of view, the material would have to be sent from this facility under a hazardous waste manifest. Then even after purification it would still be considered hazardous waste unless the company went through a process to have it delisted. Even then, the company would be seen as using

*U.S. Government Printing Office: 1992 — 648-080/60

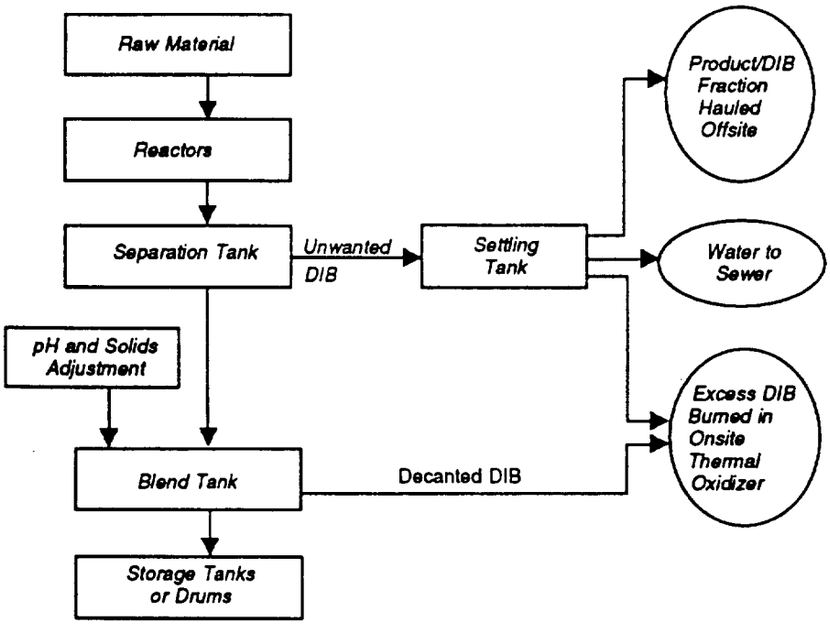

Figure 2. Abbreviated flow diagram for the dispersant process.

acid is recycled back into the reactors for use in further processing. The low-acidic content propionic acid is pumped to the wastewater treatment system where it is used to neutralize caustic wastewater from other plant operations.

From the reactor, the product is pumped to a blend tank to which other chemicals and emulsifiers are added; these substances reduce the viscosity of the product. Several wastes are generated from the annual cleaning of the reactor and blend tank including wastewater that is pumped to the wastewater treatment system, herbicide residue, and herbicide articles (contaminated employee clothing). From the blend tank, the products are loaded onto railcars and shipped. An abbreviated flow diagram for the herbicide/specialty chemical process is shown in Figure 3.

Pollution Abatement (PA) System

This plant uses a pollution abatement system to remove vapors from various areas of the plant including the monomer storage area, tanks in the resin production area, and the reactors and holding/premixing tanks in the emulsion production line. This system was installed mainly to remove vapors with persistent irritating odor from the plant.

A blower located down the line creates a pressure difference and pulls fresh air over the tanks mentioned above. Vapors collected from the monomer storage area and resin area tanks are blown to separate liquid knock-out tanks. These tanks act as condensers and use ambient air cooling to condense a portion of the vapors. The resulting condensate from these tanks is directed to the water treatment facility. From the knock-out tanks, the vapors are ducted through separate lower explosive limit (LEL) monitors that evaluate the flammability of the vapors. From the monitors, the vapors are directed through backfire preventers that act as safety valves and prevent vapors from being drawn back through the system.

Vapors from the reactors and feed tanks in the emulsion line follow a similar route through the PA system; however, they are first ducted through a caustic scrubber. Caustic solution is added to this scrubber as well as 150 gal/min of water to remove particulates from the fumes. This solution is dumped to the water treatment system every 11 days. The vapors are then directed through a liquid knock-out tank (from which water is pumped to water treatment), through a backfire preventer and then through an LEL monitor.

From that monitor, the vapors pass through a blower, another backfire preventer, and finally most of the vapors (99.97% enter a natural gas-fired thermal oxidizer at 1400°F.

Wastewater Treatment System

Another onsite waste treatment facility this plant has installed is its wastewater treatment system. Wastewater from the emulsion line and the resin line, laboratory wastewater, and a compressor and other cooling water are directed to this facility for treatment. All incoming water passes through a roto-strainer that removes suspended solid particulates. The solid waste falls into two hoppers and is eventually hauled offsite to landfill.

From the roto-strainer, the water enters a neutralization tank where carbon dioxide and low acidic propionic acid from the herbicide line are added for neutralization. The water then enters a second neutralization tank where the water is agitated to promote further neutralization. Next, the wastewater enters three open-air mixing basins in which sludge is allowed to settle to the bottom. Sludge is removed quarterly to landfill

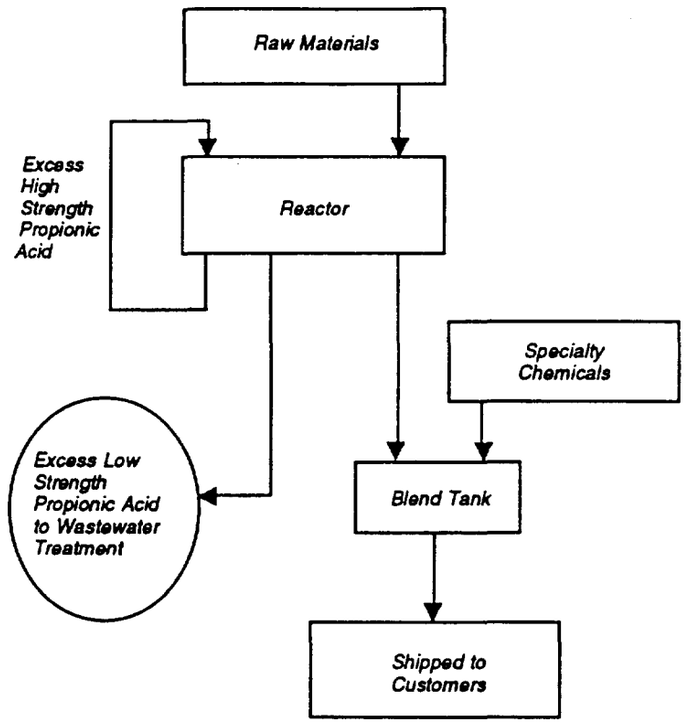

Figure 3. Abbreviated flow diagram for the herbicide/speciality chemical process.

The effluent wastewater is released to the municipal sewer. Total water discharged from the plant on an annual basis is approximately 126 million gal/yr.

Existing Waste Management Practices

- A pollution abatement system removes noxious and odorous vapors from the plant and incinerates them.
- Off-grade monomers and polymers are reused in an effort to produce salable products.
- Diisobutylene wet solvent is burned in an onsite boiler.

Waste Minimization Opportunities

The type of waste currently generated by the plant, the source of the waste, the quantity of the waste, and the annual treatment and disposal costs are given in Table 1.

Table 2 shows the opportunities for waste minimization that the WMAC team 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.

This research brief summarizes a part of the work done under Cooperative Agreement No. CR-814903 by the University City Science Center under the sponsorship of the U.S. Environmental Protection Agency. The EPA Project Officer was Emma Lou George.

Table 1. Summary of Waste Generation

Waste Generated	Source of Waste	Annual Quantity Generated	Annual Waste Management Cost ($
Burnable liquids	*Off-grade mixtures and bad reactions in the acrylic emulsion and low molecular weight resin production lines.*	*15,400 lb*	*77,110*
Composited absorbed monomers	*Spillage and clean-up of reactors in the acrylic emulsion and low molecular weight resin production lines.*	*15,400 lb*	*77,110*
Off-grade methylolacrylamide/ acrylamide	*Off-grade batches of product in the acrylic emulsion and low molecular weight resin production lines*	*5,100 lb*	*40,760*
Used filters and trapped product	*Filtering process in the acrylic emulsion production line.*	*44,800 lb*	*33,080*
Unsalable low molecular weight resins	*Expired products and off-grade batches of products in the low molecular weight resin production line.*	*20,880 lb*	*116,200*
Diisobutylene (DIB) wet solvent	*Spent solvent from the dispersant production line. DIB wet solvent is sent to an onsite thermal oxidizer.*	*316,220 lb*	*24,500*
Product/DIB interface	*Separation tank in the dispersant production line.*	*25,750 lb*	*79,860*
Absorbed propionic acid	*Spillage in the herbicide/specialty chemical production line.*	*6,000 lb*	*13,510*
Contaminated employee clothing	*Herbicide/specialty chemical production line.*	*	*
Herbicide residue	*Cleaning of the reactor and blend tank in the herbicide/specialty chemical production line.*	*1,000 lb*	*24,150*
Cold stack gases (noxious, odorous, and organic vapors drawn from monomer storage area, tanks in resin line, and resin reactors and tanks)	*Thermal oxidizer and heat exchanger in the Pollution Abatement System.*	*394,200 ft³*	*0***
Wastewater sludge	*Onsite wastewater treatment system.*	*300,000 lb*	*456,800*
Wastewater	*Onsite wastewater treatment system.*	*126,000,000 gal*	*2,121,700*

**New waste; no data available.*
***There are no direct costs reported for handling evaporative waste.*

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Table 2. Summary of Waste Minimization Opportunities

Waste Generated	Minimization Opportunity	Annual Waste Reduction Quantity	Annual Waste Reduction Percent	Net Annual Savings ($)	Implementation Cost ($)	Payback Years
Burnable liquids	Upgrade the redundant sensing and control devices on the reactor raw material lines to reduce the amount of off-specification product batches.	11,550 lb	75			
Composited absorbed monomers		2,890 lb	19	139,810	365,480	2.6
Off-grade methylolacrylamide/ acrylamide		3,480 lb	71			
Unsalable product		3,130 lb	15			
Wastewater sludge	Install a natural gas-fired dry-off oven in the waste-water treatment system to reduce the amount of sludge removed to the landfill.	244,030 lb	81	92,730	70,320	0.8

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Document: CS379

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***** DOCNO: 031-001-A-431*****

1.0 Headline: Reduction of waste oil is achieved by filtering and recirculating lubricating oil

2.0 SIC/ISIC Code: 2819, industrial inorganic chemical, hydrofluoric acid (HF)

3.0 Clean Technology Category

3.1 Technology Principle: Some reduction of waste lubricating oil was achieved by filtering and recirculating lubricating oil. Further reduction in the volume of waste oil was investigated. However, these reductions could only be achieved with major process modifications. For example, if an improved seal for bearings (braided graphite was used) would be available, it would prevent HF from leaking, contaminating the oil. Redesigning the feeder with more corrosion resistance components would reduce the frequency of oil replacement. These process modifications, however were not economically feasible because there are only two 55-gal of oil are replaced every month.

3.2 Cross-Industry Application - Inorganic chemicals manufacturing

4.0 Name & Location of Company: The name of this facility is not provided. This plant is located in New Jersey.

5.0 Case Study Summary

5.1 Incentives: N/A

5.2 Original Manufacturing Process and Previous Waste/Emission Management Methods: HF is manufactured by reacting calcium fluoride with sulfuric acid in a rotory kiln. The reactants are fed to the rotory kiln by a special feeder. Lubricating oil, which is used for the feeder's bearings, gradually becomes contaminated with HF. This oil is replaced periodically, filtered, and reused. The waste oil is disposed off-site.

5.3 Scale of Operation: This facility has 43 employees.
5.4 Stage of Development: Fully implemented

5.5 Level of Commercialization: Filtration equipment for waste oil is readily available

5.6 Results of Application: Reduced volume of waste oil

disposed off-site

5.7 Effects on Products: This approach to source reduction does not affect product quality

6.0 Economics

6.1 Investment cost: Not provided
6.2 Operational and Maintenance Costs: Not provided
6.3 Other costs: Not reported
6.4 Payback time: Not provided

7.0 Balances & Substitutions

7.1 Wastes generated - 110 gal/month (before)
7.2 Feedstocks - Quantities not provided
7.3 Water Use - Not provided
7.4 Energy Use - Not provided

8.0 Cleaner Production Benefits

8.1 Economic Benefits: Not provided
8.2 Improved public relations: This topic is not discussed
8.3 Liability reduction: Reduced liabilities by reducing the quantity of hazardous waste generated
8.4 Regulatory compliance: Regulatory compliance is easier with reduced quantity of hazardous waste generated.

9.0 Obstacles, Problems and/or Known Constraints

9.1 Technical Constraints: A more advanced design of seal bearings was not available
9.2 Problems encountered: Design of more corrosion resistance components of the feeder is not economically feasible.
9.3 Regulatory barriers: None reported

10.0 Waste and/or Emission Description

10.1 Physical state: Liquid
10.2 Composition: Lubricating oil
10.3 Description: Waste oil

11.0 Date Case Study was Performed: April 1987 (document date)

12.0 Contacts and Citation

12.1 Type of Source Material: survey study
12.2 Abstractor and Address: Manuela Erickson, SAIC, 8400 Westpark Drive, McLean, Virginia, 22102
12.3 Industry/Program Contact and Address: Richard J. Gimello, Susan B. Boyle, New Jersey azardous Waste Facilities Siting Commission, 28 West State Street, Trenton, N.J. 08608
12.4 Citation:
Author: Environmental Resources Management, Inc.
Title: A Study of Hazardous Waste Reduction and Recycling in Four Industrial Groups in New Jersey.

Title and Volume of Journal: N/A
Title of Book: N/A
Date of Publication: April 1987
Publisher and Address: N/A

13.0 Keywords

13.1 Industry Codes: 2819
13.2 Waste Type: Waste oil
13.3 Process Type: Lubrication
13.4 Waste Reduction Technique: Alternatives evaluation
13.5 Additional Keywords: filtration, recirculation, process equipment modification, hydrofluoric acid

14.0 Ordering Information

15.0 Case Study Evaluation

15.1 Are the technical aspects of the industrial process adequately characterized (manufacturing process, equipment to which option is applied; and waste generation)?: Yes.

15.2 Are the technical aspects of the cleaner production option adequately characterized (new equipment; equipment modifications; materials substitution, recovery and reuse)?: Yes.

15.3 Are the economic aspects of the cleaner production option adequately characterized (costs incurred, costs reduced, payback time)?: No.

15.4 Are the cleaner production benefits quantitatively described?: No.

KEYWORDS: SIC=2819, WASTE OIL, LUBRICANTS, FILTRATION, RECIRCULATION, EQUIPMENT MODIFICATION, HYDROFLUORIC ACID

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Doc No.: 835-001-A-000

1.0 Headline: Du Pont Incorporates Pollution Prevention Measures

2.0 SIC Code: Chemicals and Allied Products/SIC 28

3.0 Name & Location of Company: E.I. du Pont de Nemours & Co., Inc., Wilmington, DE.

4.0 Clean Technology Category: waste tracking, training programs, material substitution, recovery/reuse, and recycling

5.0 Case Study Summary

5.1 Process and Waste Information: Du Pont is a well-known manufacturer of chemical products.

Du Pont defines its "Tabulated Waste" to include RCRA-defined waste, solid waste treated or disposed of on- or off-site, waste-derived fuels, some recycled materials, deepwell injection wastes and waste water effluents.

Among the pollution prevention techniques incorporated by Du Pont:

* targeting, tracking and reporting of tabulated wastes;
* choosing an environmental coordinator for each waste-generating site;
* establishment of training programs;
* material substitution in the production of nylon (butadiene for coal);
* recycle of pump-out solution wastes (polymer and acid) from polyarymide fiber production;
* conversion of wastes generated during nylon production to a useful, marketable product;
* reducing waste stream volumes through the use of belt filters;

5.2 Scale of Operation: Information not available.

5.3 State of Development: The clean technology is fully implemented.

5.4 Level of Commercialization: Information not available.

5.5 Balances and substitutions

Material Category	Quantity Before	Quantity After
Waste Generation: lb/yr	501 M lb/yr	464 M
Feedstock Use:	Information not available.	
Water Use:	Information not available.	
Energy Use:	Information not available.	

6.0 Economics

6.1 Investment Costs: Information not available.

6.2 Operational and Maintenance Costs: Information not available.

6.3 Payback Time: Information not available.

7.0 Cleaner Production Benefits:

The pollution prevention Techniques listed above reduce the volume of several waste streams, while saving the company disposal, treatment and handling costs.

8.0 Obstacles, Problems and/or Known Constraints: None

9.0 Date Case Study Was Performed: Journal article was published in February 1988.

10.0 Contacts and Citation

10.1 Type of Source Material: Journal Article

10.2 Citation: Hollod, G.J. and Mc Cartney, R.F. Waste Reduction in the Chemical Industry: Du Pont's Approach. Journal of the Air Pollution Control Association. February 1988.

10.3 Level of Detail of the Source Material: Additional information is available in the report.

10.4 Industry/Program Contact and Address: Not available.

11.0 Keywords

11.1 Waste Type: industrial inorganic chemical, industrial

organic chemicals, acidic wastewaters, solvent

11.2 Process Type/Waste Source: industrial inorganic chemical, industrial organic chemicals, organic fibers, paints and allied products, cellulosic man-made fiber

11.3 Waste Reduction Technique:source reduction, material substitution, recovery/reuse, process modification, education

11.4 Other Keywords: disposal cost avoided, treatment cost avoided, increased productivity, waste management costs

12.0 Assumptions: Information not available.

13.0 Peer review: Unknown

KEYWORDS: industrial inorganic chemical, industrial organic chemicals, acidic wastewaters,
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Document: CS377

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***** DOCNO: 031-001-A-429*****

1.0 Headline: Source reduction alternatives were investigated for those wastes shipped off-site for treatment.

2.0 SIC/ISIC Code: 2819, industrial inorganic chemical, sodium sulfide

3.0 Clean Technology Category

3.1 Technology Principle: Several alternatives were investigated in an attempt to reduce the volume of reactive sodium sulfide with impurities shipped off-site for treatment. Process modifications, such as changes in the purification process or changes of raw materials were not cost effective. Other alternatives, such as segragation of this waste from other wastes, on-site oxidation, and off-site reuse are still under consideration.

3.2 Cross-Industry Application - Inorganic chemicals manufacturing

4.0 Name & Location of Company: The name of this facility is not provided. This plant is located in New Jersey.

5.0 Case Study Summary

5.1 Incentives: N/A

5.2 Original Manufacturing Process and Previous Waste/Emission Management Methods: Sodium sulfide crystals of reagent grade are recrystallized from an aqueous solution of sodium sulfide flakes after several intermediate purification steps. The residual solution of sodium sulfide with impurities is periodically removed from the crystallizer. Three batches produce 5,000 lb of sodium sulfide crystals and 50 gal of waste solution. This waste is mixed with other aqueous waste streams prior to off-site disposal.

5.3 Scale of Operation: This facility has 9 employees, and annual revenues of 1.5-2.0 million dollars.

5.4 Stage of Development: Under investigation

5.5 Level of Commercialization: N/A

5.6 Results of Application: This information is not available

5.7 Effects on Products: This approach to source reduction

does not affect product quality.

6.0 Economics

6.1 Investment cost: Not provided
6.2 Operational and Maintenance Costs: Not provided
6.3 Other costs: Not reported
6.4 Payback time: Not provided

7.0 Balances & Substitutions

7.1 Wastes generated - 50 gal/3-batches (before)
7.2 Feedstocks - Quantities not provided
7.3 Water Use - Not provided
7.4 Energy Use - Not provided

8.0 Cleaner Production Benefits

8.1 Economic Benefits: Not reported
8.2 Improved public relations: This topic is not discussed
8.3 Liability reduction: Reduced liabilities by reducing the quantity of hazardous waste generated
8.4 Regulatory compliance: Regulatory compliance is easier with reduced quantity of hazardous waste generated.

9.0 Obstacles, Problems and/or Known Constraints

9.1 Technical Constraints: Process modifications too costly
9.2 Problems encountered: Cost of packaging and shipping the sulfide for reuse in a POTW was much more expensive than sending the waste off-site for treatment.
9.3 Regulatory barriers: Required permits to store and treat hazardous waste on site.

10.0 Waste and/or Emission Description

10.1 Physical state: Liquid
10.2 Composition: Sodium sulfide
10.3 Description: Reactive waste with metal impurities

11.0 Date Case Study was Performed: April 1987 (document date)

12.0 Contacts and Citation

12.1 Type of Source Material: survey study
12.2 Abstractor and Address: Manuela Erickson, SAIC, 8400 Westpark Drive, McLean, Virginia, 22102
12.3 Industry/Program Contact and Address: Richard J. Gimello, Susan B. Boyle, New Jersey azardous Waste Facilities Siting Commission, 28 West State Street, Trenton, N.J. 08608
12.4 Citation:
Author: Environmental Resources Management, Inc.
Title: A Study of Hazardous Waste Reduction and Recycling in Four Industrial Groups in New Jersey.
Title and Volume of Journal: N/A
Title of Book: N/A

Date of Publication: April 1987
Publisher and Address: N/A

13.0 Keywords

13.1 Industry Codes: 2819
13.2 Waste Type: Aqueous waste with dissolved sulfides
13.3 Process Type: Recrystallization
13.4 Waste Reduction Technique: Alternatives evaluation
13.5 Additional Keywords: oxidation, crystallization, sodium sulfide

14.0 Ordering Information

15.0 Case Study Evaluation

15.1 Are the technical aspects of the industrial process adequately characterized (manufacturing process, equipment to which option is applied; and waste generation)?: Yes.

15.2 Are the technical aspects of the cleaner production option adequately characterized (new equipment; equipment modifications; materials substitution, recovery and reuse)?: No.

15.3 Are the economic aspects of the cleaner production option adequately characterized (costs incurred, costs reduced, payback time)?: No.

15.4 Are the cleaner production benefits quantitatively described?: No.

KEYWORDS: SIC=2819, AQUEOUS WASTE, SULFIDES, RECRYSTALLIZATION, OXIDATION, CRYSTALLIZATION, SODIUM SULFIDE

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Document: CS378

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***** DOCNO: 031-001-A-430*****

1.0 Headline: Tank cleanout reuse eliminate generation of corrosive waste.

2.0 SIC/ISIC Code: 2819, industrial inorganic chemical, hydrofluosilicic acid (HFS)

3.0 Clean Technology Category

3.1 Technology Principle: Unreacted sand (tank cleanouts) from HFS manufacturing had been disposed of as corrosive waste. This waste is reused by mixing it with fresh sand in the reactors. The generation of unreacted sand has been eliminated. Adequate capacity was available to store tank cleanouts. The bulk of the cost incurred was for the design time of the modified manufacturing procedure.

3.2 Cross-Industry Application - Inorganic chemicals manufacturing

4.0 Name & Location of Company: The name of this facility is not provided. This plant is located in New Jersey.

5.0 Case Study Summary

5.1 Incentives: Elimination of hazardous waste generation at a minimal cost.

5.2 Original Manufacturing Process and Previous Waste/Emission Management Methods: HFS is manufactured by reacting hydrofluoric acid (HF) with sand in the reactor.

5.3 Scale of Operation: This facility has 43 employees.

5.4 Stage of Development: Fully implemented

5.5 Level of Commercialization: Manufacturing of HFS eliminated the generation of a waste by-product from HF manufacturing. The raw material for HF production containes sand as impurity, which can be reused to make HFS.

5.6 Results of Application: Elimination of corrosive waste generation.

5.7 Effects on Products: This information is not available

6.0 Economics

6.1 Investment cost: Not provided
6.2 Operational and Maintenance Costs: Not provided
6.3 Other costs: Not reported
6.4 Payback time: Not provided

7.0 Balances & Substitutions

7.1 Wastes generated - 5tons/yr (before)
7.2 Feedstocks - Quantities not provided
7.3 Water Use - Not provided
7.4 Energy Use - Not provided

8.0 Cleaner Production Benefits

8.1 Economic Benefits: $2,000 annual savings from waste treatment costs
8.2 Improved public relations: This topic is not discussed
8.3 Liability reduction: Reduced liabilities by reducing the quantity of hazardous waste generated
8.4 Regulatory compliance: Regulatory compliance is easier with reduced quantity of hazardous waste generated.

9.0 Obstacles, Problems and/or Known Constraints

9.1 Technical Constraints: none reported
9.2 Problems encountered: none reported
9.3 Regulatory barriers: none reported

10.0 Waste and/or Emission Description

10.1 Physical state: Solid
10.2 Composition: Sand
10.3 Description: Corrosive waste (tank cleanout)

11.0 Date Case Study was Performed: April 1987 (document date)

12.0 Contacts and Citation

12.1 Type of Source Material: survey study
12.2 Abstractor and Address: Manuela Erickson, SAIC, 8400 Westpark Drive, McLean, Virginia, 22102
12.3 Industry/Program Contact and Address: Richard J. Gimello, Susan B. Boyle, New Jersey azardous Waste Facilities Siting Commission, 28 West State Street, Trenton, N.J. 08608
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Title and Volume of Journal: N/A
Title of Book: N/A
Date of Publication: April 1987
Publisher and Address: N/A

13.0 Keywords

13.1 Industry Codes: 2819
13.2 Waste Type: Inorganic solids

13.3 Process Type: Tank cleaning
13.4 Waste Reduction Technique: Recycle and reuse on site
13.5 Additional Keywords: annual cost savings, treatment costs avoided, sand

14.0 Ordering Information

15.0 Case Study Evaluation

15.1 Are the technical aspects of the industrial process adequately characterized (manufacturing process, equipment to which option is applied; and waste generation)?: Yes.

15.2 Are the technical aspects of the cleaner production option adequately characterized (new equipment; equipment modifications; materials substitution, recovery and reuse)?: Yes.

15.3 Are the economic aspects of the cleaner production option adequately characterized (costs incurred, costs reduced, payback time)?: No.

15.4 Are the cleaner production benefits quantitatively described?: Yes.

KEYWORDS: SIC=2819, INORGANIC SOLIDS, TANKS, RECYCLE, REUSE, SAND

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Document: CS376

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***** DOCNO: 031-001-A-428*****

1.0 Headline: Better housekeeping practices and building renovation reduced the volume of wastewater shipped off-site for treatment.

2.0 SIC/ISIC Code: 2819, industrial inorganic chemical, miscellaneous salts (iodides, bromides, sulfides, etc.)

3.0 Clean Technology Category

3.1 Technology Principle: The volume of wastewater shipped off-site for treatment was reduced by preventing contamination of water not related with manufacturing processes, such as rainfall and storm water run-on. Implementation of good housekeeping practices and building renovation prevented rainfall accumulation.

3.2 Cross-Industry Application - N/A

4.0 Name & Location of Company: The name of this facility is not provided. This plant is located in New Jersey.

5.0 Case Study Summary

5.1 Incentives: Economic incentives

5.2 Original Manufacturing Process and Previous Waste/Emission Management Methods: This plant carries out batch processes on a campaign basis to manufacture miscellaneous inorganic salts. Rainfall and stormwater run-on to manufacturing areas was contained due to contamination. The contaminated water was then mixed with process wastewater and shipped off-site for treatment.

5.3 Scale of Operation: This facility has 9 employees, and annual revenues of 1.5-2.0 million dollars.

5.4 Stage of Development: Fully implemented

5.5 Level of Commercialization: N/A

5.6 Results of Application: 50% reduction in wastewater shipped off-site for treatment.

5.7 Effects on Products: This approach to source reduction does not affect product quality.

6.0 Economics

6.1 Investment cost: $40,000 (1985)

6.2 Operational and Maintenance Costs: Not provided
6.3 Other costs: Not reported
6.4 Payback time: Estimated 2-4 years

7.0 Balances & Substitutions

7.1 Wastes generated - Quantities not provided
7.2 Feedstocks - Quantities not provided
7.3 Water Use - Not provided
7.4 Energy Use - Not provided

8.0 Cleaner Production Benefits

8.1 Economic Benefits: Estimated savings of $10,000-20,000 per year in off-site treatment costs.
8.2 Improved public relations: This topic is not discussed
8.3 Liability reduction: Reduced liabilities by reducing the quantity of hazardous waste generated
8.4 Regulatory compliance: Regulatory compliance is easier with improved housekeeping practices.

9.0 Obstacles, Problems and/or Known Constraints

9.1 Technical Constraints: none reported
9.2 Problems encountered: none reported
9.3 Regulatory barriers: none

10.0 Waste and/or Emission Description

10.1 Physical state: Liquid
10.2 Composition: Water
10.3 Description: Contaminated stormwater run-on

11.0 Date Case Study was Performed: April 1987 (document date)

12.0 Contacts and Citation

12.1 Type of Source Material: survey study
12.2 Abstractor and Address: Manuela Erickson, SAIC, 8400 Westpark Drive, McLean, Virginia, 22102
12.3 Industry/Program Contact and Address: Richard J. Gimello, Susan B. Boyle, New Jersey azardous Waste Facilities Siting Commission, 28 West State Street, Trenton, N.J. 08608
12.4 Citation:
Author: Environmental Resources Management, Inc.
Title: A Study of Hazardous Waste Reduction and Recycling in Four Industrial Groups in New Jersey.
Title and Volume of Journal: N/A
Title of Book: N/A
Date of Publication: April 1987
Publisher and Address: N/A

13.0 Keywords

13.1 Industry Codes: 2819
13.2 Waste Type: Wastewater
13.3 Process Type: Storm water run-on

13.4 Waste Reduction Technique: Better housekeeping
13.5 Additional Keywords: annual cost savings

14.0 Ordering Information

15.0 Case Study Evaluation

15.1 Are the technical aspects of the industrial process adequately characterized (manufacturing process, equipment to which option is applied; and waste generation)?: No.

15.2 Are the technical aspects of the cleaner production option adequately characterized (new equipment; equipment modifications; materials substitution, recovery and reuse)?: Yes.

15.3 Are the economic aspects of the cleaner production option adequately characterized (costs incurred, costs reduced, payback time)?: Yes.

15.4 Are the cleaner production benefits quantitatively described?: Yes.

KEYWORDS: SIC=2819, WASTEWATER, STORM WATER, HOUSEKEEPING

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***** DOCNO: 400-074-A-248 *****

INDUSTRY/SIC CODE:	Industrial Chemical Manufacturing/ISIC 3511
TECHNOLOGY DESCRIPTION:	Phosphorous contained in the by-product sludge from phosphorous production is converted to sodium phosphinate via alkaline digestion in an agitator reactor. The digestion suspension product contains contaminants from the sludge and is, therefore, filtered prior to further processing. Subsequent processing includes neutralization, evaporation, crystallization, centrifugation, and drying. This yields the sodium phosphinate final product, along with some CaHPO. The liquid resulting from the centrifugation is recycled to the process. Phosphine and hydrogen off-gases from the reaction are utilized in the production of phosphoric acid (combustion to H_3PO_4, mist absorption in circulating phosphoric acid).
FEEDSTOCKS:	Phosphorous sludge, acetylene-lime hydrate, sodium hydroxide, hydrochloric acid, nitrogen, steam, electric power, water.
WASTES:	With the low pollution technique there is a discharge of 340 kg PH_3 (intermediate product), 77 kg NaCl, 2 kg sodium-phosphinate dust and 5 kg filter cake.
MEDIUM:	Water, air, solid
COST:	
CAPITAL COST:	Low, relative to conventional technology, due to the use of common steel over stainless steel.
OPERATION/MAINTENANCE:	50% reduction in energy consumption over conventional technology. Elimination of heavy corrosion costs.
MONTHS TO RECOVER:	Installation can be amortized over less than three years.
SAVINGS:	
DISPOSAL & FEEDSTOCK:	Not reported
FEEDSTOCK REDUCTION:	Phosphine gas emitted from reactor is utilized in phosphorous acid plant.
WASTE PRODUCTION:	Not reported
IMPACT:	Currently, 30% of the applied phosphorous is emitted into waste water in an elementary form. 10% is emitted into waste water in the form of P_2O_5. Low-waste technology recovers nearly all the applied phosphorous, yielding sodium phosphinate for use in electrolytic nickeling, and a non-toxic filter cake.
CITATION/PAGE:	Compendium on Low and Non-waste Technology, United Nations Economic and Social Counsel, "Sodium Phosphate Made From Phosphorous Sludge", Monograph ENV/WP.2/5/Add74.
KEYWORDS:	Phosphorous, Sludge, ISIC 3511

***** DOCNO: 400-040-A-229 *****

INDUSTRY/SIC CODE:	Chemical Industry and Manufacturing of Chemical Products, Petroleum and Coal Derivatives and Rubber and Plastic Products/ISIC 3512
NAME/CONTACT:	Ministere de l'Environnement et du Cadre de Vie Direction de la Prevention des Pollutions 14, Boulevard du General Leclerc 92521 Neuilly-sur-Seine Cedex, France
TECHNOLOGY DESCRIPTION:	The company produces ammonium nitrate with direct verification of the reaction and debubbling of the water vapor extracted. In the low pollution technique, the verification of the reaction of the two basic elements (concentrated nitric acid and ammonia) is carried out through the pH analysis of the residual water collected at the end of the process. This water was originally contained in the nitric acid and was obtained by evaporation of the ammonium nitrate solution followed by condensation. In the low pollution technique, the ammonium nitrate laden water vapor passes through a debubbler before condensation which limits the nitrate bubbles carried by the vapor.
FEEDSTOCKS:	Ammonium nitrate, nitric acid
WASTES:	Wastewater containing ammonium, nitrogen, and nitric acid
MEDIUM:	Aqueous
COST:	
CAPITAL COST:	F 300,000
OPERATION/MAINTENANCE:	Not reported
MONTHS TO RECOVER:	84
SAVINGS:	
DIRECT COST:	Not reported
FEEDSTOCK REDUCTION:	
WASTE PRODUCTION:	Ammonium nitrate waste reduced by 93%.
IMPACT:	Material consumption is reduced in the low pollution technique by just under 2 per cent. Energy consumption, generally low, is more or less the same in both techniques. This technique allows closer verification of the chemical reactions that take place during production and thus gives a better material yield and less pollution. This principle should be extended to other procedures in the chemical sector.
CITATION/PAGE:	Compendium on Low and Non-waste Technology, United Nations Economic and Social Counsel, "Production of Ammonium Nitrate with Continuous Control of the Reaction and Degassing of the Resulting Water Vapors", Monograph ENV/WP.2/5/Add.40.
KEYWORDS:	Ammonium Nitrate, Reaction Verification, Debubbling, ISIC 3512

***** DOCNO: 400-112-A-271*****

INDUSTRY/SIC CODE:	Manufacture of Basic Industrial Chemicals Except Fertilizer/SIC 28
TECHNOLOGY DESCRIPTION:	The low waste technology is for the production of aluminum fluoride v utilization of waste silica. There are no significant changes in production of the aluminum fluoride. The use of waste silica permits manufacture of a marketable product to be used as a filler in rubl compounds. The steps of the process include: - Dissolution of the waste inactive silica by treating it with an ammoni fluoride solution. - Separation of ammonium cryolite by filtration, to be used in ammoni fluoride production. - Precipitation of active silica by treating the ammonium fluosilic solution with ammonia (gas) or ammonia water. - Separation and washing of active silica on the press filter. - Evaporation of ammonium fluoride solution. - Drying and packaging of active silica.
FEEDSTOCKS:	Silicon (inactive) from aluminum fluoride production (23% SiO_2) - 4,: kg/metric ton output; H_2SiF_6 (100 %) - 269 kg; NH_3 - 327 kg; proc water - 2,330 kg; industrial water - 150 m^3.
WASTES:	Residual gases (50 m^3/ton) from the calcination of active silica, contain less than 10 mg/m^3 F, are washed and passed into the atmosphere. Proc waters and waste water from equipment washing are recycled to the proc for washing active silica cake.
MEDIUM:	Gaseous, liquid
COST:	(Rubles per metric ton)
CAPITAL COST:	9,500 thousand rubles
OPERATION/MAINTENANCE:	330 rubles/metric ton
MONTHS TO RECOVER:	Not reported
SAVINGS:	
DISPOSAL & FEEDSTOCK:	120 rubles/metric ton gross profit on active silica filler.
FEEDSTOCK REDUCTION:	Not reported
WASTE PRODUCTION:	Five percent savings from depreciation charges on pollution co measures attributed to the elimination of the waste silica disposal addition to disposal costs.
IMPACT:	Elimination of silica disposal in a landfill site or storage pond, by cre a profitable use for this waste by-product.
CITATION/PAGE:	Compendium on Low and Non-waste Technology, United Na Economic and Social Counsel, "Production of Aluminum Fluoride wit Utilization of Waste Silica" Monograph ENV/WP.2/5/Add112.
KEYWORDS:	Silica, Precipitation, Solid Waste Recovery, Fillers, Aluminum Fluo SIC 28

***** DOCNO: 400-092-A-318*****

INDUSTRY/SIC CODE:	Manufacture of Basic Industrial Chemicals Except Fertilizer/ISIC 3511
POLLUTION PREVENTION OPTIONS SUMMARY:	Liquors containing soda chlorate and sodium chloride are injected into electrolyzers which transform chloride into chlorate with titanium anodes. The resulting liquors are then sent to a crystallizing pond where part of the chlorate is recovered. The remaining part is returned to the electrolyzers after addition of sodium chloride.
FEEDSTOCKS:	Sodium chloride, electrical energy, titanium anodes
WASTES:	None
MEDIUM:	Not applicable
COST:	
CAPITAL COST:	9,000,000 francs (1978)
OPERATION/MAINTENANCE:	601 francs/ton of product (1980)
MONTHS TO RECOVER:	Not reported
SAVINGS:	
DISPOSAL & FEEDSTOCK:	191 francs/ton in electrical energy, which is offset by increased cost of 100 francs/ton for titanium anodes.
FEEDSTOCK REDUCTION:	Reduced energy requirements.
WASTE PRODUCTION:	Conventional technology uses graphite anodes which requires recovery and rejection of graphite powder sludge
IMPACT:	The standard technique involves filtration of the liquors prior to crystallization because the graphite anodes are gradually consumed (at a rate of 6 kg/ton). Consequently, waste disposal of graphite sludge is required. Additionally, energy consumption is reduced with the low waste technology. Titanium anodes may be used wherever alkaline chlorates are produced via electrolysis.
CITATION/PAGE:	Compendium on Low and Non-waste Technology, United Nations Economic and Social Counsel, "Manufacturing of Soda Chlorate by Electrolysis of Sodium Chloride with Graphite Anodes", Monograph ENV/WP.2/5/Add.92.
KEYWORDS:	Electrolytic Recovery, Chlorate, ISIC 3511

***** DOCNO: 400-123-A-330*****

HEADLINE:	Low waste technology process used in producing hydrogen fluoride ac reduces volume of synthetic anhydrite produced by 85%.
INDUSTRY/SIC CODE:	Manufacture of Basic Industrial Chemicals Except Fertilizers/ISIC 3511
POLLUTION PREVENTION OPTIONS SUMMARY:	Synthetic anhydrite (calcium sulphate), produced from the production hydrogen fluoride acid, is prepared to form a standardized anhydrite bind for use in floor construction in buildings. Part of the anhydrite produc is applied in the cement industry as a setting regulator. Convention method is to dispose of the anhydrite. The low waste technology proce involves an additional step of milling to reduce the grain size, requiri additional classifiers, mills, and bagging apparatus.
FEEDSTOCKS:	CaOH - 50 kg/ton anhydrite, ventilated paper sacks - 6.25 kg, activator- kg, electricity - 97.2 MJ, compressed air (0.3 MPa) - 220 m^3
WASTES:	Anhydrite waste
MEDIUM:	Solid
COSTS:	
CAPITAL COST:	4,000,000 Marks
OPERATING/MAINTENANCE:	80% of capital investment
MONTHS TO RECOVER:	Not reported
SAVINGS:	
DISPOSAL & FEEDSTOCK:	Investment costs are increased by 1,700,000 Marks, operating costs a reduced by 20%. Savings are realized through reduced disposal costs a sales of anhydrite.
FEEDSTOCK REDUCTION:	None
WASTE PRODUCTION:	To-date, 60% of the anhydrite has been produced as anhydrite binder, 25 as setting regulator, and 15% was disposed of as a waste (6 kt/a per 10 k HF).
IMPACT:	The volume of solid waste requiring disposal from production of HF reduced by 85%. Operating costs are reduced by 20% due transportation and disposal costs, and a profitable product is produced t offers advantages in the construction of floors over other binding age used for the same purpose.
CITATION/PAGE:	Compendium on Low and Non-waste Technology, United Nati Economic and Social Counsel, Monograph "Use of Anhydrite Formed the Hydrogen Fluoride Production Process" ENV/WP.2/5/Add.123.
KEYWORDS:	Solid Waste Recovery, Hydrofluoric Acid, Anhydrite, ISIC 3511

***** DOCNO: 450-011-A-001*****

1.0 Headline: New Sodium Chlorate Factory Triples Production and Employs Source Reduction Techniques to Avoid Treatment Costs

2.0 SIC: 2812

3.0 Name and Location of Company

La Societe Quenord, Magog, Quebec, Canada

4.0 Clean Technology Category

5.0 Case Study Summary

5.1 Process and Waste Information: Quenord is the largest manufacturer of sodium chlorate in the world. Their product is principally used in the fabrication of chlorine for use in the pulp and paper industry. In 1985, Quenord built a new factory that tripled its production and because of reduction techniques, its effluent was reduced to almost nothing. The company decided the most effective modifications could be made regarding the refrigeration waters which cool the liquor before their return to electrolytic cells. They used a closed circuit and an open circuit to recover calorific energy (about 22 megawatts), to reduce the amount of water used as much as possible, and to avoid contaminating the waters to eliminate the need for treatment.

The company also used other preventative measures to reduce the amount of pollutants they generate. To reduce the volume of sludge to be disposed, they used table salt and a filter press. To eliminate the separation of their existing anodes, they used metallic anodes. To eliminate the contamination of condensation waters, the company used a surface condenser rather than a barometric condenser. The company used a demisting device that allowed condensate to be recycled. To limit losses of primary material and finished products, a series of pits and pumps returned the material to production and any dust generated was sprayed to wet it. To capture runoff or accidental releases of primary materials, the company used angled barriers and drainage channels around the reservoir and also used good insulation around the buildings and equipment. To eliminate hot purge waters, the company employed an electric heating system. To reduce the risk of chromium release to the environment, the company produced chlorate crystals that were already washed and dried.

By using source reduction, the company saved the $600,000 cost of installing a treatment system. They were able to completely recycle refrigeration waters through closed circuit instead of treating them, they were able to recover energy that normally would have been lost by using an open circuit. This measure saved the company $500,000/year in production costs. Using metallic anodes, eliminating graphite sludge and increasing the output of electricity at a more efficient rate allows the company to save $2,000,000/year.

5.2 Scale of Operation: The company produces approximately 95,000 tons of sodium chlorate/year.

5.3 Stage of Development: This technology was fully implemented at the time of the case study.

5.4 Level of Commercialization: This technology was commercially available at the time of this case study.

5.5 Material/Energy Balances and Substitutions

Effluent		Standards
Total Flow [m^3/d]	715	———
Free Chlorine [g/m^3]	0.05	———
NaClO(3) [g/m^3]	5.5	———
[kg/d]	4.0	———
Total Chrome [g/m^3]	0.01	1.0
*S.S. [g/m^3]	6.0	30
S.D. [g/m^3]	200-351	3000
DCO [g/m^3]	26	30
pH - 7-8.5		5.5-9.5

* Suspended Solids

6.0 Economics*

6.1 Investment Costs: The company spent $900,000 total. Use of the techniques saved $600,000 i the cost of a treatment system.

6.2 Operational and Maintenance Costs: Operational and maintenance costs of the program were nc provided. However, $500,000/year were saved in production costs and $2,000,000/year were save in energy costs.

6.3 Payback Time: The payback time of this operation was approximately 4 months.

It is assumed that costs were reported in Canadian dollars.

7.0 Cleaner Production Benefits: As a result of using source reduction techniques, the company virtuall eliminated all effluents except for the release of disinfection waters from the refrigeration process. The periodically sell condensate from their crystallization system and they save $600,000/year in treatmen costs, $500,000/year in production costs, and $2,000,000/year in energy costs.

8.0 Obstacles, Problems and/or Known Constraints: Not Available

9.0 Date Case Study Was Performed: The pollution prevention measure were initiated in 1985.

10.0 Contacts and Citations

10.1 Type of Source Material: Report

10.2 Citation: Secteur Chimie Inorganique, Technologies Propres, Production du Chlorate de Sodium Gouvernement du Quebec, Ministere de l'Environnement, Gestion et Assainissement des Eaux Revised June 1988. Source document is in French.

10.3 Level of Detail of the Source Material: Additional detail is available regarding the actu refrigeration process and the open and closed circuits. Greater explanation is also given regardin other preventative measures.

10.4 Industry/Program Contact and Address: Regional offices, addresses and phone numbers are given on the back of the report.

10.5 Abstractor Name and Address: Blair M. Raber, Science Applications International Corporation, 7600-A Leesburg Pike, Falls Church, VA, 22043.

11.0 Keywords

11.1 Waste Type: Wastewater, refrigeration waters.

11.2 Process Type/Waste Source: Basic Wastewaters, Chlorine, Industrial Inorganic Chemical, Inorganic Chemicals, Refrigerant, Sodium Chlorate.

11.3 Waste Reduction Technique: Source Reduction, Crystallization, Energy Recovery, Equipment Modification, Insulation, Process Redesign, Refrigeration and Heating Equipment, Volume Reduction, Wastewater Reduction.

11.4 Other Keywords: Canada, Dust, Increased Productivity, Increased Efficiency.

(*) Disclaimer: Economic data will vary due to economic climate, varying governmental regulations and other factors.

Keywords: Wastewater, Refrigeration Waters, Basic Wastewaters, Chlorine, Industrial Inorganic Chemical, Inorganic Chemicals, Refrigerant, Sodium Chlorate, Source Reduction, Crystallization, Energy Recovery, Equipment Modification, Insulation, Process Redesign, Refrigeration and Heating Equipment, Volume Reduction, Wastewater Reduction, Canada, Dust, Increased Productivity, Increased Efficiency

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