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INDUSTRIAL WASTEWATER MANAGEMENT PRACTICES IN AIR FORCE LOGISTICS COMMAND

THESIS

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AFIT/GEM/DEV/91S-13

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THESIS

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Abstract

This research examined how the performance of AFLC's industrial wastewater treatment plants could be improved through changes in management practices. The examination looked into what management practices are found in a model program. The selection of a "model plant" was based upon criteria established by a review of current literature. The criteria were permit compliance, plant performance, and the adoption of pollution prevention as a corporate environmental philosophy. In this study, private sector firms were examined to identify the best industrial wastewater management practices using a Total Quality Management (TQM) tool called benchmarking. The data gathering process consisted a survey of water pollution control organizations, and a survey of benchmark candidates. The purpose of surveying water pollution control organizations was to objectively identify possible benchmark candidates. A questionnaire was then used to gather technical data on each benchmark candidate's performance. After an analysis of survey data, a large aircraft manufacturing firm in the Northwest was chosen as the benchmark. The benchmark firm can be used to identify management practices which would help AFLC improve its operations.

INDUSTRIAL WASTEWATER MANAGEMENT PRACTICES
IN
AIR FORCE LOGISTICS COMMAND

I. Introduction

General Issue

Air Force Logistics Command (AFLC) is concerned about continued problems in the management of industrial wastewaters at Air Logistic Centers (ALC), and in meeting the requirements for the discharge of effluent established by the National Pollutant Discharge Elimination System (NPDES). These problems have resulted in repeated Notices of Violation (NOV) which threaten to curtail or shutdown critical weapon system maintenance functions. According to Lieutenant Colonel Laurent R. Hourclé, chief of the Central Environmental Law Office, Headquarters Air Force,

> A southwestern base (AFLC) in the fall of 1985 came within hours of a regulatory deadline that would have forced it to stop discharges of domestic and industrial sewage to its wastewater treatment facility. . . . The base had no legally acceptable technical alternative for the discharge of its wastes, nor would most Air Force bases in a similar situation. . . . the lesson to be learned is that the Air Force's ability to discharge (industrial) wastewater is essential to the ability of the Air Force to operate its installations and to accomplish its military mission. (1:95)

A 1984 Government Accounting Office (GAO) report stated that 11 of 13 plants investigated were discharging effluents that did not always meet prescribed standards (2:1). This condition, in some cases, was due to deficiencies in plant design (2:1). However, in many cases, failure to consistently comply with the NPDES permit was caused by failures in plant operation and maintenance (2:1). As of February 1991, 80% of the unresolved environmental violations within the Air Force were due to management of hazardous wastes and wastewater treatment plants (3).

Concern for environmental compliance has been expressed by the Air Force senior leadership. Major General Joseph A. Ahearn has said, "I want the Air Force to be known as much for protecting the environment as much as protecting national security" (3). From these statements, it can be concluded that the DOD and Air Force are intent on improving their performance regarding environmental compliance.

Concurrently, under the Clean Water Act Amendments, the EPA has transferred authority for NPDES to the states (4). This transfer of permitting authority has resulted in three of the five ALC's being notified that new permits will impose even stricter effluent standards (5). These stricter standards may result in additional Notices of Violations.

Specific Problem

This research examined how the ALCs performance in the management of industrial wastewater could be improved with regard to decreasing the annual number of Notices of Violation through changes in management practices. The examination looked into what management practices are found in a model program, with emphasis on treatment plant performance. Ideally, a search for a model plant would reveal one with technology similar to that used at the ALCs, and model performance would be a function of managerial practices.

Definition of Key Terms

The are some key terms which must be defined to understand the work which follows.

An industrial wastewater treatment plant is a central facility designed to treat wastewater used during manufacturing processes and render the water as environmentally benign as possible. Failure to treat wastewater properly results in pollution to the nation's lakes, rivers, and streams, which could possibly endanger the public's health.

A waste stream is considered any water discharge from an industrial operation to the central collection system of a treatment plant. The characteristics of a waste stream vary between operations, and must be clearly understood.

An exceedance is the violation of any permit issued by a federal, state, or municipal agency to a treatment plant.

Influent is the flow entering a wastewater treatment plant from a specific process, such as electroplating, or from a central waste collection system.

Effluent is flow out of a wastewater treatment plant into a publicly owned treatment work (POTW), or to a surface body of water.

Research Objective

The objective of this research was to identify a model industrial wastewater management program to serve as a benchmark for Air Force Logistics Command wastewater management. In accomplishing this objective, two research questions guided the investigation of identifying a model program.

Research Question 1. What are appropriate criteria by which to select a benchmark wastewater management program?

Research Question 2. What are considered some of the best management practices regarding wastewater management?

Hypothesis. The researcher's hypothesis is that a model wastewater management program would use treatment technology similar to those found at the ALCs; experience no exceedances in the past year; no more than two exceedances in the past four years; and would have adopted pollution prevention as a environmental philosophy.

Outline of Research Design

The research questions posed were investigated through a review of the literature, and are addressed in Chapters Two and Three, respectively. Wastewater management programs of selected private sector firms were analyzed to identify the best industrial wastewater management practices using a Total Quality Management (TQM) tool called benchmarking. David T. Kearns, Chief Executive Officer of Xerox, stated that benchmarking is a "process of measuring oneself against the . . . practices of our toughest competitors" (5:86). Chapter Three explains this methodology in further detail. The process of data gathering and analysis, as described in Chapter Four, consisted of two parts: a survey of water pollution control organizations, and a survey of benchmark candidates. The purpose of surveying water pollution control organizations, including EPA, was to objectively identify possible benchmark candidates. The results of this survey were used to identify benchmark candidates, who were contacted to determine if they would participate in the benchmarking process. A questionnaire was administered to the candidates to gather technical data on each firm's performance. Using the data collected, the benchmark firm was identified in Chapter Five, using the criteria established. Once a benchmark was identified, AFLC could incorporate these management practices.

Scope and Limitations of the Study

It is possible that the survey of water pollution control organizations did not reveal all possible benchmark candidates. This weakness in the investigation is due to the limitation that candidate firms treat wastes with similar characteristics as those found at AFLC bases. The purpose of surveying professional associations and regulators was to strengthen the study's face validity, and remove potential biases of the researcher. Nevertheless, the biases of the organizations surveyed could have resulted in selection of a benchmark candidate that was not truly the best of all industrial wastewater treatment programs.

II. Literature Review

Overview

Air Force Logistics Command (AFLC) is concerned about the discharge of industrial wastewater meeting the requirements for the discharge of effluent established by the National Pollutant Discharge Elimination System. This problem has resulted in repeated permit exceedances, which threaten to curtail or shutdown critical weapon system maintenance functions. This research seeks to determine how the management of industrial wastewater can be improved with the goal of reducing the number of Notices of Violation.

This chapter first reviews water pollution ecology and industrial wastewater control technology to provide a framework for understanding the technical problems faced by plant managers. Secondly, the current regulatory framework for establishing plant performance standards is described. Third, problems found to exist at AFLC treatment plants which prevent them from complying with applicable standards are discussed. Finally, perspectives of the EPA are used to establish criteria for identifying the benchmark.

Water Pollution and Control

The purpose of this section is to provide a basic understanding of water ecology and industrial wastewater treatment.

Water Pollution Ecology. In their text Environmental Engineering, Peavey, Rowe and Tchobanoglous define water pollution as "the presence in water of impurities in such quantity and of such nature as to impair the use of the water for a stated purpose" (6:14) Self-purification of natural water systems is a complicated process involving physical, chemical, and biological processes working together (6:83). Chemical and biochemical reactions convert wastes into inert substances, which are then physically removed from the water by physical processes, such as sedimentation or gas transfer (6:83). The dissolved oxygen content of water is an important factor in sustaining aquatic life (6:83). If the waste discharged consumes large amounts of dissolved oxygen, then the 2 mg/L of dissolved oxygen required to sustain higher forms of life will not be met (6:83). Therefore, the amount of dissolved oxygen in a stream is one of the best measures of ecological health.

Types of Pollutants. Lieutenant Colonel Laurent R. Hourclé in his manual Environmental Law of the Air Force states that both conventional pollutants and toxic pollutants are being discharged into the nation's lakes, rivers, and streams (1:66). Toxic pollutants are considered to be substances which are known to be physically harmful to human health. The EPA currently lists 65 different herbicides, pesticides, heavy metals and other chemicals as toxic pollutants (1:66). Industrial wastewater contains toxic pollutants as a result of various processes used in manufacturing.

Water Pollution Treatment Technology. Peavey et al. state that the discharge of wastewater into streams and rivers is a common practice, following the old adage "the solution to pollution is dilution" (6:208). This practice was a viable alternative for most regions of the world until the early 1900's, when the assimilative capacity of most streams and rivers started to be exceeded (6:208). According to Hourcle, every major Air Force installation discharges wastewater either after in-house treatment or processing through a Publicly Owned Treatment Works (POTW) into a stream, river, or lake (1:70). Though some special techniques exist to treat industrial wastes before discharge, most wastewater treatment relies upon turn-of-the-century technology (1:62,72). According to Frank L. Cross in his book Management Primer on Water Pollution Control, industrial wastewater treatment uses pretreatment, primary, secondary and tertiary processes to treat both conventional and toxic pollutants. Figure 1 shows the layout of a generic industrial wastewater treatment plant, although each plant is specifically designed for the wastes it treats.

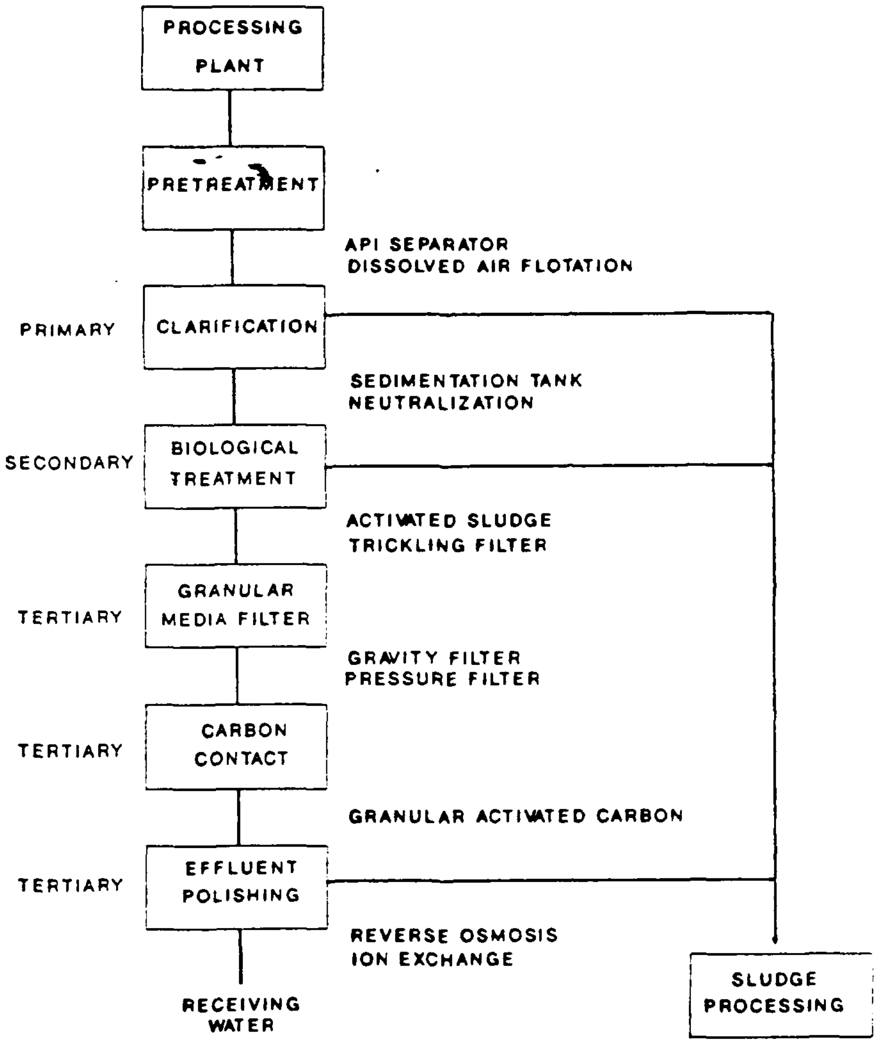

Figure 1. Typical Industrial Wastewater Treatment Plant

Pretreatment. Pretreatment occurs prior to the typical "end-of-pipe" treatment processes, and may be applied either to the entire waste stream, or to selected portions (7:157). The purpose of pretreatment is to chemically or physically modify a waste stream, reduce fluctuations in wastewater quantities and characteristics, or provide optimum conditions for additional treatment near the specific source of the waste (7:157). A variety of processes are used to accomplish this, including equalization, neutralization, temperature adjustment, recycling and detoxification (7:157). These processes are generally justified economically on the basis of reductions in treatment plant size, operating costs, and cost savings from recycling (7:157).

Primary Treatment. Primary treatment involves physical and sometimes chemical treatment for the removal of settleable or floatable materials from the incoming waste stream (6:212), (7:157). This amounts to a filtering and holding process, which removes the larger solids. Primary treatment includes screening, grit removal, sedimentation, dissolved gas flotation, and gravity differential separation of liquids (such as oils and greases), leaving the organic solids for removal by sedimentation (7:157, 6:213-214). Removal of large solids and grit lowers maintenance costs by preventing damage to and clogging pumps, pipes and weirs (7:157). The purpose of primary sedimentation is to concentrate and remove organic solids (6:224). The solids formed due to settling are known as sludge, which is later digested to reduce its volume and render any undecomposed or pathogenic material inert (6:224-225, 1:72). Hourcle states that primary treatment will remove 40-70 percent of the suspended solids and 25-40 percent of the dissolved organic solids from a typical industrial waste stream. (1:72) In addition, a large portion of the oxygen demand is due to suspended solids, and primary treatment can significantly reduce BOD and COD, as well as, inorganic loadings on later treatment processes (7:157).

Secondary Treatment. The purpose of secondary treatment is to accelerate the processes which occur naturally in surface waters over extended periods of time. The main element of secondary treatment is the aerobic biological conversion of dissolved and colloidal organics into solids which can be removed by sedimentation (6:214). Organic materials dissolved in a wastewater are removed by microbiological growths and stabilized by biochemical synthesis and oxidation reactions (7:158). The basic requirements of biological processes are a consistent food supply, adequate contact (mixing) between biological growth and food supplies, an ample oxygen supply, sufficient nutrients, proper pH and temperature control, and the absence of toxic materials (7:158). The two principal types of secondary treatment are trickling filters and activated sludge reactors (6:214, 1:72).

Tertiary Treatment. Tertiary treatment involves a variety of water pollution control technologies to improve the quality of the effluent by removing residual organics, dissolved inorganics, and nutrients such as phosphorous and nitrogen (7:161). The purpose of tertiary treatment is to treat a specific problem caused by chemical substances commonly found in industrial waste streams (1:73). Because the characteristics of industrial wastewater are different for every process and industry, treatment processes are contaminant specific (6:209). This variation complicates the technical problems faced by plant operators in complying with regulatory requirements.

Tertiary treatment includes adding chemicals to balance pH, or using sophisticated filtration systems to remove organics or other chemicals (1:73). The main processes used are activated carbon adsorption and chemical oxidation for removal of refractory compounds, color, taste and odor control (7:161). Chemical flocculation and sedimentation are used for removal of dissolved organics and colloidal materials. Ion exchange, solvent extraction, foam separation, electrodialysis, reverse osmosis, and multiple effect evaporation are classified as tertiary treatment (7:161). Most tertiary treatment processes concentrate the pollutants which require further disposal.

Sludge Disposal. The removal of solids from wastewater and the generation of solids in biological and chemical treatment produces sludges that require further treatment and disposal (7:163). Sludge disposal includes pretreatment, concentration, and disposal (7:163). These sludges are dilute and usually require pretreatment to concentrate the solids, and to prevent decomposition (7:163). Many would argue that sludge disposal is the most difficult area of wastewater treatment today (7:163).

Problems with Wastewater Treatment Technology. Secondary treatment, as previously stated, is an organic process. Wastewater treatment systems use microorganisms to maintain high levels of aerobic decomposition. Problems are frequently encountered in operation of wastewater treatment plants in keeping these microorganisms alive (1:74). For instance, large amounts of rainwater mixing with the sewage impede the growth of the bacteria due to dilution of the food supply (1:74). These bacteria are very susceptible to being killed by many toxic substances, including oil, pesticides, and many industrial chemicals (1:74). If the bacteria are destroyed, several days are required for the bacteria to grow, forcing the plant to use only primary treatment (1:74). This disruption results in the discharge of effluent that fails to meet permit standards (1:74). The fragility of the system is why plant managers are concerned about the coordination of discharges from industrial operations and waste oils from the general public (1:74). According to Hourcle, another concern is that the waste stream may contain heavy metals, which eventually become deposited in the sludge, complicating its disposal (1:74).

<u>Water Pollution Control Statutory Framework</u>

<u>Federal Law</u>. Congress has developed several strategies for the protection of surface water, regardless of location or cause of pollution. The water pollution statute that most directly affects day-to-day Air Force operations is the Clean Water Act, also known as the Federal Water Pollution Control Act of 1972 (8:4). The act identifies four main approaches to controlling pollution of surface water: point source control; research and development into wastewater treatment technology; waiver of sovereign immunity; and public involvement including citizen suit provisions (1:80).

The Clean Water Act and its amendments have the objective of restoring and maintaining

> . . . the chemical, physical, and biological integrity of the nations' waters by eliminating the discharge of pollutants into navigable waters of the United States by 1985 (2:1).

Hourcle says this goal of no discharges has not been achieved and probably will never be achieved, considering the broad definition of pollutant includes: solid waste, sewage, garbage, chemical wastes, biological materials, heat, sand, and industrial, municipal and agricultural wastes (1:80). However, two important ideas are apparent in the act's goals: no one has an inherent right to pollute the nation's waters and the states are responsible for water availability and water quality within their borders (1:80). Until recently, the concept of water pollution abatement focused on point source control. The Clean Water Act defines a point source as any

> . . . discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. (2:2)

The Clean Water Act of 1987, also known as the Water Quality Act, has been the most significant water pollution legislation since the original 1972 act. This legislation mandates the treatment of nonpoint source pollution by 1992 (8:7). Examples of nonpoint sources include runoff from construction sites, urban areas, and agricultural areas. Compliance with this law has opened a new realm of problems for wastewater engineers and operators (8:7). For example, prior to 1987, only point source treatment was mandatory; however, the Clean Water Act of 1987 requires mandatory treatment of nonpoint sources.

Permits and Licenses. The controlling mechanism of the Act is a permit system to limit discharges from point sources (1:84). This mechanism is formally known as the

National Pollutant Discharge Elimination System (NPDES) which requires every waste treatment plant to obtain a permit from the EPA or the state to discharge any pollutant into navigable waters (2:1).

> Permits are issued on the condition that the discharge will meet all applicable requirements of EPA or state regulations relating to effluent limitations, water quality standards, new source performance standards, toxic effluent standards, inspections, and monitoring and entry provisions (2:1).

As a result, all sewage treatment plants, including those operated by the DOD, are required to obtain a NPDES permit. The philosophy behind NPDES is that no point source can discharge into a surface water of the United States without first having a permit (1:84). The permits specify what can be discharged, how much can be discharged over a specified period of time, and when discharges are allowed to take place (1:84). Any industrial activity discharging into a stream, river, or other waterway must have a current, valid NPDES permit. Therefore, any discharge from a point source without a NPDES permit is illegal. The NPDES permit program can be run by EPA through its regional offices or can be delegated to the states (1:84). To obtain a NPDES permit the applicant must provide the permit granting authority with data about the industrial processes involved and the effluent to be discharged. Once the NPDES permit is granted, it will specify the specific operating conditions as to what and how discharges are to be made (1:85). These conditions base discharge limits on the effluent regulations, capability of the actual wastewater treatment process, and on the designated water quality standards for the receiving body of water. The actual conditions set in a NPDES permit fall into two categories: those dealing with standards, and those regarding monitoring and record keeping (1:85).

Effluent Limitations. The objective of the effluent limitations is to designate the levels of water pollution control technology that dischargers are required to use (1:85). Dischargers are broken down into two classes: publicly owned treatment works and others (1:85). Effluent limitations are then set for the two categories (1:85). In the "all others" category the standards are also set by the industrial process involved (1:85). All federal wastewater treatment facilities fall into this second category because they do not met the regulatory definition of a POTW (1:86).

The effluent limitations are derived from the effluent standards regulation and the technology available. They are issued by EPA in a rule-making process and published in final form in the Federal Register and Code of Federal Regulations (CFR) (1:85). There are both effluent standards to be met by persons discharging directly into a waterway, and pretreatment standards for persons discharging into a POTW, sometimes referred to as direct dischargers and indirect dischargers, respectively.

Toxic Standards. The Clean Water Act employs a separate process to set standards for the discharge of toxic substances, either directly into surface water, or as a pretreatment discharge into a POTW (1:83). The Clean Water Act authorizes the EPA to prohibit the discharge of toxic pollutants in amounts dangerous to the public (1:83). The reason for this difference is that the standard is set for a specific toxic substance, based upon a thorough risk analysis. Effluent standards are set for a specific process (1:83). If toxic pollutants are in the waste stream, toxic standards will be specified in the permit. These standards can be as strict as a no-discharge requirement (1:83).

Water Quality Standards. The 1987 Clean Water Act Amendment strengthened the water quality standards program for the zoning of different classes of surface water for significant deterioration (1:83). Under the water quality standards program, states are encouraged to zone surface waters by use, and set water quality standards for these uses in accordance with EPA guidelines (1:84). Water quality standards include criteria related to dissolved oxygen, heavy metals, nitrates and phosphates (1:84). EPA minimums for dissolved oxygen range from seven to four milligrams (mg) per liter (1:84). Heavy metals, such as mercury, silver, arsenic, chromium, copper and lead, have as a minimum no detectable amount due to their toxicity and ability to accumulate in fish and animal life (1:84). The water quality standards program is gaining the attention of federal installations as states gain permitting authority, and begin applying these much stricter standards for permit renewal.

<u>Pretreatment Standards</u>. Knowing the composition of the sewage entering a typical plant, as previously discussed, is crucial for a plant to operate within permit limits. There are many pretreatment standards for different industries and industrial processes, several of which affect base-level activities (1:84). In addition, municipal sewage plant operators may require additional limitations in the form of pretreatment standards on sewage sent to their facility (1:84). The main effluent pretreatment standards the Air Force is concerned with are for electroplating, steam power generating, and metal finishing (1:84).

<u>Monitoring and Reporting Permit Requirements</u>. The second set of requirements in the NPDES permit are for the permit holder to monitor the composition of the effluent discharged under the permit, maintain records of plant performance, and periodically report all results to the permit granting agency (1:86). The NPDES permit will specify what monitoring equipment is to be used (1:86). In addition, enforcement authorities have a right to review and copy reports, inspect monitoring equipment or methods,

and take effluent samples (1:86). With a limited exception, any information obtained will be in the public domain, and can be used as evidence of permit violations (1:86).

Enforcement Actions. Hourcle states that the three options available to the enforcement agency for a violation are: a compliance order, an action for a civil penalty, or a criminal action (1:89). The most common enforcement is the administration of a Notice of Violation (NOV) or administrative compliance order on a base (1:89). Administrative compliance orders usually specify 30 days for the discharger to bring the situation into compliance (1:89). The Clean Water Act specifies several offenses that are subject to enforcement penalties. These offenses include violations of a permit, knowingly falsifying or falsely certifying a required application report or other data, or tampering with monitoring equipment or testing process can result in criminal penalties (1:89).

Federal versus State Control. As with the Clean Air Act, the authority to permit federal installations can be delegated to states (1:88). Until 1987, very few states had received delegated authority to regulate federal facilities. (1:88). The 1987 Clean Water Act amendment was designed to encourage the EPA to delegate this authority to the states in accordance with the Act's objective of making the states responsible for the waters within its borders.

Originally, federal facilities were only encouraged to comply with all applicable federal, and state requirements; however, the federal government was not obligated to comply with these standards (8:5). In 1978, Executive Order 12088 required that federal agencies comply with applicable standards dealing with pollution control (8:5). As a result, sovereign immunity was officially waived, requiring the head of each federal agency

> . . . to insure that facilities under his jurisdiction comply with federal and state water quality standards and to present a plan each year to the Director of the Office of Management and Budget for improvements necessary to meet federal, state, interstate, and local water quality standards and effluent limitations (2:11).

Executive Order 12088 distinguished between compliance requirements of federal and nonfederal sewage treatment plants (8:5). Federal agencies were required to provide a plan on how to achieve and maintain compliance when they were found to be in violation of applicable standards by an appropriate state, interstate or local agency (8:5).

AFLC Treatment Plants and Their Performance

The laws, directives, and regulations governing industrial wastewater treatment are becoming stricter; therefore, compliance will be more difficult and costly. Air Force industrial wastewater treatment plants are experiencing many problems in complying with the current standards, much less the stricter ones. Renaud states that typical problems faced by the DOD include incompatible wastes entering the plant, design or equipment problems, and management problems during plant operation (8:8). He goes on to state that many of the NOVs levied by the EPA or state agencies against an installation resulted from these types of deficiencies (8:16).

This section will discuss, in depth, documented problems found at DOD wastewater treatment plants, and current Air Force policy regarding them. Then, background on each base within AFLC is presented to show specifically how these problems impact operations at base level.

Incompatible Wastes Entering the Plant. The IWTPs frequently encounter problems which disrupt operation due to hazardous and toxic substances entering the waste stream (1:76). Historically, these substances are waste oils, solvents used in maintenance, chemicals used for corrosion control, and firefighting foam (1:74). Strict pretreatment requirements would help contain the problem when the wastes are discharged from industrial activities; however, this solution will not solve the problem of "midnight dumpers" who illegally dump hazardous substances into the waste collection system (1:75). A 1985 GAO study of a large Air Force Logistics Command (AFLC) base found numerous cases where the base IWTP was shut down by industrial chemicals spilled or poured down drains due to illegal dumping of hazardous materials (2:7).

Operation and Maintenance Problems. The 1984 GAO report, Improvements Needed in Operating and Maintaining Waste Water Treatment Plants found that "many Department of Defense (DOD) facilities did not meet water quality standards and that DOD had not taken adequate measures to insure compliance . . ." (2:3) The report stated that, among other problems, a lack of proper operation and maintenance was the chief cause of noncompliance.

A study conducted by the GAO in 1983 of thirteen sewage treatment plants at DOD installations found

> . . . that most of the DOD plants visited have been unable to consistently meet National Pollution Discharge Elimination System (discharge) permit requirements for a number of years (2:22).

The GAO went on to say that typical operations and maintenance (O&M) problems found were due to a lack of DOD guidance; failure to correct problems found by internal audits and regulatory agencies; equipment deficiencies; stormwater overflows; and continuing operation and maintenance problems (2:22).

One of the main causes for the inadequate O & M programs was the failure of the DOD and the Air Force to issue clear and specific guidance (2:22). The DOD and each service is responsible for issuing this guidance to enable each plant to achieve and maintain compliance (2:24). The GAO report stated only general guidance had been provided through "infrequent formal O&M inspections performed by DOD, EPA, and state environmental engineers" (2:24).

Specific guidance had been received only informally from EPA and state agency inspectors (2:24). The GAO's review of 49 formal inspection reports at 13 bases identified many problems such as a lack of spare parts, broken equipment items, and lack of attention to O&M requirements. Many operators cite funding shortfalls as the primary reason for corrective actions not being made.

> This [lack of funds] has resulted from several factors including the low priority of sewage treatment plants for O&M projects and problems in getting larger projects through the military construction process. (2:25)

Equipment failures such as a bent scum removal arm, inoperable secondary clarifiers, broken pumps, and inoperable chlorine feeders also affect a plant's ability to meet permit requirements (2:26). Renaud found that although the Air Force has a reporting system to track these requirements, these projects were not receiving the proper attention (8:14).

Certified Operators. Wastewater treatment can be considered an art as much as a science. Exacerbating the situation faced in AFLC wastewater treatment plants is the level of experience or competency of operators. Employment as a sewage treatment plant operator may not be a highly sought after job for most Americans, but the profession is very important in an economic sense. More than $56 billion has been spent on upgrading sewage treatment plants since passage of the 1972 Federal Water Pollution Control Act.

According to Hourcle,

> . . . the people running treatment plants must know and care [about] what they are doing, and the users need to know the plant's limitations. Training and keeping knowledgeable sewage plant operators is probably the highest hurdle the Air Force must surmount in complying with the Clean Water Act. (1:75)

One cause for the lack of certified operators is the absence of reciprocity between states (8:15). For example, if an operator certified in one state moves to another state with stricter certification requirements, then the entire certification process must be completed again in the new state (8:15). This problem affects the DOD more than civilian operators, since military personnel typically move more frequently amongst DOD installations. Currently, efforts are underway to develop a national certification program which would end this problem (8:15).

Air Force Policy on Water Pollution Control Facilities. Air Force Regulation 91-1, Water Pollution Control Facilities, establishes policies governing the operation and maintenance (O&M) of water pollution control facilities (both industrial and domestic) at Air Force installations (9:1). This regulation, issued in 1989, was designed to address many of the problems found by the GAO, and other regulatory agencies. The Air Force's overall objective is to operate and maintain water pollution control facilities efficiently and effectively (9:1). This objective is accomplished by the Base Civil Engineer following regulations and permit requirements (9:1).

Air Force Regulation 91-9 recognizes the importance of controlling pollution at the source. It states,

> An effective base program for controlling industrial wastewater and nondomestic waste requires the full support of activities that generate the waste. (9:2)

This support is obtained by specifying procedures for the discharge of wastes for all generators on base (9:2). These procedures describe the collection, segregation, pretreatment, and on flow limitations for these special wastes (9:2). This type of base level guidance is intended to make generators directly responsible for controlling nondomestic waste discharges, and encourage generators to reduce toxic or hazardous discharges by material substitution or process change (9:2). As discussed previously, operation and maintenance problems compose a large portion of the cause for NOVs. AFR 91-9 candidly addresses these concerns with specific guidance on work center manning, facility attendance, and plant design (9:2-3).

Background on AFLC Industrial Treatment Plants. This section provides background on the problems faced within Air Force Logistics Command, in light of the previous discussion on the regulatory climate, and typical problems faced by DOD wastewater treatment plants. This information was provided courtesy of Headquarters Air Force Logistics Command, Deputy Chief of Staff for Civil Engineering, Directorate of Environmental Management.

Robins Air Force Base, Georgia. The effluent from Industrial Wastewater Treatment Plant 1 flows to the sewage treatment plant for polishing and for ammonia and phenol removal (4). The Sewage Treatment Plant (STP) effluent is a combined domestic and industrial flow (4). The NPDES permit for Robins, issued on December 30, 1988, requires non-stormwater runoff to meet significantly lower limits for metals and total cyanides, effective December 30, 1991 (4). These discharge limits are water quality based, due to the classification of the receiving water as best use fishing (4). Three segregated waste streams containing either cyanide, acid/alkali, or chromium are treated (4). Chemical treatment, precipitation and clarification precede direct discharge to the receiving waters (4). These treatment processes are not capable of meeting the limits which become effective December 31, 1991. Additional treatment is required to meet discharge limits for cyanide, cadmium, copper, lead, and silver (4). The STP effluent, which includes the IWTP 1 effluent, meets the current NPDES discharge limits (4). Additional treatment will be needed to meet the discharge limits which become effective on December 31, 1991 for copper, chromium, lead, and silver (4). These discharge limits are extremely low and will require considerable plant modification and improved performance to meet extremely low limits (4).

Kelly Air Force Base, Texas. For the industrial discharges, the base has permits with EPA Region VI and the Texas Water Commission (4). The industrial wastewater treatment facility went into operation in July 1988 (4). This plant routinely meets discharge permit limits; however, the causes of past sporadic exceedances of phosphorous, ammonia, and chemical oxygen demand remain undetermined (4). Additionally, sporadic cases of hydraulic overloading during intense rainfall have occurred, upsetting plant operations (4). The revised NPDES permit with EPA Region VI, went into effect on 27 July 1990, adds chronic biomonitoring, and new lower limits for copper, silver, lead and cyanide, with a July 1992 compliance schedule (4). Base personnel feel the plant can meet these new standards (4). The base is currently carried by EPA Region VI as noncompliant with NPDES, due to hydraulic overloading of the IWTP during heavy rains due to the condition of the collection system. Projects are planned in Fiscal Year 1993 to correct this problem.

Tinker Air Force Base, Oklahoma. Tinker AFB has had a long history of recurring problems with achieving National Pollutant Discharge Elimination System (NPDES) limits on its IWTP (4). Tinker's problems have been primarily in meeting the metals discharge limits since 1983 (4). These problems ultimately resulted in the base entering into a Federal Facilities Compliance Agreement

(FFCA) with the EPA on April 7, 1987 to settle on negotiated solutions to the problem (4). Subsequent plant modifications and construction of a pretreatment facility enabled the base to achieve compliance in July 1988 (4). In August 1988, EPA Region VI issued a new NPDES permit for Tinker that lowered discharge limits for the IWTP (4). Under these new discharge limits, the IWTP could not sustain compliance with the new metal limits (4). Inability to meet the new limits forced the base to renegotiate the FFCA with the state and the EPA in February 1989, with a deadline for resolution of the compliance problems by January 31, 1991 (4). Biomonitoring tests started in December, 1988, showed the combined effluent was highly toxic. These conditions resulted in the EPA requesting the base undertake a Toxicity Identification/Reduction Evaluation to identify sources of toxic pollutants and recommend ways to clean up discharges. This study calls for studying all aspects of industrial waste management, including plant housekeeping, use of chemicals, plant operations, finding sources of toxicity, and recommending plant or pretreatment process to eliminate the toxicity.

The base is currently reported by EPA Region VI as noncompliant with NPDES, due to a lack of adequate treatment. The IWTP needs additional treatment processes added to meet proposed lower limits. The State of Oklahoma has informally advised the base that they will be taking over permitting from EPA Region VI, and that limits will be much lower and more in line with stream criteria. A new state discharge permit is expected in 1992. Several repair projects are planned and the base is negotiating a FFCA extension based on a Fiscal Year 1993 military construction program for plant upgrade. As a long term solution, the base is studying connection to a regional POTW.

Even after elimination of cross connections and other projects, potential exists for noncompliance due to improper discharges through floor drains. Continued management emphasis and compliance monitoring will be necessary to sustain compliance.

Hill Air Force Base, Utah. All industrial wastewater streams are treated at the base (IWTP) (4). The treated industrial effluent is commingled with raw sanitary sewage and discharged to a North Davis County Sewer District POTW for further treatment (4). The base has had an excellent record with its discharges to the North Davis County Sewer District and has not experienced any permit exceedances since June 1989. Despite this excellent record, the base has continued to look for improvement both within its plant operations and in the depot maintenance activities. Hill AFB is in full compliance with current limits for their combined effluent discharge and is expected to stay in compliance (4). The base has had an active program to repair and maintain existing systems and has maintained an aggressive program to reduce the volume and toxicity of wastewater discharges (4).

McClellan Air Force Base, California. Although McClellan AFB is not considered a major discharger, the base treats all industrial wastewater streams discharged to the industrial waste lines (IWL) at Industrial Wastewater Treatment Plant 1 (4). The base pretreats electroplating rinse water in IWTP 2 and oily wastewaters in an oil/water separator before feeding the effluents into IWTP 1 for final treatment and discharge (4). The treated industrial effluent is commingled with raw sewage and discharged to the Sacramento County Regional System for further treatment (4). Several projects underway will minimize hazardous waste generation, and help meet future commitments to regulatory agencies. One example is the implementation of a five year hazardous waste source elimination plan that will eliminate discharge of any hazardous waste by finding alternative disposal methods, chemical substitution source monitoring, and use other available technology. The base is in full compliance with current pretreatment limits for their combined effluent discharge, and is expected to remain unchanged (4). The base has an ambitious effort underway, and has taken the lead in eliminating discharge of hazardous wastewaters. Their efforts will improve compliance, as well as, assist compliance actions at other AFLC bases.

Criteria for a Model Program

In order to select a benchmark for AFLC industrial wastewater management programs, criteria must be established to objectively measure candidate performance. For this criteria to be meaningful, the perspective of the EPA on industrial wastewater management performance is described, suggesting possible criteria for benchmarking.

EPA's Perspective on Treatment Plant Performance. In response to the GAO's 1984 report mentioned in Chapter One, the Operation, Maintenance and Training Assistance Program (OMTAP) was created by the Office of the Deputy Assistant Secretary of Defense for Environment (10:1-2). OMTAP was "based on the generic protocol for a comprehensive diagnostic evaluation of management and operation of wastewater utilities, prepared by the Environmental Protection Agency (10:1-2). According to the EPA, the primary objective of this diagnostic tool was to investigate if wastewater treatment plant operation consistently produced effluent that was in compliance with current permit limits (10:2-4). To perform this investigation required the observation and evaluation of each step in the treatment process and the treatment system as a whole (10:2-4). Plant records and Discharge Monitoring Reports (DMR) submitted to regulatory agencies covering the preceding twelve months of operation were used to judge plant performance against NPDES permit requirements. Plant performance was operationally defined in two ways. First, overall system performance is demonstrated by compliance with NPDES permit provisions. Second, individual process steps were measured in terms of contaminant removal efficiency for each unit process. These operational definitions result in a model plant as being characterized by no recent permit violations, and as the most efficient in contaminant removal.

EPA's Perspective on Wastewater Management. According to Mr. James E. Hayes, from the Office of Pollution Prevention, Environmental Protection Agency, the perspective of the EPA has undergone a significant shift in the past two years with regard to environmental management (11). The EPA views the permit system used to control all industrial processes for air, land, and water as inadequate to restore the nation's environment to near pristine conditions as promised in the 1972 Clean Water Act (11). This shift is the result of a risk paradigm acknowledging that the only acceptable risk for human health and protection of the environment is zero risk (11). This idealistic goal can be better understood as "a pollution prevention philosophy, rather than a waste minimization one" (11). The move toward a philosophy of pollution prevention is best evidenced by the stricter effluent limitations being issued for NPDES permits. According to Patricia S. Dillon, from the Center for Environmental Management, Tufts University,

> . . . environmental issues are of increasing importance to companies and central to the operation of corporations. Environmental issues can be managed like any other business activity, that is, by planning, organizing, executing, and controlling. Ideally, environmental management should be integrated into business operations rather than operate as an independent function. (12:1)

The adoption of pollution prevention as a corporate environmental philosophy can be operationally defined using four metrics: strategic planning that integrates environmental issues, incorporating environmental issues in product and process design, the setting of environmental goals, and requiring vendors to be in compliance (12:3-4). By incorporating environmental issues throughout the strategic planning process, environmental performance goals and objectives can be integrated with business plans (12:3). The systematic incorporation of environmental issues into research, product development and process design can be accomplished by development of general design criteria, preapproved lists of acceptable chemicals, and process hazard analysis (12:4). The setting of numerical goals, and a precise time frame to accomplish those goals are important for motivating change (12:5). Dillion stated that participants in a recent workshop consider challenging goals desirable because they make people think differently (12:5). Hayes stated that a model IWTP would be one that has adopted pollution prevention as a corporate environmental philosophy (11).

Summary

This chapter first reviewed water pollution ecology and control technclogy to provide a framework for understanding the technical problems faced by plant managers. Next, the current regulatory framework establishing standards for plant performance was described. Then problems found to exist at AFLC treatment plants which prevent them from complying with applicable standards were highlighted. Finally, the criteria for identifying a model plant were developed. These criteria are permit compliance, plant performance, and the adoption of pollution prevention as a corporate environmental philosophy.

III. Best Management Practices

Overview

Chapter One introduced the problem of improving the performance of AFLC industrial wastewater treatment programs. The objective of this research being identification of a model or benchmark program. Two investigative questions were designed to help in this process. The first question, what criteria should be used to select a model plant, was addressed in Chapter Two. These criteria were permit compliance, plant performance, and adoption of a pollution prevention philosophy. The second investigative question sought to identify some of the best management practices in the wastewater management literature.

The purpose of this chapter is to describe these best management practices. This review will be accomplished within the framework of Total Quality Management (TQM) as described by Steel. One company which has been very effective in implementing pollution prevention will be described, using these same principles of TQM and Dillion's four elements of pollution prevention. Since pollution prevention is one of the criteria for selecting a model program, this case study shows how a benchmark pollution program has been implemented. Finally, with the growth of microcomputer applications in all areas of management, their impact on wastewater management will be discussed. Uses of computers is included as a best management practice because of their potential for improving decision making, process performance, and effluent quality.

Best Management Practices Described

Total Quality Management. Total Quality Management can be described as a quality improvement approach targeting organization's people, processes, products, and culture. The methods for implementing this approach are in the teachings of quality leaders such as Philip B. Crosby, W. Edwards Deming, Armand V. Feigenbaum, Kaoru Ishikawa, J. M. Juran, and Masaaki Imai (13:18). Masaaki Imai in Kaizen, The Key to Japan's Competitive Success, defines TQM as

> (continuing improvement) activities involving everyone in a company, managers and workers, in a totally integrated effort toward improving performance at every level. This improved performance is directed toward satisfying such cross functional goals as quality, cost, scheduling, manpower development, and new product development (14:27,15:xxv).

The role of quality in environmental management has been defined by Coopers and Lybrand, an environmental consulting services firm, as

> . . . the process used by environmental management to assure that the organization's environmental compliance goals are achieved. The objective of TQM for environmental management is to pursue and achieve continuous improvement in every process of an organization's environmental compliance program through integrated efforts of all members of the program. This process will lead to a reduction in the total cost of environmental quality. (16:21)

Dr. Robert P. Steel, writing in "Quality Improvement Technologies for the 90's: New Direction for Research and Theory" says TQM is a multifaceted endeavor, with the common goal of achieving excellence in the quality of organizational outputs (14:27). Steel goes on to say it is difficult to distill a unified view of TQM due to the significant overlap within the literature (14:28). However, in his review of writings on the subject, eleven recurring themes were highlighted (14:28). These themes are summarized in Table , and described with examples from the wastewater management literature (14:28).

TABLE 1

STEEL'S ELEVEN PRINCIPLES OF TOTAL QUALITY MANAGEMENT

1. Changing the Corporate Culture
2. Top Management Commitment
3. Problem-solving Training
4. Continuous Process Improvement
5. Measurement Bias
6. Employee Empowerment
7. Quality Engineering
8. Supplier-Relations Management
9. Cross-Functional Problem Solving
10. Customer Relationship Management
11. Quality Policy Deployment

(14:28)

Changing the Corporate Culture. Steel states that commitment to TQM requires a complete transformation of the organization's quality culture (14:28). The commitment must be company-wide, and incorporate all employees from every level and function of the organization (14:28). In TQM organizations, responsibility for quality control falls upon all employees (14:28). In the same vein, commitment to environmental quality requires companies to undergo a holistic change in environmental management philosophy. According to William Beck, manager of waste and emissions reduction at I. E. DuPont de Nemours & Co., Inc., "Environmental quality isn't solely the responsibility of environmental professionals; it is the job of workers, executives, and everyone in between" (16:22).

Top Management Commitment. In addition to a change in corporate culture, management must be committed to improving the organization's quality management practices (14:28). Top management must be prepared to accept a leadership role in the TQM process (14:29). Dr. W. Edwards Deming, the "father of quality movement" states "support is not enough: action is required" (14:29). Top management may demonstrate its commitment to quality by creating the position of corporate quality officer (14:29). With regard to environmental quality, this commitment can be translated into establishing a corporate vice president for environmental management. Richard Heller, an expert electroplating waste management, said top management should place the burden for wastewater treatment not with plant operators, but with production supervisors (17:45).

Hiller's message is that if production personnel were responsible for wastewater treatment, they would understand the repercussions of indiscriminately dumping toxics (17:45).

Problem Solving Training. TQM is not only a group of ideas and concepts, but it also relies heavily upon problem solving techniques, using a variety of quantitative and qualitative tools (14:29). These special tools are designed to use basic statistical process control to enable all personnel to improve product quality (14:29). Imai identified two groups of techniques for problem solving, and are listed in Table 3.

TABLE 2

IMAI'S TOOLS FOR PROBLEM SOLVING

Old Seven Tools	New Seven Tools
1. Pareto diagrams	1. Relations diagram
2. Cause-and-effect diagrams	2. Affinity diagram
3. Histograms	3. Tree diagram
4. Control charts	4. Matrix diagram
5. Scatter diagrams	5. Matrix data analysis diagram
6. Graphs	6. Process Decision Program Chart
7. Checksheets	7. Arrow diagram, (PERT, CPM)

(15:240-241)

The "Old Seven" basic problem solving tools were intended to be used by small groups, such as quality control circles (production employees), staff engineers and managers for identifying and solving problems (14:29,15:240-241). The "New Seven" tools are more advanced, and rely less heavily upon quantitative data (14:29,15:241). Instead they incorporate a design approach to problem solving, using the ideas of managers, which are rearranged into meaningful form for decision making (15:241). This design approach is a comprehensive way of problem solving, focusing on attention to details (15:241). It requires the involvement of people from varied backgrounds, which makes it effective for solving cross-functional problems (15:241). Imai cites some of the typical applications of the New Seven tools as development of new technology, production management, cost reduction and energy saving, safety improvement, and pollution prevention (15:242).

Continuous Process Improvement. The continuous search for improvement is the cornerstone of TQM philosophy, because it is a process oriented strategy rather than a results oriented one (14:30). This never ending search is referred to as Kaizen, and is both holistic and systemic (14:30). The goal in environmental management is continuous improvement in environmental quality. William Ruckelshaus, CEO of Browning-Ferris Industries and former administrator of the EPA says "when applied to environmental management, TQM means waste reduction and getting things done the first time versus cleaning up" (18:5).

The push for the continuous improvement of environmental quality is echoed by Bill Hill. According to Hill, Vice President of Operation and Maintenance at Camp, Dresser, and McKee, "many facilities are hardly managed at all" (19:38). This mismanagement results in high operating costs, internal friction, poor morale, missed schedules, and backups (19:38). These problems have been traced to management's indecisions, mistakes, and the absence of accountability (19:38). Hill states that improvements can be achieved by the development of management systems addressing the complex problems faced by operators (19:38). These management systems must include personnel, process control, maintenance, purchasing, financial, and information-system management (19:38). The key to developing each of these systems, is to focus on the objective of each management activity, and ensure procedures exist to achieve it (19:38). Once these procedures are developed, they should be documented as completely and succinctly as possible (19:38). However, Hill cautions that procedures often become too detailed to be of any use; therefore, steps should be kept to a minimum (19:38). Managers should examine each routine for its simplest elements, and examine the elements for their relative significance (19:38). Only those essential elements should be listed in the documentation (19:38). Hill adds that training can help managers implement these systems effectively, and help equip the staff to handle new procedures, but management must be attentive to ensure these measures are well received with input from the personnel involved (19:38).

Measurement Bias. TQM relies upon measurement and data collection in the problem solving process (14:31). Florida Power & Light Co., the only U.S. recipient of Japan's coveted Deming Award, learned that measuring environmental outputs can help with compliance. Upon measuring outputs, Florida Power & Light reduced their citations 34 percent (18:5). George Carpenter, Director of Environmental Management at Proctor & Gamble, stated that, while it may take longer to institute quality principles in environmental management than in other endeavors, the tools are basically the same (18:5). According to Carpenter, many production people say TQM cannot be applied to the environment because nothing is measurable; however, Carpenter argues everything regarding environmental performance can be measured, including such diverse factors as the number of personnel trained, effluent quality, and other factors (18:5).

One example of measurement to improve environmental quality is presented by D. Don Huang and Norbert S. Jagodzinski in their paper on "Analytical Approach to Managing Wastewater Treatment Facility Influent". In their paper, they present one example of how statistical process control can be used to improve wastewater treatment plant performance. Since a product stream (effluent) is dependent upon raw materials (influent) and plant operations, it is important to provide control of the influent stream (20:21). To achieve the objectives of process control, statistical techniques such as Extreme Value Statistics and Acceptance Control Charts have been implemented to identify levels and trends of wastewater parameters (20:21). By using these techniques, plant operations personnel can identify unusually high levels of pollutants, statistically (20:21). The upward trends of the wastewater parameters can be detected prior to the onset of operational problems, and allow operators to take corrective actions proactively (20:21). Acceptance control charts have been used in the factory to decide whether to accept or reject a process on the basis of the product meeting specifications (20:22). These tools provide a means for detecting the upward trend of wastewater parameters, thus the loads to the industrial wastewater treatment facility can be effectively managed (20:25). Huang et al recommends a range chart also be used concurrently to monitor variability in the acceptance control chart (20:25).

Another example of a measurement bias is demonstrated by the use of benchmarking (14:31). Prior to benchmarking, organizational elements are encouraged to dissect their work processes into components (14:31). A search is then undertaken for industry leaders who excel in the performance of key processes and suppressors (14:31). The pool of potential benchmark firms is not restricted to direct competitors (14:31). Organizations with different products may be selected as long as the work processes are the same (14:31). Measures of an industry leader's performance then become the benchmark used by the focal organization to improve performance (14:32). It is these qualities of benchmarking that have resulted in selecting it as the research methodology for this investigation.

Employee Empowerment. TQM is noted for holding all employees responsible for quality (14:32). To reward employee initiative, TQM includes some form of employee recognition (14:32). Robert Gorsline, an Assistant City Manager writing in Public Works, describes how a city, operating an aged wastewater treatment plant, used greater employee empowerment as a way of improving plant performance (21:70). Previous to a change in management styles, operators and maintenance personnel were closely supervised and instructed on how to proceed with each step of an operation (21:70). In line with increased decision making by employees, the plant manager began a program of reorganizing the department's operation (21:70). Employees were trained how to accomplish tasks, and given responsibility to carry out tasks (21:70). As a result, morale and productivity increased significantly, while the number of operational personnel decreased from 17 to 12 (21:70). To maintain an optimum level of operations and long term reliability, a preventive maintenance program was initiated (21:70). By operating more efficiently, an additional maintenance crew was formed to handle plant maintenance (21:70). The key ingredient in the program was employee involvement and a commitment to excellence (21:70). This effort resulted in the city receiving several awards from the state and EPA for environmental excellence through wastewater operations and maintenance (21:70). Gorsline says that although this plant was a POTW, the principle of employee involvement holds true, regardless of the type of plant (21:70). Two lessons learned from this experience were that relatively inexpensive solutions to wastewater treatment problems can be found, but it takes a commitment by management and employees to work together to achieve excellence (21:70). Employees must be properly trained, given appropriate responsibilities, and provided with the necessary resources to do their job (21:70). The other lesson is that just because a plant does not use state-of-the-art technology, does not mean it cannot operate efficiently and effectively (21:70).

Quality Engineering. TQM stresses the importance of thoroughly testing system components during product design

(14:32). Steel states that Japanese firms consider quality as a characteristic which is "designed into" products, while American firms often try to "inspect out" poor quality products (14:32). Several techniques frequently used during quality engineering are known as Taguchi methods (14:33). These methods rely heavily upon experimentation and sophisticated statistics to design "robust" products (14:33). Steel continues by saying

> Taguchi methods emphasize a holistic approach to product engineering. Besides evaluating the individual contributions of product components to overall product integrity, Taguchi methods also seek to account for the more-frequently overlooked interaction between component parts. (14:33)

Supplier Relations Management. Many TQM models emphasize the importance of vendor management in the production process (14:33). A high percentage of quality problems have been attributed to the failure to properly manage suppliers (14:33). W. A. Lauritch in Water/Engineering and Management, reinforces this principle by stating that working with manufacturers can help avoid problems with equipment failures and improve operation of the plant (22:16). Lauritch says that manufacturers can be a valuable resource in planning parts inventories, scheduling inspections, training personnel, using service manuals, establish operating themes, identifying needs and developing new ideas (22:16). Developing a parts inventory should be a joint effort, which includes the manufacturers recommendations of critical parts (22:16). This practice could significantly reduce costs by eliminating plant upsets, fines, premature failure of plant equipment, and overtime for repairs during off hours (22:16). Additionally, because equipment needs can be predicted, an inventory could improve budget planning, and eliminate the extended equipment shutdowns caused by long waits for parts (22:16). The value of service manuals to proper operation and maintenance of equipment should not be overlooked (22:16). Manuals can serve as the last trouble shooting tool in maintaining and operating equipment (22:16). Lauritch concludes that the benefits of working with vendors as being development and production of higher quality, and more reliable products (22:16).

Cross-functional Problem Solving. Steel says the TQM literature recognizes many quality problems are caused by the work flow crossing functional lines (14:34). The solution to these problems, TQM proponents say, is the establishment of cross-functional teams comprised of workers and managers (14:34). Cross-functional teams are encouraged to develop plans to improve cross-functional quality using the tools previously mentioned by Imai (14:34). No area is better suited for the application of cross-functional problem solving than environmental management and pollution prevention. Environmental problems are by their very nature multi-disciplinary, requiring solutions that address technical, legal, financial, and managerial aspects of the problem.

Gerald Rich, from the Ohio EPA, writing in Pollution Engineering, describes one example of how cross-functional problem solving can be applied to deal with a problem frequently encountered by plant operators, maintenance of pollution control equipment. Interest of most company management focuses on costs and production scheduling, and not on day-to-day operation of pollution control equipment (23:32). Purchase of pollution control equipment has been mandated by EPA regulations; however, the lowest price is often the prime consideration of management in making a decision (23:32). Pollution control costs must compete with process maintenance funding, which tends to limit the amount of maintenance environmental systems receive (23:32). Rich goes on to say that with no apparent return of investment, associated operation and maintenance costs detract from management's objective of profitability (23:32). This lack of attention tends to minimize maintenance of control equipment, and often leads to exceedances, permit denials, and possibly court cases (23:32). Various reasons given for neglect in maintenance of pollution control equipment include the following:

1. Control equipment was thought to run itself, outside of periodic cleaning and greasing.
2. Personnel are not inclined to maintain equipment that is dirty, dusty, inaccessible, or perhaps hazardous.

3. Management bought it, but the maintenance department gets stuck with it.
4. The maintenance department has insufficient technical know-how to diagnose or troubleshoot problems.
5. There are insufficient maintenance funds or people.
6. Since the equipment was not correctly sized and breakdowns occur so often, why put so much effort into fixing it?
7. The equipment was incorrectly applied to varying plant loads.
8. The person who was in charge of the equipment was transferred, quit, or was insufficiently trained (23:33).

The upgrading of pollution control equipment maintenance must start with top management becoming involved (23:33). All costs must be carefully considered, including fines, clean up expenses, insurance premiums, and the revenue lost from a negative public image (23:33, 16:25). An effective program for maintaining pollution control equipment should include the following:

1. Have a formal plan stating which individuals, both in management and operations have authority to make decisions.
2. Involve maintenance personnel in some portion of the decision making or procedure writing process.
3. Supplement the equipment instruction manuals with actual worker experience.
4. Estimate maintenance costs, man-hours, and materials required for the upcoming year.
5. Acquire an adequate inventory of essential spare parts, and where to buy other components.
6. Clearly define the equipment that must be inspected, maintained, and how often (23:33).

Customer Relationship Management. TQM considers the primary objective of the firm is to satisfy the customer (14:34). Ruckleshaus states that, basically, there is no difference between what manufacturing produces and what wastewater treatment does (18:5). The customers are not only the ones who buy goods, but they are also government officials, who regulate the industry, and citizens in the community (18:5). TQM begins by identifying all the firm's customers in the broader sense; and among them will be customers for environmental values (18:5).

Quality Policy Deployment. The emphasis of TQM on customer satisfaction is best demonstrated by the idea of Quality Function Deployment (QFD). QFD is a corporate planning tool using market research to identify the product performance features desired by customers. With this information, customer preferences are translated into engineering and technical requirements (14:35).

An Example of Pollution Prevention Implemented

The connection between TQM and pollution prevention is an obvious one. In his book, Making Peace with the Planet, Barry Commoner simply states

> . . . pollution prevention works; pollution control does not. If "noncompliance" were substituted for "pollution", we'd have a target worthy of any quality practitioner. (24:7)

The question remains: how does an organization begin pollution prevention? The response is the way an organization pursues nonconformance to product specifications. Both endeavors are solved by applying the principles of Total Quality Management. Thomas Zosel, Manager of Pollution Prevention Programs at 3M, presented how his company went about applying many of the principles of TQM to prevent pollution in a recent article appearing in Pollution Prevention Review.

Introduction to 3M and the 3P Program. One company frequently cited as having a model pollution prevention program is the 3M Company. 3M is a leading "blue chip" company, which produces abrasives, adhesives, films, and magnetic tapes (25:67). In 1975, 3M adopted an environmental philosophy known as the Pollution Prevention Pays (3P) Program (25:67). This program has been recognized throughout the world for its achievements in waste minimization and preventing pollution, and has been duplicated by many companies (25:67). In 1985, 3M received the first Award for International Corporate Environmental Achievement from the World Environmental Center for its pollution prevention program (26).

The idea is to prevent pollution at the source, in products and manufacturing processes, rather than remove pollution after it is created (25:67). This philosophy parallels the notion repeatedly stated by TQM proponents to design and build quality in, rather than inspect bad quality out. Although 3M acknowledges this idea is not new, the concept of applying pollution prevention on a company wide basis, had not been done before (25:67). The

3P Program, in the beginning, was established because of "the recognition that prevention is more environmentally effective, technically sound, and less costly than conventional control procedures" (25:67). Natural resources, energy, manpower and money were all used in building conventional pollution control facilities, and more resources were consumed to operate them (25:67-68). Additionally, the company recognized conventional pollution control facilities would only solve the problem temporarily; they would not eliminate the problem (25:68). This continuing effort to eliminate pollution by the company at the source is achieved by product reformulation, process modification, equipment redesign, recycling, and the recovery of waste materials for resale (25:68).

Implementation of Pollution Prevention. The Pollution Prevention Pays Program is run by a coordinating committee composed of representatives from engineering, manufacturing, research, and the corporate environmental management organization (25:68). The program relies upon the involvement of technical employees to initiate individual projects (25:68). Typical projects are started when employees recognize a specific pollution or waste problem and a possible solution (25:68). An employee team is developed to analyze the problem and develop solutions (25:68). Such a team might consist of employees from several disciplines including engineering, research, marketing, and legal (25:68). A proposal is submitted to the affected operating division and a decision is made whether to commit funds, time, and other resources to it (25:68).

These proposals are evaluated for awards based on four distinct payoffs that 3M identified as goals before initiating its 3P Program: (1) a better environment, (2) conserved resources, (3) improved technologies, and (4) reduced costs (25:68). To receive formal recognition under the 3P Program, a project must meet the following guidelines (25:68). First, a proposal must, through process change, product reformulation, or other preventive means, eliminate or reduce a pollutant that is currently a problem or has the potential of becoming a problem (25:69). Second, a proposal should exhibit, in addition to reduced pollution, an environmental benefit through reduction in energy consumption, more efficient use of raw materials, or improvement in the use of other natural resources (25:69). Third, a proposal should involve a technical accomplishment, innovative approach, or unique design in meeting its objective (25:69). Finally, a proposal must have some monetary benefit to the company (25:69). This benefit may be through reduced or deferred pollution control or manufacturing costs, increased sales of an existing or new product, or other reduction in capital costs or expenses (25:69).

More recently 3M has set goals for its more than fifty divisions, which in turn have passed goals on through their organizations (25:69). As of December, 1990 there have been 2,511 recognized 3P projects since 1975 within the company (25:69). Of these, 785 have been in the United states and 1,726 have been from company operations overseas (25:70). The results of the 3P Program have been dramatic. In the fourteen years the program has been in existence, the pollution prevented has resulted in a savings of $500 million (25:70). Equally dramatic are the reductions in pollution as a result of the program. Since 1975, the 3P Program has reduced pollution by an estimated 50 percent (25:70).

Employee participation is encouraged through the use of recognition and awards (25:68). Projects that are developed under the 3P Program are eligible for recognition by management (25:68). In order to qualify for an award, a 3P project must fulfill certain established criteria (25:68). Only persons who have made a direct, personal and measurable contribution are eligible (25:69). Members of the corporate environmental management committee are not eligible, nor are winning project supervisors or managers, unless they meet the criteria for a "hands on" contribution to the effort (25:69). Division management staff members present the awards frequently at a meeting of the unit's management committee (25:69). These awards are considered a significant honor, and can influence decisions on pay increases and promotions (25:69).

Emphasis on Continuous Improvement. Because of its emphasis on continuous improvement of environmental quality, 3M believes its task is to reach as high a percentage of pollution elimination and pollution minimization as possible (25:70). According to Zosel, 3M believes so strongly in this, that it restated its goal for the 3P Program to promote further reductions by developing new and environmentally better ways to manufacture its products (25:70). 3M intends to cut all hazardous and nonhazardous releases to the air, land and water by 90 percent and to reduce the generation of all waste 50 percent by the year 2000, and to achieve as close as possible to zero emissions from a base of 1987 (25:70). These goals will take the company from a position of compliance with governmental regulations to being substantially under the limitations established by the environmental regulations (25:70).

Zosel says 3M plans to achieve this goal through an updated program called 3P Plus (25:71). 3P Plus involves both a commitment to substantially reduce emissions, through whatever means are available, and longer term scientific research to reduce sources of pollution in the manufacturing processes (25:71). 3P Plus will be a more structured effort than the voluntary 3P Program (25:71).

Waste minimization teams are being formally established in every operating division to identify source reduction and recycling opportunities and develop plans to address them (25:71). These teams are interdisciplinary groups consisting of representatives of manufacturing, research, engineering, marketing, packaging, and other units to ensure as broad a perspective as possible (25:71-72). A pollution prevention staff within the corporate environmental organization has also been established to promote the program (25:72). The pollution prevention staff will monitor the program, and report to management on problems, technical breakthroughs, and overall progress (25:72). This staff will also encourage the sharing of ideas and technical achievements between the divisions (25:72). Although 3P Plus primarily involves internal operations, vendors will also participate (25:72). Suppliers of materials to 3M will be asked to improve their products to ensure that they cause a minimum of hazardous waste (25:72).

According to the CEO of 3M, Mr. Jacobsen, all new air pollution control installations will be judged not by return on investment but by their technical acceptability and environmental benefit (25:72). With or without cost savings, 3M will spend what is necessary to protect the environment (26).

> We are faced today with increasing our efforts on the development end, to do it right the first time by bringing research and development people into the process even more. With this change in emphasis, we can focus on the problems (the causes of pollution) rather than the symptoms (the pollution itself). (26)

Mr. Jacobsen continues by stating 3M's perspective on customer satisfaction with regard to environmental quality.

> Customers are asking for products that don't produce by-products and wastes. They, too, are faced with costs and responsibilities of handling and cleaning up pollutants. As a result, we are going to have to come up with 'cleaner', higher quality products as a requirement of doing business. The time is coming when words quality and waste just aren't going to be compatible. (26)

Computer Applications in Wastewater Management

The revolution in computer technology over the past fifteen years has resulted in several new tools for environmental managers to use in treating industrial wastewaters. The first of these technologies is the use of minicomputer systems for process control. In this section, the advantages of using microcomputers by managers will be described, including examples of how modeling in decision support systems and automated report generation can assist wastewater managers in plant operation and decision making.

Supervisory Control and Data Acquisition Systems. A recent improvement in treatment facilities across the country cited in *Public Works* journal, uses a technical solution to solve a managerial problem (27:70). An automated control system allows process parameters to be easily modified (27:70). The result is reliable wastewater treatment under adverse conditions, and in full compliance with environmental regulations (27:70). These custom designed control systems allow the facility to monitor, control and modify operations quickly and easily for optimum wastewater treatment (27:70). The system enable plant operators to access current data via a distributed terminal system, which provides instant control via a set of interactive program screens to modify process parameters (27:70).

This system, known as Supervisory Control and Data Acquisition (SCADA) systems allows operations to be closely monitored, so treatment processes can be adjusted as required (27:71). The addition of chemicals to the wastewater is calculated by on-line monitoring of the composition of the wastewater at any given time (27:71). As changes in the wastewater chemistry are detected, the process controllers automatically compensate by increasing or decreasing aeration, introducing chemicals, or adjusting other variables (27:71). Historically, such variables were controlled at an "optimum", often excessive rate, to assure complete treatment, but at added expense to the facility (27:71).

The comprehensive SCADA system also provides automatic operating reports to regulatory agencies (27:71). These reports detail daily conditions of BOD, pH, influent volume, and chemical additions (27:71). In addition, cost reductions have been realized from the automatic acquisition of historical operating data (27:71). These reductions were achieved by allowing management to determine when pollution control equipment was not operating effectively, and performing maintenance to ensure reliable equipment operation (27:71).

Microcomputer Applications for Wastewater Managers. The development of microcomputers has had a significant impact on the wastewater industry (Radick:36). According to Keith A. Radick in his article "Why computers for wastewater operations?" appearing in Pollution Engineering, computers have become a necessity for two reasons, time and money (28:36). These two factors not only affect managers lives professionally, but also the quality of the effluent (28:36). Use of microcomputers can save time, and allows managers the opportunity to change the way they spend their time (28:36). A good example of the potential for time savings is in compliance reporting (28:36). Generally, these reports are considered time consuming, and are important in the grand scheme of things, but are of little use as a management tool (28:36). A survey of plant operators indicated that they spend anywhere from 10 to 50 hours per month generating compliance reports (28:36). Computer generation of these same reports requires less than one hour per month (28:36).

The money savings through use of microcomputers was best demonstrated by a water treatment plant in West Virginia (28:37). The plant began using the graphing capabilities of a process monitoring software package to analyze chemical feed performance (28:37). Previously, feed rate control was an adjust-respond nature, resulting in fluctuating water quality (28:37). The quality fluctuation decreased significantly, and total chemical feed was reduced by one third, at a savings of $5,000 through the use of microcomputer applications (28:37).

Wastewater management columnist Paul Hersch in his article, "Treatment Technology Advances Affecting Management's Style", appearing in Water/Engineering and Management, argues that advances in wastewater technology portend far-reaching changes in management practice (29:17). The technological advances are taking place in an era of increased concern for pollution control (29:17). Technical advances continue to affect wastewater management, but microcomputers have impacted the manager's world the most (29:17). The microcomputer revolution is occurring throughout treatment plant offices the worldwide (29:17). According to Hersch, computers were originally brought into management offices over 15 years ago, only to be abandoned (29:17). Managers felt uncomfortable trying to adapt to these new systems, and the systems themselves were far from being user friendly (29:17). Microcomputers are giving managers better information, better ways to do more with that information, and time to tackle the concepts and concerns being brought about by other systems and new technology (29:17). These advances have been accomplished by allowing managers to perform "what-if" analysis, using particular data and immediate comparison of them, and on the spot projections (29:17). Microcomputer-based modeling and expert systems have even substituted for technical experts in some problem solving situations (29:18). As models improve, management will benefit by understanding the new systems (29:18). Models that identify factors contributing to effluent quality variations and which process control strategies can be formulated are the most valuable (29:18). Allowing managers to plan further in the future with greater assurance (29:18). Modeling may offer management the opportunity to build plants with the flexibility to perform differently at different times of the year, doing away with past standard plant designs (29:18). The confirmation provided by microcomputer modeling and the knowledge to implement the models can be useful during managerial planning or policy discussions (29:18).

Summary

This chapter described some of the management practices that have been used to improve wastewater treatment. These practices were examined within the framework of eleven principles of Total Quality Management as described by Steel. A case study of the 3M company, considered to have a benchmark pollution prevention program, was used to show these same principles can be applied to improve environmental quality. The use of computers was shown to improve plant performance by improving the decision making capability of wastewater managers, and automate many of the process control functions within the treatment plant.

IV. Methodology

Overview

Chapter I discussed the current problems faced by AFLC in managing industrial wastewater. These problems have resulted in repeated Notices of Violation (NOV) which threaten to curtail or shutdown critical weapon system maintenance functions. The objective of this research is to identify a model industrial wastewater management program to serve as a benchmark for Air Force operations to help solve the environmental problems faced by AFLC.

Chapter II provided background on water pollution ecology and control technology to provide a framework for understanding the technical problems faced by plant managers. Secondly, the current regulatory framework for establishing plant performance was described. Many of the problems found to exist at the ALCs, which prevent them from complying with applicable standards, were discussed to provide an understanding of the current problems. Finally, perspectives of the EPA were used to help establish criteria for identifying a model program using the best management practices.

This chapter first describes the process of benchmarking in general and how it was used to accomplish the research objective. Next the planning phase is outlined. The planning phase was important because it determined what was benchmarked, the criteria for selecting the benchmark, and how the data was collected. Finally, the analysis and integration phases of benchmarking are briefly discussed.

General Methodology of Research

Benchmarking Described. The objective of this research was to determine what management practices are found in a model industrial wastewater management program. To answer this question, the researcher used a technique pioneered in the private sector for process improvement called benchmarking. David T. Kearns, Chief Executive Officer of Xerox, states that benchmarking is a "process of measuring oneself against the . . . practices of our toughest competitors" (5:86). Robert C. Camp, in his book Benchmarking: The Search for Best Practices that Lead to Superior Performance says benchmarking is a five phase, proactive process to change operations in a structured fashion to achieve superior performance (30:72). The planning phase consists of three steps: identifying what processes are to be benchmarked; identifying comparative companies; and determining a data collection method, and collecting the data (30:72). The second phase is analysis, which consists of two steps: determining the current performance gap, and projecting future performance levels (30:72). The third phase is integration, and requires the following steps: communicating the findings, and establishing functional goals (30:72). The fourth and fifth phases are developing action plans and maintaining superior performance (30:72). This research carried out the benchmarking process only through phase one. The final result was locating an organization AFLC could compare its wastewater management program with, and improve performance by incorporating the best management practices.

Planning Phase. The purpose of the planning phase was to identify what products would be benchmarked, who would serve as the benchmark, and how the data was collected.

What Was Benchmarked. Camp states that every organization delivers a product, whether it be a consumer good, a report, or an idea (30:72). The product of an industrial wastewater treatment program can be clearly defined as effluent, the discharge of treated wastewater from manufacturing processes.

Who Were the Benchmark Candidates. The organization serving as the benchmark must be considered the best in the industry. To find out what qualities the benchmark should have, the researcher reviewed available literature on traits characteristic of a model program. Based upon this review, criteria were established for the benchmark. Before describing these criteria, it is important to understand what qualities are necessary for the criteria to become credible.

Defining Criterion-related Validity. C. William Emory, in his text Business Research Methods, described criterion-related validity as one of the major forms of internal validity (31:95). He goes on to say "this form of validity reflects the success of measures used for some empirical estimating purpose" (31:95). Use of criterion-related validity allows the researcher to predict some outcome, or estimate some type of behavior or condition (31:95). One source referenced by Emory suggests that any criterion measure must have four qualities: relevance, freedom from bias, reliability, and availability (31:96). A criterion is relevant if it is defined and measured in terms judged to be a proper measure (31:96). Freedom from bias is achieved when each sample element had an equal opportunity to perform well (31:96). A reliable criterion is stable, and can be reproduced (31:96). Finally, the information specified by the criterion must be available to the researcher (31:96). Having defined the traits valid criteria must possess, the criteria used to select the benchmark firm are described with regard to these qualities.

Permit Compliance. The first criterion, permit compliance, was operationally defined as a program with the fewest permit exceedances in the past four years, and none in the past calendar year. This criterion was selected to measure the quality of the output since the last major water quality legislation was enacted. Ideally, a plant with no NOV's during the entire period would be desired. This criterion was judged relevant because it reflects the level of performance with regard to regulatory requirements. Whether this criteria was free of bias is debateable, since a firm discharging to an effluent based stream may have a better chance of meeting effluent limitations than a firm discharging to a quality based stream. This trait may act as a source of potential confounds, and was accepted as such by the researcher. In terms of reliability, this criterion is stable and easily reproducible by other researchers. Its availability in the public domain in the form of reports to permitting agencies satisfies the last criterion.

Plant Performance. The second criterion, plant performance, was used to judge the performance of unit treatment processes with regard to the quality of the effluent versus influent. This criteria was operationally defined as the percentage of decrease of each permit parameter. The values for each parameter were then averaged to indicate the overall plant performance. This criteria was considered relevant because it indicated how well the plant management practices for maintenance, supply, safety, and operator training were being implemented. The objectivity of this criterion may be debateable because a plant could have an influent parameter that is not significantly greater than the discharge limit, due to pretreatment at the source. This situation would result in a plant not receiving as a high of a score as another plant, which has an influent with higher concentrations and the same type of treatment process. This source of potential confounds will be dealt with by collecting information on pretreatment operations and their impact on the waste stream. In terms of reliability, this criteria is stable and reproducible by others, because it represents the average for the preceding twelve months from Discharge Monitoring Reports, in most cases.

Pollution Prevention Philosophy. The third criterion was used to judge organizational environmental performance as a whole, based on the firm that best displays the adoption of pollution prevention as a corporate environmental philosophy. The adoption of a pollution prevention philosophy was measured in terms of strategic planning, product and process design, vendor management, and environmental goal setting using a combination of multiple choice questions, and a series of statements measuring the organization's attitude toward pollution prevention (12:3-4). The purpose of these two types of questions was to verify company attitudes and philosophy with objective indicators of the company's environmental policy. Part A was comprised of seven multiple choice questions that served as indicators of a pollution prevention philosophy according to Dillion. Part B consisted of 14 statements, each statement addressing one of the four areas of pollution prevention previously mentioned. For this study, a five-point Likert scale was used because of its popularity, and familiarity with respondents (31:255). The respondent was asked to indicate how closely their company's action or policies matched the attitude expressed in the statement. Each response was numerically scored to reflect its degree of congruence to pollution prevention. The scores for each statement were then totaled, indicating to what degree an organization had adopted a pollution prevention philosophy.

Use of pollution prevention as a criterion was relevant because it best indicated a firm's long term commitment to environmental compliance, and the desire to eliminate the discharge of pollutants. The criterion's objectivity was weakened by the use of an arbitrary scale. This approach was based only upon the researcher's logic, and extensive consultation with experts in the field; therefore, no objective evidence existed that all of the items were viewed by the respondents from the same frame of reference (31:253). The lack of a large population prevented any systematic analysis, such as item analysis, for verifying scale reliability. Confounds, as previously mentioned, were dealt with by using a combination of questions to measure some objective indicator of a firm's environmental policy. The reliability of this data, although available, could be questioned due to the lack of rigor in question development; however, for the purposes of this examination, the researcher felt the criterion adequate for the purpose it was intended.

Defining the Population and Sample. The population of private sector firms with industrial wastewater management programs could be defined based on a listing of approvedNPDES permits. However, for the purposes of this study, only firms with similar processes as those used within the ALC's were considered. Emory described the handpicking of sample members as judgement sampling, a type of nonprobability sampling (31:280). These sample firms were chosen by surveying professional associations and regulators, such as the Water Pollution Control Federation and the EPA, to ensure the sample contained qualified benchmark candidates.

Emory gave three reasons to use nonprobability sampling. The first reason was nonprobability sampling could be used when it satisfies the sampling objectives, especially in exploratory research (31:279). Secondly, nonprobability sampling could be used due to the time and cost requirements of probability sampling (31:279). The third reason to use nonprobability sampling was when it may be the only feasible alternative (31:279). The use of judgement sampling in this research satisfied all three reasons. The sampling objective was to identify only the "best program"; therefore, obtaining any measure of central tendency or variance would have been of little value. The time and cost of performing a probability sample would have outweighed the value of the results, since the objective of the research would have not been satisfied. These conditions resulted in judgement sampling being the only feasible alternative.

<u>How will The Data be Collected</u>. Camp stated there is no single method for conducting a benchmarking investigation (30:72). A combination of methods that best meets the objectives of the study are often the most beneficial (30:72). He emphasized the investigation should focus on identifying practices and methods rather than measuring quantifiable performance standards (30:72). Examples of potential sources for identifying the best practices include industry surveys, literature reviews, interviews with functional experts, and contact with professional associations (30:74).

<u>Survey of Professional Associations and Regulators</u>. The purpose of surveying water pollution control organizations, including the EPA, was to objectively identify possible benchmark candidates. This survey was conducted by telephone and written correspondence, and based upon its results, benchmark candidates were identified. These candidates were

contacted to determine if the firm would participate in the benchmarking process.

Survey of Benchmark Candidates. To determine the benchmark from candidate firms, a survey questionnaire was constructed based on the investigative questions and criteria previously discussed. A combination of multiple choice questions, open ended questions, and an item analysis using a Likert scale was used to gather data on plant performance, managerial practices, and corporate philosophy. To improve the validity of the survey, the questionnaire was tested through discussion with the author's thesis advisor, wastewater engineers, and the senior professor responsible for the thesis program. This questionnaire was administered by mail to the treatment plant superintendent and the senior environmental manager in each firm. Based on the questionnaire results, a benchmark program was selected that best meets the criteria for a model plant.

Summary

This chapter first described the process of benchmarking in general and how it accomplished the research objective. The planning phase was then discussed, identifying what product was benchmarked, the criteria for selecting the benchmark, and how the data was collected. The product for a wastewater treatment program was defined as the effluent, or treated wastewater. The criteria were evaluated with regard to validity, and judged valid, although some potential confounds due exist. The data for the benchmarking process will be collected using two questionnaires. The data collection process and analysis of survey responses is provided in Chapter Five.

V. Data Collection and Analysis

Overview

The previous chapters described the initial work necessary for this chapter. The first chapter introduced the problems in the management of industrial wastewater at Air Logistic Centers (ALC), and in meeting the requirements for the discharge of effluent established by the National Pollutant Discharge Elimination System (NPDES). The second chapter provided background information necessary for understanding the problem and its solutions. Chapter three highlighted management practices found in the literature on wastewater management, and presented a case study of one *firm who had implemented many of those practices.* The fourth chapter outlined the methodology used to identify the benchmark program, employing two questionnaires. In this chapter, the information collected during the benchmarking process is presented and analyzed.

The information in this chapter is divided into three parts. The first part describes the problems encountered during the collection of data and its analysis. The second part identifies the candidate companies, based upon the results of surveying water pollution control authorities. The third part of this chapter includes an analysis of the data to determine the benchmark program.

Problems During Data Collection and Analysis

Several problems were encountered during the collection of data from the professional associations, regulators, and the candidate firms.

Response from Professional Associations. The organizations contacted by the researcher demonstrated varying levels of enthusiasm toward completing the questionnaire; however, as a whole, they were not able to identify any firms as benchmark candidates. Also, these associations had no clear perspective on what could be considered best management practices within the area of industrial wastewater management. There seemed to be more experience within these groups in the treatment of municipal wastes, and some limited background with the handling of pretreated wastewater discharged from industrial sources to a POTW. In the researcher's opinion this lack of response was caused by sending the questionnaire to the managing editor of the professional journals published by these organizations, instead of the organization's technical staff and committees. In future research involving contact with professional associations, the researcher recommends contacting the heads of technical committees as a starting point, rather than the editors of the journals published.

Response from Headquarters EPA. A similar problem was experienced when the Water Compliance Division, Office of Water, Headquarters Environmental Protection Agency was contacted. As a headquarters office, the personnel contacted were more knowledgeable on policy, and tracking the worst violators from across the nation; however, they were not able to recommend any outstanding companies or describe management practices they had found particularly effective. This office recommended contacting the regional offices of the EPA, who were considered the experts in the compliance of individual firms.

Following the advice of the EPA, the ten regional offices were contacted, and administered the same questionnaire as the professional associations. This path of investigation proved fruitful in developing an adequate list of benchmark candidates.

<u>Response from Benchmark Candidates</u>. After compilation of the firms recommended by the regional EPA offices was completed, each firm was contacted by the researcher via telephone to ascertain their willingness to participate in the benchmarking process. This initial contact resulted in three of the ten candidate firms opting not to participate. All three firms indicated that although their compliance records were very good, their waste streams were not characteristic of those found at the ALCs; therefore, they felt they would not serve as adequate benchmarks. One firm, known to have an award winning pollution prevention program, did send information on its pollution prevention program.

A problem encountered after the questionnaires were sent to the candidate firms was the unavailability of influent data at all of the plant's involved. Although the questionnaire was adapted from an EPA diagnostic tool, and this type of information was regularly collected within the DOD, the industrial wastewater treatment programs surveyed did not collect this type of information. Due to the unavailability of this data, plant performance could not be measured, because there was no basis for comparison of the effluent data. This problem resulted in eliminating the use of the plant performance criterion in the model plant selection. The lack of data on plant performance criteria could seriously affect the rigor of the investigation; the severity of impact was difficult for the researcher to judge.

Survey of Water Pollution Control Organizations

The professional associations and regulatory agencies contacted are listed in Appendix A. In some instances, interviews with the EPA regional offices resulted in further discussions with state and local agencies, who provided input on benchmark candidates. The questionnaire administered to the professional associations and regulatory agencies is located in Appendix B. Due to guarantees of confidentiality, names of the candidate firms were not used, instead each company was randomly assigned a letter for ease of identification during data analysis.

Survey of Benchmark Candidates

The questionnaire administered to *benchmark candidates* is shown in Appendix C, with their responses shown in Appendix D.

Permit Compliance Scoring. The permit compliance section comprised 60 percent of the overall score. This weighting was based upon recommendations from AFLC, based on the reasoning that, though a firm may practice pollution prevention, if they were not complying with their permit limitations, then management practices were not coping with existing problems. The score for long term permit compliance over the past four years used the scale shown in Table 4, Appedix E. The score for near term permit compliance was obtained using the scale presented in Table 5, Appendix F. Section I scores are depicted in Figure 2.

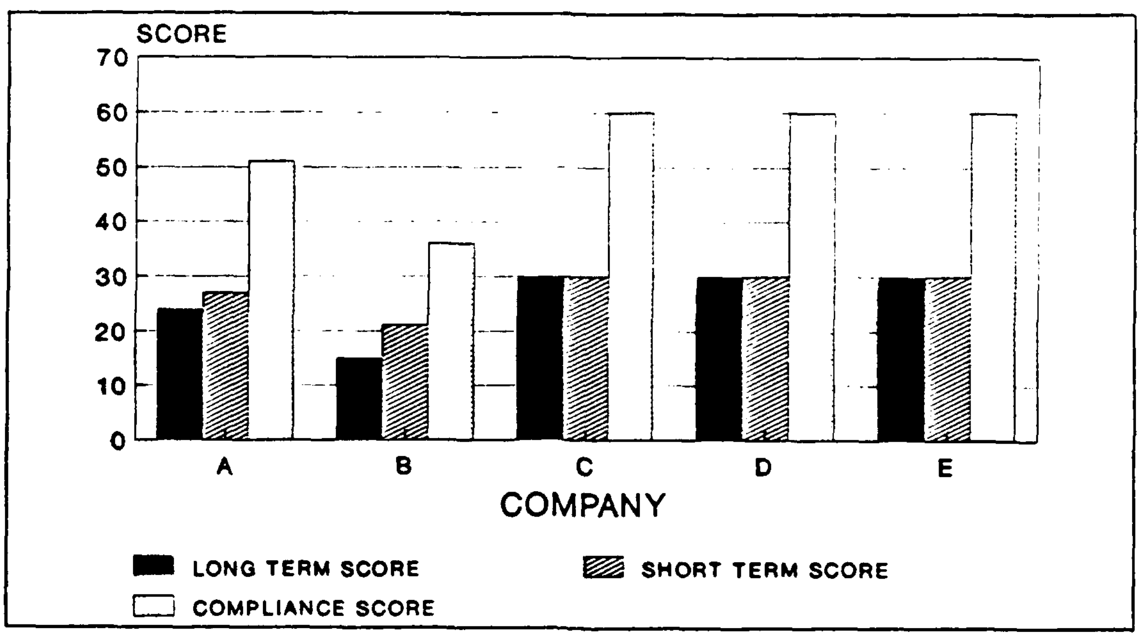

Figure 2. Scores for Permit Compliance

Pollution Prevention Philosophy Scoring. The score for the Pollution Prevention section of the questionnaire was based on the scale in Table 6, Appendix G. Each question was assigned points based on the possible responses, with the highest total score reflecting the highest congruence toward a pollution prevention philosophy. The results for Section III are presented in Figure 3.

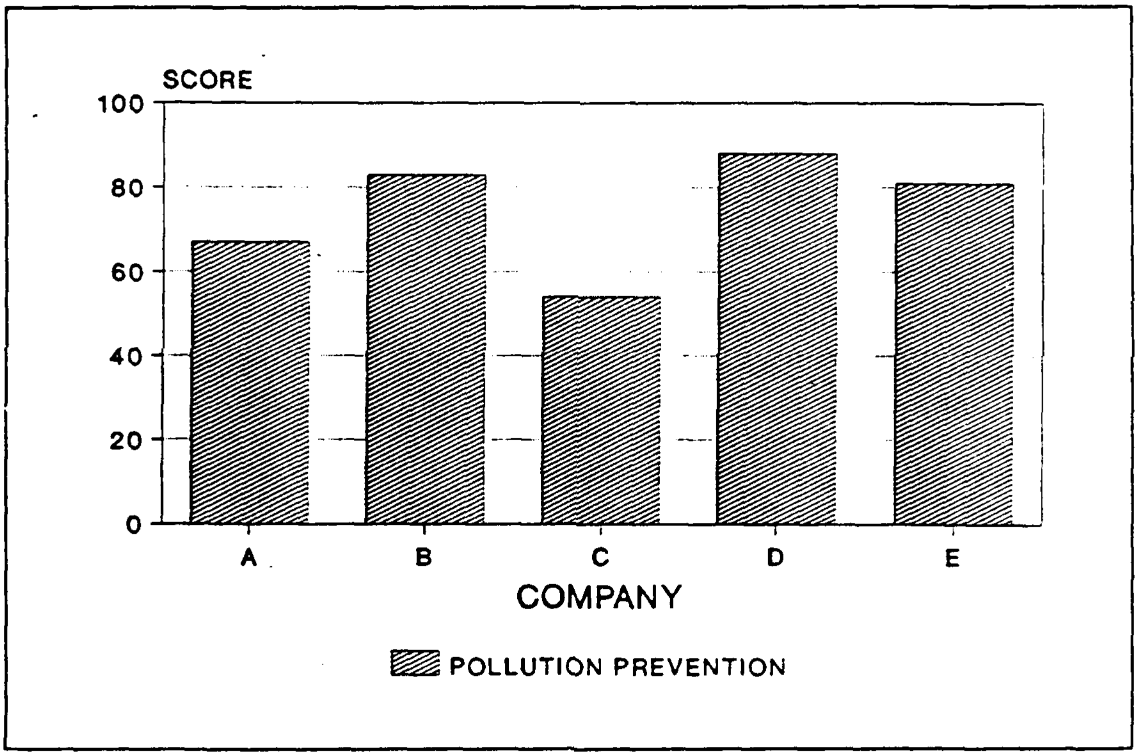

Figure 3. Scores for Pollution Prevention

Final Results. The following scores are a result of the points allotted for each section. The reader should be reminded that the score for Section III is 40 percent of the total points awarded. These results are depicted in Table 3 and Figure 4.

TABLE 3

FINAL RESULTS FOR THE BENCHMARKING PROCESS

Company	Section I Score	Section II Score	Total Score
A	41	26.8	67.8
B	26	33.2	59.2
C	60	21.6	81.6
D	60	35.2	95.2
E	60	32.4	92.4

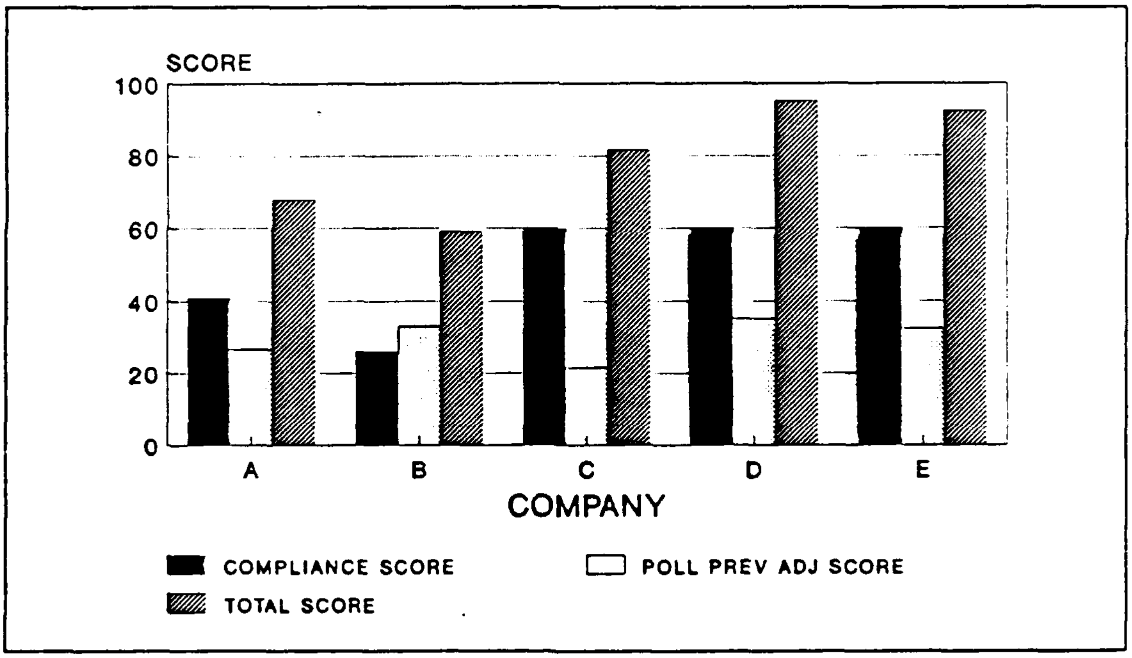

Figure 4. Final Results for Benchmarking Process

Summary

Several problems encountered during data collection and analysis were identifying potential benchmark candidates, obtaining consent from all of the companies nominated, and collecting all of the required data to measure plant performance. This last problem resulted in dropping plant performance as a criterion for selecting a model program. Once the benchmark candidates were identified and their questionnaires returned, each company was scored based on a pre-established system, and the results were presented. It is believed that the analysis of the survey results was thorough and definite conclusions can be reached which are valid, despite the elimination of one of the criteria. The presentation of these conclusions, and recommendations for further research will be presented in Chapter Six.

VI. Conclusions and Recommendations

Overview

The past five chapters presented research designed to determine if Air Force Logistics Command's industrial wastewater treatment plant's performance could be improved. The research objective was to identify an industrial wastewater management program to serve as a model for AFLC. The investigative questions which guided this research were the following: What are appropriate criteria by which to select a benchmark wastewater treatment program? What are considered the best management practices within the area of water pollution control? To accomplish this objective, the researcher used a process known as benchmarking to identify the best firm in the private sector that treats industrial waste streams similar to those found in AFLC.

This chapter, using the information presented in Chapters One through Five, synthesizes the salient information required to identify a benchmark firm for further comparison. Responses are provided for the two investigative questions originally posed in Chapter One to guide the benchmark investigation. The final two phases of the benchmarking process are described, the analysis phase and integration phase. Recommendations for further research are discussed, building upon the benchmarking process described.

Benchmark Firm Identified

Research Question 1 - Benchmark Criteria. These criteria were permit compliance, and the adoption of pollution prevention as an environmental philosophy. A model program, in terms of permit compliance, was operationally defined as a treatment plant with the fewest Notices of Violation in the past four years, and none in the past calendar year. The adoption of pollution prevention as a corporate philosophy was used to judge organizational environmental performance as a whole, and was measured in terms of strategic planning, product and process design, vendor management, and goal setting (12:3-4).

Research Question 2 - Best Management Practices. A survey of the wastewater management literature using the principles of TQM as a framework, yielded wastewater management practices that have been shown to improve process performance. A case study showed how the principles of TQM have improved environmental quality at one company, who is considered a benchmark in the area of pollution prevention. The development of microcomputer applications has caused a significant change in the way environmental programs are managed. Use of microcomputers is considered a best management practice because they have been shown to help improve plant operations, and aid wastewater managers in the decision making process.

The Benchmark. The analysis of survey data presented in chapter five revealed that the benchmark firm was Company D, a large aircraft manufacturing firm in the Northwest. This program achieved a perfect score for permit compliance, and had the highest overall score for pollution prevention.

The researcher's hypothesis stated a benchmark industrial wastewater treatment program would have experienced no exceedances in the past year, and no more than two exceedances in the past four years. In addition, the model program would have adopted pollution prevention as a corporate environmental philosophy. The benchmark convincingly verified this hypothesis by its outstanding compliance record and emphasis on pollution prevention. With the benchmark identified, the remainder of the process will be described to provide an understanding of how benchmarking is carried out.

Completion of the Benchmarking Process

Analysis Phase. Camp says the analysis phase requires a thorough understanding of current practices of both oneself, and the benchmarking partner. To obtain this understanding, follow up interviews and a site visit of the benchmark firm should be conducted. Concurrently, the survey developed for the private sector firms should be administered to AFLC plant operators and senior environmental personnel to determine their current management practices. A review of past Notices of Violation would also be useful to classify the types of practices that have resulted in poor performance.

Determining the Performance Gap. Once the management practices of both organizations are understood, a comparative analysis of the two could begin. Camp states that this comparative analysis should be guided by the following questions:

> Is the benchmarking partner significantly better? Why are they better? By how much are they better? What best practices are being used now or anticipated? How can their practices be incorporated or adapted for implementation? (30:72)

The responses to these questions will become the dimensions of the performance gap, which can be positive, negative or at parity (30:72).

Projecting Future Performance Levels. Using the performance gap as an objective basis, future performance levels can be projected for AFLC facilities. These projected performance levels should be described in quantifiable and qualitative terms. Camp emphasizes that an understanding of current practices is needed, but management must continually look to where performance will be in the future to make benchmarking truly meaningful (30:73). In his words, "benchmarking must be a continuing process so performance is constantly recalibrated to ensure superiority" (30:73).

Integration Phase. Integration uses the benchmark findings to incorporate new practices into daily operations and all formal planning processes.

Communicating Benchmark Findings. The first step toward gaining operational and management acceptance of benchmark findings is to clearly and convincingly demonstrate them as credible, based on substantive data (30:73). Ultimately, the results of this study should be formally presented to the AFLC Command Staff, and the Air Force Civil Engineer. The best way to ensure these findings are implemented is to secure the commitment of senior leadership. However, these findings must also be communicated to all levels of the organization for support and commitment (30:73).

Establishing Functional Goals. For the communication of benchmark findings to be meaningful, they must be converted into statements of operational principles which the entire organization can understand, and by which future actions can be judged (30:73). This conversion of findings into operational principles to improve AFLC industrial waste treatment plants must be the ultimate goal of the research.

Recommendations for Further Research

The following are recommendations for further research based on the contents of this study.

1. Completion of the benchmarking process involves performing the analysis and integration phases previously mentioned. A site visit is highly recommended to collect the data needed to determine the performance gap, and project future levels of performance. These levels of performance will enable managers to establish functional goals for AFLC wastewater treatment plants.

2. Employ the benchmarking process to identify organizations who are considered the best in the areas of hazardous waste management, pollution prevention, environmental auditing, and air pollution control.

3. Examine to what degree the Air Force has adopted pollution prevention as an environmental philosophy.

4. Identify how the tools of Total Quality Management can be, or have been applied, to solving the cross-functional issues faced in the environmental arena.

Appendix A: Professional Associations and Regulatory Agencies Contacted

1. Water Pollution Control
   Bureau of National Affairs
   1231 25th Street, NW
   Washington, D.C. 20037

2. Water Pollution Control Federation
   601 Wythe Street
   Alexandria, Virginia 22314-1994

3. Water/Engineering and Management
   Scranton Gillette Communications, Inc.
   380 Northwest Highway
   Des Plaines, Illinois 60016

4. EPA Region I
   Water Compliance Branch

5. EPA Region II
   Water Permits and Compliance Branch

6. EPA Region III
   Permits Enforcement Branch

7. EPA Region IV
   Facilities Performance Branch

8. EPA Region V
   Water Quality Branch

9. EPA Region VI
   Enforcement Branch

10. EPA Region VII
    Water Compliance Branch

11. EPA Region VIII
    Compliance Branch

12. EPA Region IX
    Compliance Branch

13. EPA Region X
    Water Permit and Compliance Branch

14. Georgia EPA
    Water Compliance Branch

Appendix B: Questionnaire Sent to Professional Associations and Regulatory Agencies

Dear Sir,

My name is Captain Pat Smith and I am a graduate student at the Air Force Institute of Technology, pursuing a masters degree in environmental management. I spoke to you on June 6th regarding my thesis research on identifying the "best management practices" for the treatment of industrial wastewater, with the objective of improving the management of Air Force industrial wastewater treatment plants through "benchmarking". Benchmarking is a process of identifying and studying an "ideal" industrial wastewater treatment program that can be used as a model for improving Air Force operations. The model IWTP should treat water which are similar to those treated at Air Force plants. Typical Air Force waste streams contain heavy metals, oils, and phenols from electroplating, chemical cleaning and paint removal processes.

The benchmarking process is improved by surveying professional associations and trade journals to identify potential "benchmark candidates". These candidates would be firms considered to have very good industrial wastewater management practices, which would then be further studied to identify the "benchmark partner" or model plant, according to preestablished criteria. These criteria are permit compliance, the quality of effluent versus influent, and the adoption of pollution prevention as a corporate environmental philosophy. Your input into this research, by responding to the following questions, would be valuable.

1. What industrial wastewater treatment program do you consider to be the most outstanding in terms of permit compliance, quality of effluent versus influent, and success at implementing pollution prevention?

2. What do you consider to be the three most challenging problems faced by plant management in treating industrial wastewater?

3. What do you consider to be three of the better management practices for treating industrial wastewater you have observed or know of?

This information will be used to survey benchmark candidates and identify the "benchmark partner" for further study and analysis. Thank you for your support. Attached is an executive summary describing this project in greater detail. Please call me regarding any questions you may have at (513) 667-6162 or (513) 255-8989.

Appendix C: Questionnaire Sent to Benchmark Candidates

Dear Sir,

My name is Captain Pat Smith and I am a graduate student at the Air Force Institute of Technology, pursuing a masters degree in environmental management. I spoke to you recently regarding my thesis research on identifying the "best management practices" for the treatment of industrial wastewater, with the objective of improving the management of Air Force industrial wastewater treatment plants (IWTP) through "benchmarking". Benchmarking is a process of identifying and studying an "ideal" industrial wastewater treatment program that can be used as a model for improving Air Force operations. The model IWTP should treat wastewater which is similar to those treated at Air Force plants. Typical Air Force waste streams contain heavy metals, oils, and phenols from electroplating, chemical cleaning and paint removal processes.

The benchmarking process is improved by surveying potential "benchmark candidates". These candidates would be firms considered to have very good industrial wastewater management practices, which would then be further studied to identify the "benchmark partner" or model plant, according to preestablished criteria. These criteria are permit compliance, plant performance, and the adoption of pollution prevention as a corporate environmental philosophy. Based upon a survey of federal and state regulatory agencies, your plant has been selected as one of ten benchmark candidates.

Your input into this research by responding to the attached questionnaire would be valuable. Please take the time to complete the attached questionnaire and return it in the self addressed, stamped envelope, or by facsimile machine (513/255-5188, Attention: Lt Col Goltz) before 15 July, 1991. The information you provide will remain strictly confidential. If selected as the model plant, your firm's name will not be used without the express written consent of your firm's principals. Once your questionnaire is returned, I may wish to contact you to clarify responses and gain further insight in to what makes your plant an effective performer. Please contact me regarding any questions you have at 513/667-6162. Thank you for your support.

Sincerely,

PATRICK J. SMITH, Captain, USAF
Graduate Student

Attachment
Questionnaire

INDUSTRIAL WASTEWATER MANAGEMENT QUESTIONNAIRE

Instructions: Select your responses directly on the questionnaire booklet; a separate answer sheet is NOT provided. Your written comments can be made on a separate sheet if desired. Please answer each question as honestly as possible. Some additional instructions are provided at each section, please read them carefully before you begin. Please note that Section III should be completed by the senior manager for environmental matters.

SECTION I - PLANT DESCRIPTION AND COMPLIANCE

Instructions: Select the appropriate response(s) to each question. Please include your name, phone number, and position.

Name: ______________________________________

Phone: ______________

Position: ____

1. Who is the permitting authority for your plant? (i.e. local pretreatment, state, federal)

2. If you have a NPDES permit, when was it issued, and when does it expire?

3. What kind of unit treatment processes does your plant use? (Please include a plant schematic if available.)

4. What is your plant's average flowrate? _____________ MGD

5. Please complete the following table describing the type of waste streams experienced at your plant and their sources to the best of your ability.

	Activity	Flow	Waste Characterization	Pretreatment or Recycle
a.				
b.				
c.				
d.				
e.				
f.				
g.				
h.				

Activity - type of production operation/process, (i.e. electroplating, parts washing, paint stripping, etc.).

Flow - Gallons per minute.

Waste characterization - type of wastes, (i.e. heavy metals-chromium, phenol, cyanide, etc.).

Pretreatment or Recycle - type of pretreatment or recycling used at the source, if any, prior to discharge to IWTP.

6. How many permit exceedances has your plant experienced since 1987? _____

7. How many permit exceedances has your plant experienced since June of last year? _____

SECTION II - PLANT PERFORMANCE

Instructions: The table on the next page is designed to gather information about overall treatment plant performance, and should be completed by the industrial wastewater plant manager. The values provided should be based on an average of the preceding twelve months. Please indicate the units used (i.e. mg/l), influent and effluent concentrations, and permit limits in the appropriate columns. An example is provided in the first row of the table. Please provide your name, phone number, and position.

IF THIS INFORMATION IS AVAILABLE IN A REPORT FORMAT YOU ALREADY HAVE, PLEASE JUST SEND THE REPORT.

Parameter	Units	Influent	Effluent	Discharge Permit 30-day (xx)	 7-day ( )	 Daily Max ( )
EXAMPLE	mg/l	5	.04	.05		
BOD5						
COD						
pH						
Oil/Grease						
TSS						
TTO						
Phenol						
Cyanide						
Heavy Metals, please specify each type						

TTO = Total Toxic Organics

SECTION III - POLLUTION PREVENTION

Instructions: This section should be completed by your company's senior person responsible for environmental management. Please provide your name, phone number, and position.

Part A

Instructions: Select the appropriate responses to each question.

1. What is the position of the most senior individual directly responsible for environmental matters within your company?

___ Chief Executive Officer's personal staff
___ Senior Vice President
___ Department Manager
___ Branch Chief
___ Other, please specify ______________________________

2. What is the estimated completion date for your company's longest range environmental project?

___ Less than 2 years
___ 2 to 3 years
___ 4 to 5 years
___ More than 5 years

3. What areas has your company set goals for? (Select as many as apply)

___ Hazardous waste reduction (waste minimization)
___ Recycling/reuse of raw materials in waste stream
___ Regulatory compliance
___ Facility performance against established company standards
___ Others, please specify ______________________________

4. Of the groups listed below, which ones receive training on the environmental issues affecting their job? (Select as many as apply)

___ Production employees and plant maintenance personnel
___ Lower level managers (shop supervisors, foremen)
___ Middle management (department staffs, production control)
___ Senior management (vice presidents, department heads)
___ Other, please specify ______________________________

5. Does your company perform any of the following actions when evaluating potential vendors? (Select as many as apply)

___ Review regulatory compliance documentation
___ Contact appropriate regulatory agencies regarding vendor compliance
___ Include environmental staff in site visits with purchasing and inspection personnel
___ Other, please specify ______________________________

6. Within your company, how early in the design of products or manufacturing processes are environmental issues considered?

- ____ Idea generation or concept design
- ____ Preliminary design
- ____ Final design

Part B

Instructions: Please circle the number that corresponds to your response on the following statements.

7. Overall, my company adequately incorporates environmental issues into strategic planning.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
1	2	3	4	5

8. My company considers the performance of vendors with regard to environmental issues important for stability in production. (For example, having to slow or stop production because parts from a vendor are unavailable due to vendor plant shutdown caused by noncompliance problem).

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
1	2	3	4	5

9. My company does an adequate job of evaluating the environmental compliance of material vendors.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
1	2	3	4	5

10. My company does an adequate job of addressing environmental issues in product research, development and process design.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
1	2	3	4	5

11. Overall, my company has established adequate environmental goals.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
1	2	3	4	5

12. The company's environmental goals established are specific and measurable.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
1	2	3	4	5

13. The company's environmental goals are considered challenging, but achievable.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
1	2	3	4	5

14. My company considers itself responsible for ensuring vendors comply with applicable laws and good environmental practices.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
1	2	3	4	5

15. My company's senior management is committed to improving the environment by pollution prevention.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
1	2	3	4	5

16. Over the past ten years, my company has experienced some positive change in the corporate culture with regard to environmental issues.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
1	2	3	4	5

17. In assessing the quality of environmental management systems, my company has adopted satisfactory measurement and evaluation tools (i.e. environmental auditing).

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
1	2	3	4	5

18. My company considers holds production employees responsible for environmental compliance.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
1	2	3	4	5

19. My company adequately rewards employee efforts to prevent pollution and improve environmental compliance.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
1	2	3	4	5

20. When trying to solve technical problems, my company uses cross-functional teams in the problem solving process.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
1	2	3	4	5

21. On a scale of 1 to 5, how would you rate the overall effectiveness of your company toward pollution prevention.

Poor	Marginal	Fair	Excellent	Outstanding
1	2	3	4	5

22. Do you have any comments regarding this questionnaire?

Appendix D: Responses from Benchmark Candidates Questionnaire

CANDIDATE: A SECTION 1 - PERMIT COMPLIANCE

PERMIT TYPE: LOCAL			
AVERAGE FLOW RATE:		0.75 MGD	
INDUSTRIAL ACTIVITY	FLOW	WASTE CHARACTERIZATION	PRETREATMENT/ RECYCLING
ELECTROPLATING		CYANIDE	CHLORINATION
ELECTROPLATING		CHROMIUM	SULFUR DIOXIDE
ELECTROPLATING		NICKEL	NEUTRALIZATION
		FREQUENCY	SCORE
EXCEEDANCES FROM 1987		20	14
EXCEEDANCES IN 1990		3	27
SECTION 1 SUBSCORE			41

CANDIDATE: A SECTION 3 - POLLUTION PREVENTION

QUESTION	MEASUREMENT AREA	SCORE	QUESTION	MEASUREMENT AREA	SCORE
1	PLANNING	4	12	GOALS	4
2	PLANNING	4	13	GOALS	4
3	GOALS	2	14	VENDORS	5
4	GOALS	1	15	PLANNING	3
5	VENDORS	2	16	PLANNING	4
6	DESIGN	0	17	PLANNING	3
7	PLANNING	4	18	GOALS	4
8	VENDORS	3	19	GOALS	2
9	VENDORS	4	20	DESIGN	3
10	DESIGN	3	21	OVERALL	4
11	GOALS	4			
			SECTION 3 SUBSCORE		67

CANDIDATE: B SECTION 1 - PERMIT COMPLIANCE

PERMIT TYPE: NPDES			
AVERAGE FLOW RATE:		1.5 - 2.0 MGD	
INDUSTRIAL ACTIVITY	FLOW (MGD)	WASTE CHARACTERIZATION	PRETREATMENT/ RECYCLING
A/C WASHING	0.4	OILY WASTE	NONE
COOLANT	0.4	OILY WASTE	NONE
PENETRANT INS	0.4	OILY WASTE	NONE
BOILER BLOW D	0.4	OILY WASTE	NONE
EMULSION CLEA	0.4	OILY WASTE	NONE
ELECTROPLATE	0.8	HEAVY METALS	NONE
PROCESS DUMP	INTERMIT	CONCENTRATED ACI	NONE
PROCESS DUMP	INTERMIT	CONCENTRATED BAS	NONE
		FREQUENCY	SCORE
EXCEEDANCES FROM 1987		46	5
EXCEEDANCES IN 1990		9	21
SECTION 1 SUBSCORE			26

CANDIDATE: B SECTION 3 - POLLUTION PREVENTION

QUESTION	MEASUREMENT AREA	SCORE	QUESTION	MEASUREMENT AREA	SCORE
1	PLANNING	1	12	GOALS	5
2	PLANNING	4	13	GOALS	5
3	GOALS	4	14	VENDORS	3
4	GOALS	2	15	PLANNING	5
5	VENDORS	4	16	PLANNING	5
6	DESIGN	3	17	PLANNING	5
7	PLANNING	4	18	GOALS	3
8	VENDORS	4	19	GOALS	4
9	VENDORS	4	20	DESIGN	5
10	DESIGN	5	21	OVERALL	4
11	GOALS	4			
			SECTION 3 SUBSCORE		83

CANDIDATE: C SECTION 1 - PERMIT COMPLIANCE

PERMIT TYPE: NONE			
AVERAGE FLOW RATE:		0.75	MGD
INDUSTRIAL ACTIVITY	FLOW (GPM)	WASTE CHARACTERIZATION	PRETREATMENT/ RECYCLING
ELECTROPLATING	7	COPPER, ZINC,	SEE NOTES
		CYANIDES	
ELECTROPLATING	15	CHROME	SEE NOTES
ELECTROPLATING	30	ACID, ALKALINE	SEE NOTES
		DUMPS	

	FREQUENCY	SCORE
EXCEEDANCES FROM 1987	0	30
EXCEEDANCES IN 1990	0	30
SECTION 1 SUBSCORE		60

CANDIDATE: C SECTION 3 - POLLUTION PREVENTION

QUESTION	MEASUREMENT AREA	SCORE	QUESTION	MEASUREMENT AREA	SCORE
1	PLANNING	1	12	GOALS	5
2	PLANNING	1	13	GOALS	5
3	GOALS	4	14	VENDORS	1
4	GOALS	2	15	PLANNING	5
5	VENDORS	0	16	PLANNING	4
6	DESIGN	2	17	PLANNING	2
7	PLANNING	4	18	GOALS	1
8	VENDORS	1	19	GOALS	1
9	VENDORS	1	20	DESIGN	1
10	DESIGN	4	21	OVERALL	4
11	GOALS	5			
			SECTION 3 SUBSCORE		54

CANDIDATE: D SECTION 1 - PERMIT COMPLIANCE

PERMIT TYPE: LOCAL			
AVERAGE FLOW RATE: 0.50 MGD			
INDUSTRIAL ACTIVITY	FLOW (GPD)	WASTE CHARACTERIZATION	PRETREATMENT/ RECYCLING
ELECTROPLATING	10,000	HEAVY METALS	
PAINTING	40,000	ORGANIC, PHENOLS	
STEAM CLEANING	200	ORGANICS	
		FREQUENCY	SCORE
EXCEEDANCES FROM 1987		0	30
EXCEEDANCES IN 1990		0	30
SECTION 1 SUBSCORE			60

CANDIDATE: D SECTION 3 - POLLUTION PREVENTION

QUESTION	MEASUREMENT AREA	SCORE	QUESTION	MEASUREMENT AREA	SCORE
1	PLANNING	4	12	GOALS	5
2	PLANNING	4	13	GOALS	5
3	GOALS	5	14	VENDORS	5
4	GOALS	3	15	PLANNING	5
5	VENDORS	1	16	PLANNING	5
6	DESIGN	2	17	PLANNING	5
7	PLANNING	5	18	GOALS	0
8	VENDORS	5	19	GOALS	4
9	VENDORS	5	20	DESIGN	5
10	DESIGN	5	21	OVERALL	5
11	GOALS	5			
			SECTION 3 SUBSCORE		88

CANDIDATE: E SECTION 1 - PERMIT COMPLIANCE

PERMIT TYPE: LOCAL			
AVERAGE FLOW RATE:		0.75 MGD	
INDUSTRIAL ACTIVITY	FLOW (GPM)	WASTE CHARACTERIZATION	PRETREATMENT/ RECYCLING
TUMBLE MEDIA	60	NONHAZARDOUS	SEE NOTES
ELECTROPLATING	9	HEAVY METAL	SEE NOTES
		FREQUENCY	SCORE
EXCEEDANCES FROM 1987		0	30
EXCEEDANCES IN 1990		0	30
SECTION 1 SUBSCORE			60

CANDIDATE: E SECTION 3 - POLLUTION PREVENTION

QUESTION	MEASUREMENT AREA	SCORE	QUESTION	MEASUREMENT AREA	SCORE
1	PLANNING	1	12	GOALS	5
2	PLANNING	2	13	GOALS	5
3	GOALS	3	14	VENDORS	4
4	GOALS	4	15	PLANNING	5
5	VENDORS	2	16	PLANNING	5
6	DESIGN	3	17	PLANNING	4
7	PLANNING	4	18	GOALS	4
8	VENDORS	4	19	GOALS	4
9	VENDORS	4	20	DESIGN	5
10	DESIGN	4	21	OVERALL	4
11	GOALS	5			
			SECTION 3 SUBSCORE		81

Appendix E: Long Term Permit Compliance Scoring

TABLE 4

LONG TERM PERMIT COMPLIANCE SCORING

Number of NOV's Over Past Four Years	Points Allotted
0 - 2	30
3 - 5	29
6 - 8	28
9 - 11	27
12 - 14	26
15 - 17	25
18 - 20	24
21 - 23	23
24 - 26	22
27 - 29	21
30 - 31	20
32 - 34	19
35 - 37	18
38 - 40	17
41 - 43	16
44 - 46	15
47 - 49	14
50 - 51	13
52 - 54	12
55 - 57	11
58 - 60	10

Appendix F: Near Term Permit Compliance Scoring

TABLE 5

NEAR TERM PERMIT COMPLIANCE SCORING

Number of NOV's in the Past Year	Points Allotted
0	30
1	29
2	28
3	27
4	26
5	25
6	24
7	23
8	22
9	21
10	20
11	19
12	18
13	17
14	16
15	15
16	14
17	13
18	12
19	11
20	10

Appendix G: Pollution Prevention Philosophy Scoring

TABLE 6

POLLUTION PREVENTION PHILOSOPHY SCORING

Question Number	Measurement Area	Points Allotted
1	Planning	4
2	Planning	4
3	Goals	5
4	Goals	5
5	Vendors	5
6	Design	5
7	Planning	5
8	Vendors	5
9	Vendors	5
10	Design	5
11	Goals	5
12	Goals	5
13	Goals	5
14	Vendors	5
15	Planning	5
16	Planning	5
17	Planning	5
18	Goals	5
19	Goals	5
20	Design	5
21	Overall	5

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Vita

Captain Patrick J. Smith was born 19 December 1961 in Rochester, New York. He graduated from high school in Denton, Texas, in 1980 and attended the United States Air Force Academy. He received his degree of Bachelor of Science in Civil Engineering and a commission in the USAF in May of 1984. He then served as Design Engineer and Chief of Readiness with the 2854th Civil Engineering Squadron at Tinker AFB, Oklahoma until July 1987. He served as Foreign Military Sales Construction Engineer and Chief of Readiness Division with Headquarters Air Force Logistics Command until entering the School of Systems and Logistics, Air Force Institute of Technology, in May 1990. His next assignment will be as construction manager, Logistics Support Group, Air Force Logistics Command in Saudi Arabia.

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REPORT DOCUMENTATION PAGE

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13. ABSTRACT (Maximum 200 words)

This research examined how the performance of AFLC's industrial wastewater treatment plants could be improved through changes in management practices. The examination looked into what management practices are found in a model program. The selection of a model program was based upon criteria established by a review of current literature. The criteria were permit compliance, plant performance, and the adoption of pollution prevention as a corporate environmental philosophy. In this study, private sector firms were examined in order to identify the best management practices using a Total Quality Management (TQM) tool called benchmarking. The data gathering process consisted of a survey of water pollution control organizations, and a survey of benchmark candidates. After an analysis of survey data, a large aircraft manufacturing firm in the Northwest was chosen as the benchmark. The benchmark firm can be used to identify management practices which would help AFLC improve its operations.

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