An Analysis of the Effectiveness of Pollution Prevention in Reducing Environmental Compliance Costs

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AN ANALYSIS OF THE EFFECTIVENESS OF POLLUTION PREVENTION IN REDUCING ENVIRONMENTAL COMPLIANCE COSTS

THESIS

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Abstract

The objective of the Air Force's compliance through pollution prevention (CTP2) program is to reduce overall environmental compliance (EC) cost and risk (compliance burden) associated with maintaining compliance at an installation through increased pollution prevention (P2) efforts. However, no quantifiable evidence has been produced that suggests P2 projects are actually reducing compliance burden. Therefore, this research attempts to determine if projects categorized as P2 truly reduce compliance burden.

This research demonstrated that, under the current burden calculation methodology, the compliance site inventory data should not be used to measure or track compliance burden reductions. The time value of money, net present value, and correlations were used to analyze the Wright-Patterson AFB (WPAFB) and Air Force Materiel Command (AFMC) EC and P2 programs from 1995 through 2000.

Overall, this research showed that CTP2 is effective because EC costs are falling, EC savings are greater than the P2 investments, and EC savings are highly correlated to P2 investments. The analysis of WPAFB provided the strongest evidence; however, the AFMC analysis provided mixed results, which were explained by relatively high laboratory and product center P2 costs and mission changes due to base closures. When the analysis focused on Arnold, Edwards, Kirtland, and Wright-Patterson AFB, the results were supportive. Each of these bases saw a decline in EC costs, had a net positive overall savings, and had a moderate to strong correlation between EC savings and P2 expenditures.

AN ANALYSIS OF THE EFFECTIVENESS OF POLLUTION PREVENTION IN REDUCING ENVIRONMENTAL COMPLIANCE COSTS

I. Background and Problem Statement

General Issue

Environmental management is the means of conserving, protecting, and restoring our environment and natural and cultural resources while accomplishing the military mission (33). Two essential pieces of environmental management include compliance and pollution prevention (P2). Although strict environmental compliance (EC) legislation, such as the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), have been around since the mid-1970s, P2 legislation is much more recent. It was not until 10 years ago, when following a period of increased public environmental awareness, that Congress passed legislation regarding pollution prevention. The Federal Pollution Prevention Act (PPA) of 1990 established P2 as a national objective. It required the Environmental Protection Agency (EPA) to develop and implement a strategy to support source reduction. It declared that pollution, which could not be prevented, must be reused or recycled. If pollution cannot be reused or recycled, it should be treated; and disposal or other release into the environment should be used only as a last resort (37). Hence, the first real push for pollution prevention began.

Environmental Compliance. In order to fully understand the importance of P2, one must first understand EC, which dictates that we must ensure our operations meet federal, state, local, tribal and host nation environmental requirements. Areas affected include operations such as wastewater discharge, sewage treatment, noise abatement, endangered species and wetlands management, air quality attainment, historic property management, and solid and hazardous waste management. (7; 33)

In order to appreciate the importance of maintaining compliance, one must fully understand the extent to which environmental laws affect the Air Force. In 1992, Congress passed the Federal Facility Compliance Act (FFCA), which amended RCRA and allowed state environmental agencies and the federal EPA to impose civil penalties and administrative fines on Federal facilities under RCRA section 6001 for violations of federal, state, and local environmental laws (36). Therefore, violations of federal, state, and local environmental statutes can result in both civil and criminal penalties. One-time fines range up to $250,000 and additional cumulative fines can be as high as $50,000 per day per violation (7; 33).

Pollution Prevention. Pollution prevention entails reducing pollution at its source and reducing or eliminating the creation of pollutants through increased efficiency in the use of raw materials, energy, water, and other resources. Aside from being an executive and congressional mandate, and "the right thing to do," pollution prevention makes good business sense. In most cases, significant cost savings are realized by conducting operations and maintenance in a manner that results in less waste and fewer releases of toxic pollutants. Other benefits include a more healthful work environment, reduced future liabilities, and improved public perception of the impacts and attitude towards the environment. The Air Force believes that P2 can be used as an effective means to drive down long-term EC costs. (7; 18; 33:9-10)

Compliance Through Pollution Prevention. The Air Force implemented its program of compliance through pollution prevention (CTP2) on January 8, 1999, when it issued the Compliance Through Pollution Prevention Implementation Guidance, which highlighted the Air Force's strategy of reducing compliance sites and compliance burden through a three-phase implementation process. The guidance defined a compliance site as any source of pollution on a base and its associated compliance burden, which is determined by combining compliance costs and risks associated with the site. The three-phase implementation process includes accomplishing an inventory of all compliance sites; assigning a compliance burden to each site, using the Operational Risk Management (ORM) process, and subsequent rank ordering the sites; and identifying sites for P2 process-specific opportunity assessments. (18)

Problem Statement

The Headquarters, United States Air Force (Air Staff), is seeking cost-effective ways to decrease the number of compliance sites and compliance burden while still accomplishing the mission. One method of accomplishing this is to transfer funds from the EC budget into the P2 budget with the intent to reduce both EC cost and risk. Therefore, the Air Staff instituted a goal in January 1998 that 20 percent of the EC budget would be transferred to the P2 budget by the year 2003 (22). This and other initiatives led to an aggressive pursuit of cost-effective P2 solutions across the Air Force. The reasoning behind these objectives is that increased P2 efforts will reduce the overall EC cost and risk (compliance burden) associated with maintaining compliance at an installation. The Air Force is now three years into the process of migrating funds from the compliance budget to the P2 budget, with the historical funding amounts for both budgets being shown in Figure 1-1.

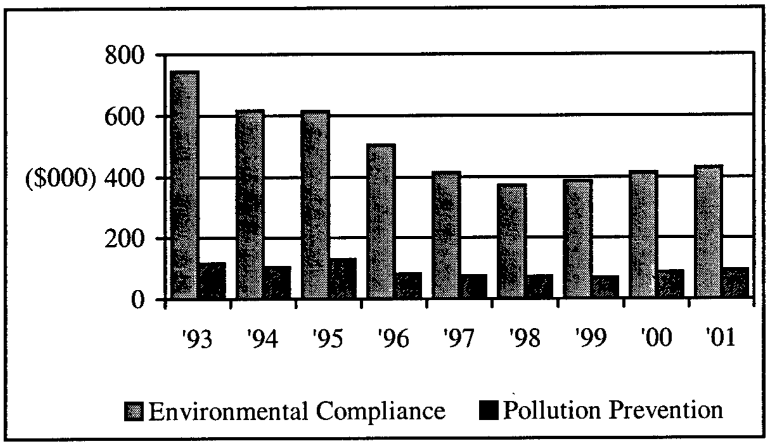

Figure 1-1. Air Force Fiscal Year EC and P2 Budgets (12)

Although the Air Force has consistently put vast amounts of funding into P2 initiatives since 1993, no quantifiable evidence has been produced that suggests that these P2 projects are actually reducing the compliance burden at Air Force installations. Therefore, the goal of this research effort will be to determine if P2 actually reduces compliance burden by analyzing the Air Force CTP2 investment strategy. It will do so by analyzing the Air Force Materiel Command (AFMC) compliance site inventory database as well as cost records for Wright-Patterson Air Force Base (AFB) and then AFMC as an entire entity. It will attempt to determine if projects categorized as P2 truly reduce/eliminate cost and risk.

Research Approach

To determine if P2 truly reduces compliance burden, an analytical review of the Wright-Patterson AFB (WPAFB) and AFMC EC and P2 programs from 1995 through 2000 will be conducted. This analysis will begin by showing why the existing compliance site inventory (CSI) is unsuitable for measuring compliance performance. The research will then show that compliance costs are being reduced, that the reductions are more than the amount being spent on P2, and finally that the environmental savings are correlated to the P2 investments.

The initial part of the research will show that the CSI database cannot be used to determine whether or not an installation's overall compliance burden is either rising or falling. Although AFMC started inventorying compliance sites in the mid-1990s, they first assigned compliance burden to sites in the 1999 iteration of the CSI. Therefore, no historical data is yet available regarding cost and risk associated with the sites, making it impossible to draw any comparisons at this time. Additionally, categorizing cost and risk based on a percent ranking method further restricts the CSI database from being used to measure compliance burden changes. Since the range of cost and risk values is reestablished each year, it eliminates a baseline that could be used to show changes in compliance burden.

The subsequent part of this research will show that P2 efforts cause a reduction in EC costs by analyzing trends in the WPAFB EC and P2 budgets from 1995 to 2000. This analysis will use time value of money (TVM), net present value (NPV), and correlation calculations. The TVM analysis, using inflation rates based on the producer price index

(PPI), will put the annual budgets in terms of year 2000 dollars to show that EC budgets are truly decreasing. The NPV analysis will be used to show that P2 investments have been less than the resultant EC cost savings, and therefore worthwhile. Finally, the correlation calculations will show a strong relationship between annual P2 investments annual EC cost savings.

Preview

This thesis will begin with a review of literature related to Air Force P2 and EC programs, as well as a detailed explanation of the CSI, in chapter two. Chapter three details the research approach by explaining the CSI burden assignment, TVM, NPV, and correlation methodologies. Chapter four presents the detailed analysis of the WPAFB and collective AFMC data using the methodology detailed in chapter three. Finally, chapter five will draw conclusions and determine if the Air Force's CTP2 funding strategy has been effective. Essentially, an assessment as to whether or not pollution prevention reduces compliance cost and risk will be made.

II. Literature Review

Overview

The Federal Pollution Prevention Act of 1990 (PPA) established pollution prevention (P2) as a national objective. It declared that pollution, which could not be prevented, should be reused or recycled. When infeasible to prevent, reuse, or recycle, pollution should be treated. Finally, disposal or other release into the environment should be used only as a last resort (37:452).

Since passage of the PPA, the Air Force (AF) has embraced P2, as it emphasizes source reduction, reuse/recycling, and recovery methods as the primary means to achieve environmental compliance (19:1). It is Air Force policy to use P2 as the first choice to meet new legal requirements, ensure compliance, and return to compliance when violations are identified. In 1997, the Air Force directed its base level environmental staffs to work with process owners to review, identify, and program P2 projects that meet or eliminate compliance management, treatment, or disposal requirements (21).

On 8 Jan 99, the Air Force published its Compliance Through Pollution Prevention (CTP2) Implementation Guidance. This guidance describes the CTP2 concept, discusses the investment strategy to eliminate "compliance sites" and reduce compliance burden, and identifies the three phases of the implementation process. The Air Force believes that the initial startup costs to execute this CTP2 initiative should lead to reduced life cycle costs (LCCs), which is defined as the total cost to the Government over the full life of the program. It includes research and development, initial inventories, training, facilities, operations, support, and disposal. The goal is to reduce LCCs through lower compliance costs and decreases in associated operational and environmental safety and occupational health (ESOH) risks. (19)

Pollution Prevention

Underlying Philosophy. Aside from being an executive and congressional mandate and "the right thing to do," pollution prevention makes good business sense. In most cases, significant cost savings are realized by conducting operations and maintenance in a manner that results in less waste and fewer releases of toxic pollutants. This is attributed to a reduction in the procurement and management of hazardous materials and the reduction in the management and disposal of hazardous wastes. Other benefits include a more healthful work environment, reduced future liabilities from waste disposal, and an improved public perception. (33:9-10)

History. Solid waste management can be traced as far back as 500 B.C. to the first municipal dump in Athens, Greece (30:1.2). However, recycling efforts, which are the earliest proactive forms of pollution prevention, are relatively new to the world. Our society of the 1950s, often referred to as the "throwaway society," saw manufacturers creating products designed for convenience and did not perceive waste disposal as a problem. It was not until the end of the 1960s, with the counter-culture and "hippie" movements, that people realized the use of recycled materials could save enormous amounts of energy and resources.

The 3M Company, a multi-national corporation with manufacturing plants in 41 countries was quick to realize the potential benefits of pollution prevention. In 1975, it became the first to implement a company wide P2 program focusing on source reduction. The goal of its successful Pollution Prevention Pays (3P) program is to make P2 a way of life throughout 3M. Each year, 3M budgets approximately $150 million for research and development related to environmental issues, which has resulted in a 20 percent reduction in energy consumption and a 35 percent decrease in waste generation. Additionally, the company has realized savings of more than $150 million in lower cost for energy, process chemicals, and waste treatment. (1:1-3)

However, due to the relatively low cost of waste disposal during the 1970s and early 1980s, recycling efforts remained less than enthusiastic. It was not until the late 1980s when a sharp rise in waste disposal costs turned the tide and created a public environmental awareness (2:3-4). The passage of laws such as the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 provided large incentives for P2 by legislating joint and several liability for cleanups (26:12). Joint and several liability makes all parties disposing of waste at particular site responsible for the cleanup, regardless of whether the wastes were disposed of in compliance with the established laws at the time of disposal. Additionally, any one party can be held responsible for the total cost of the cleanup regardless of their disposal amount at the site. This further strengthens the case for pollution prevention as it makes it difficult for managers to predict the disposal standards for future regulations (26:13).

Following CERCLA, the Hazardous and Solid Waste Amendment (HSWA) of 1984 greatly increased the number of wastes classified as hazardous under the Resource Conservation and Recovery (RCRA). It added to RCRA's cradle-to-grave law, which makes generators responsible for all future cleanups regardless if the waste was originally disposed of properly. It also restricted land disposal and the treatment of chemicals (39:63-64). These restrictions drastically increased disposal costs due to the decrease in disposal alternatives. This spurred organizations to use pollution prevention as a means to reduce raw material, production, and disposal costs (26:13). Following this increased public environmental awareness, Congress passed the PPA of 1990, which became the catalyst for P2 of the 1990s. The Air Force's pollution prevention programs were born shortly thereafter.

Environmental Management Hierarchy. In the PPA, Congress declared that source reduction is the highest tier in a hierarchy of acceptable practices, which begin with source reduction, then reuse and recycling, then treatment, and finally disposal. (37)

Source Reduction. Source reduction is defined in the PPA as any practice that 1) reduces the amount of any pollutant discharged into the environment prior to recycling, treatment, and disposal; and 2) reduces the hazards to public health and the environment associated with the release of such pollutants (37). For the Air Force, this term includes material substitution; equipment or technology modification; process modification; product redesign; and maintenance, training, or inventory control improvements (7).

Reuse and Recycling. Reuse entails returning a product for reuse without any change in its identity by finding different purposes for the materials (7). Recycling is the result of a series of activities by which materials, that would become or otherwise remain waste, are diverted from the waste stream and used as raw materials in the manufacture of other goods (7). Returnable bottles provide one of the best examples of reuse, as the product is reused a number of times until it is damaged and can no longer be used (1:387).

Recycling, on the other hand, involves the reformation or processing off a recovered material and generally occurs in the factory (1:387).

Treatment. Treatment entails rendering a product safe through the removal of pollutants hazardous to the public or environment prior to discharging into the environment. A good example of treatment would be the processes of a wastewater treatment plant that remove pollutants before discharging water into a local waterway.

Disposal. Disposal involves the act of physically discarding a product once all other avenues, higher in the hierarchy, have been exhausted as a means to deal with the product. The local sanitary landfill, where solid wastes are compacted in layers and covered at the end of each day, is an example of disposal (1:108).

Key Definitions

Pollution Prevention. Pollution prevention entails reducing pollution at its source and reducing or eliminating the creation of pollutants through increased efficiency in the use of raw materials, energy, water, or other resources. Examples of P2 techniques include improved hazardous materials management, reuse, material substitution, product reformulation, process redesign or modification, improved operation and maintenance, source reduction, and integrated recycling. (7; 33)

Compliance. Compliance dictates that we must ensure that our operations meet federal, state, local, tribal and host nation environmental requirements. Areas affected include operations such as wastewater discharge, sewage treatment, noise abatement, endangered species and wetlands management, air quality attainment, historic property management, and solid and hazardous waste management. Compliance status can, and often does, vary according to the regulated environmental medium. For example, you could be in compliance with water quality regulations but be out of compliance with hazardous waste regulations. Another example of noncompliance is not having an Army Corps of Engineers (COE) permit for projects that result in degradation of wetlands (7; 33:5, 9).

Environmental Liability. Environmental liability is more difficult to define than either P2 or compliance. With respect to the Air Force's P2 strategy, it is related to vulnerability, which is related to cost and risk. In the broadest sense, cost is the total ownership costs or life cycle costs (operations and maintenance, user/owner costs, utilities, industrial process costs, training, etc.); and in its narrowest sense, it is equated to recurring environmental permit fees (27).

According to the Environmental Protection Agency (EPA), environmental liability consists of the following broad categories (24:9):

- Compliance obligations related to laws and regulations that apply to the manufacture, use, disposal, and release of chemical substances and to other activities that adversely affect the environment
- Remediation obligations (existing and future) related to contaminated real property
- Obligations to pay civil and criminal fines and penalties for statutory or regulatory non-compliance
- Obligations to compensate private parties for personal injury, property damage, and economic loss
- Obligations to pay "punitive damages" for grossly negligent conduct
- Obligations to pay for natural resource damages

Compliance Through Pollution Prevention. Compliance through P2 is an environmental management system-based process that preferentially applies cost-effective P2 solutions to achieve compliance while reducing LCCs, reducing risks as determined through the operational risk management process, improving environmental and mission performance, and reducing the compliance burden. Cost-effective P2 solutions use processes, practices, materials, or products that avoid or reduce pollution and may include source reduction through process changes or material substitution, reuse, or recycling. Additionally, it is designed to take advantage of new technologies and to accommodate mission changes in order to achieve continuous improvement in environmental and mission performance, total ownership cost (TOC) reduction, and compliance requirement reduction. (7)

Compliance Burden. As the theme of CTP2 is to reduce compliance burden, one must know its meaning. It is a two-part entity consisting of cost and risk. Cost entails compliance costs, which equates to the cost to remain in compliance (7). Risk equates to operational and environment, safety, and occupational health risks as defined using the operational risk management (ORM) approach described in AFI 91-213, Operational Risk Management Program (7). Each compliance site in the Air Force is assigned a compliance burden of low, medium, high, and extremely high (18).

Compliance Site. The draft version of Air Force Instruction (AFI) 32-7080, Compliance Assurance and Pollution Prevention, defines a compliance site as follows (7):

> A compliance site is any regulated facility, regulated process, or a discharge to a regulated facility or process. This includes any discrete location under Air Force control wherein activity occurs that is subject to current or known future (resulting in known consequences) federal, state, and local statutes and regulations; Executive Orders; Department of Defense and Air Force policies; and the Overseas Environmental Baseline Guidance Document, Final Governing Standards and international agreements. Compliance sites include, but are not limited to, air emissions from each stationary source; points where hazardous waste is accumulated, treated, stored, or disposed; confirmed solid waste management units; underground storage tanks; aboveground storage tanks; potable water system components, treatment systems, major storage sites, and distribution systems; National Pollutant Discharge Elimination System and/or permitted storm water out falls and other permitted discharges; Emergency Planning and Community Right-to-Know Act (EPCRA) sites that exceed reporting thresholds defined under EPCRA, 42 U.S.C. 11022; storage and mixing facilities operated by certified pesticide applicators; on-installation solid waste permitted landfills; and Resource Conservation and Recovery Act Subpart X permitted or interim status sites.

Importance of Pollution Prevention

Environmental Protection Agency Policy. The EPA promotes pollution prevention as the preferred method for pollution control and risk reduction. This EPA policy is constantly being reinforced, as Executive Order (EO) 13148 states, "… regulatory requirements shall emphasize pollution prevention through source reduction as the means of first choice to ensure compliance, with reuse and recycling alternatives having second priority as a means of compliance" (31). Additionally, it is evident that this policy is not new as the Science Advisory Board (SAB) stated in 1990 that treatment and disposal (T&D) controls and remediation are no longer sufficient for environmental activism (34:1). An excellent example of the Air Force's focus on source reduction is a new aircraft de-icing system developed under partnership with private industry, which reduces the use of environmentally unfriendly de-icing chemicals by 30 to 50 percent (29). This P2 opportunity actually speeds aircraft de-icing operations while reducing the high cost of T&D associated with the waste de-icing chemicals.

The EPA indicated in 1990 that it intended to initiate market-based incentives to encourage pollution prevention. Under the plan, "the major categories of incentive systems include: 1) pollution charges, 2) marketable permits, 3) deposit-refund systems, 4) removal of market barriers, and 5) revision of legal standards of liability" (34:15). These incentives would make it more cost effective to implement pollution prevention controls rather than continue with traditional methods.

Air Force Policy. Air Force Policy Directive (AFPD) 32-70, Environmental Quality, states that the Air Force will prevent future pollution by minimizing the use of hazardous materials and reducing the release of pollutants into the environment to as near zero as feasible. This will be done first through source reduction; where environmentally damaging materials must be used, their use will be minimized. When the use of hazardous materials is unavoidable, the waste will be reused or recycled whenever possible. When spent material and waste cannot be reused or recycled, disposal of the spent material and waste will occur in an environmentally safe manner. (9)

Air Force Pollution Prevention Vision. The Air Force vision for P2 emphasizes source reduction, reuse, and recovery methods as the primary means to achieve compliance. AFPD 32-70, Environmental Quality, states, "... the Air Force is committed to...eliminating pollution wherever possible" (9). Environmental compliance that focuses only on T&D solutions does not always produce the best decisions. P2 can reduce TOCs, also known as LCCs, compliance requirements, health and safety risks, and pollutant discharges by addressing pollution as close to the source as possible (7). Furthermore, the Air Force's Pollution Prevention Strategy Document, defines the Air Force P2 vision as (17:1):

> "Effectively promote pollution prevention by minimizing or eliminating the use of hazardous materials and the release of pollution into the environment. Meet or exceed regulatory requirements through the use of education, training and awareness programs, health-based risk assessments, acquisition practices, contract management, facilities management, energy conservation, and innovative pollution prevention technologies."

Air Force Pollution Prevention Strategy. The Air Force's P2 strategy document also outlined the following P2 objectives for the Air Force (17:1-10; 41:B-6).

> Objective 1: Permeate all mission areas with the pollution prevention ethic through comprehensive education, training, and awareness
>
> Objective 2: Institutionalize pollution prevention into all phases of the weapon system life cycle
>
> Objective 3: Incorporate pollution prevention in all aspects of installation operations
>
> Objective 4: Develop and transition innovative pollution prevention technologies to the field

Leadership's View on Pollution Prevention. The following statement was made by President Clinton during the EO 12856 signing ceremony on 3 Aug 93 (41:B-5):

> "... Federal facilities will set the example for the rest of the country and become the leader in applying pollution prevention to daily operations, purchasing decisions and policies...by stopping pollution at its source. Federal government can make a significant contribution to protecting the public health and our environment."

The Honorable Sherri Goodman further iterated the importance of good environmental stewardship by the military in her Earth Day 30th Anniversary address (41:B-5).

> "The U.S. military is the proud steward to 25 million acres of land. On it we train our troops, test our equipment and forge our weapons. Healthy land, air and water are critical to the defense mission. As Secretary Cohen says, "Protecting our interests around the world are inextricably linked with protecting the Earth itself." He understands that in today's world, the throwaway mind-set does not cut it anymore – not in the military, and not anywhere in America. We simply cannot afford the waste, the expense, or the harm to our people and our scarce natural resources."

Benefits of Pollution Prevention. The benefits of pollution prevention, although most commonly thought to be of a monetary nature because of recycling efforts, can be classified into two general classes: tangible benefits, which includes the monetary gains, and intangible benefits, which are the more difficult to describe.

Tangible Benefits. One of the critical functions of a P2 program is to minimize the amount of wastes being generated. Tracked by Air Force metrics, this should lead to reduced waste disposal requirements and therefore reduced waste disposal costs. Due to the high costs for disposal, especially that of hazardous wastes, the money saved in this area can be extensive. From 1990 to 1993, the Air Force Air Logistics Centers (ALCs) disposed of 10,000 tons of hazardous waste annually (25:90-92). During this timeframe, each ALC spent well over $10 million annually to pay for environmental compliance costs (4). With the high cost of hazardous waste disposal, reducing just a small percentage of this waste has a potential to save the Air Force millions of dollars annually. In addition to waste minimization, the large cost associated with the cleanup of contaminated waste disposal sites should be a clear incentive to prevent pollution (25:15).

Waste minimization efforts at an automotive maintenance facility at Fort Riley, Kansas, demonstrate the potential benefits of reducing waste disposal requirements. The Fort Riley battery shop was shipping battery acid with trace elements of lead and cadmium in 15-gallon drums to the Defense Reutilization and Marketing Office (DRMO) for ultimate disposal as hazardous waste. The shop generated 7,200 gal/yr of RCRA hazardous waste with a disposal cost of $27,900 per year. The EPA proposed that the battery acid be collected in a holding tank, treated and made reusable, and then reused in reconditioned or new batteries. This process resulted in 75 percent of the acid being reused. Recycling the battery acid required a capital investment of $15,200 but saved $36,000 per year in raw material and disposal costs (35:30-31).

Intangible Benefits. The most difficult P2 benefits to quantify are the intangible ones. The reduction in energy required to produce materials and products and the reduction in the amount of natural resources, which must be consumed to produce materials and products, are both difficult to measure. Besides these obvious areas of intangible benefits, less visible benefits are important as well.

Pollution prevention also affects job safety. As the use and/or toxicity of hazardous materials increase, so does the potential for and degree of adverse impact if an accident involving hazardous materials occurs. This directly translates into increased costs associated with workplace accidents. It also indirectly translates into reduced risk of criminal and civil liability, reduced operating costs, improved employee moral, enhanced organizational image within the community, and improved public health and the environment (23:1; 26:17). In the case of hazardous waste disposal, P2 efforts minimize the handling, transportation, and disposal of the waste. Therefore, the generator reduces the potential for lawsuits resulting from mishaps as well as the cost of transportation and disposal (25:17). Even more difficult to quantify are the intangible benefits received through the conservation of natural resources.

Past and Existing Measures of Pollution Prevention

Measures of P2 within industry were found to focus on P2 opportunities and specific compliance areas. The focus was primarily on the gains achieved when an individual opportunity was implemented; however, little information was found that addressed an industry's overall environmental liability. The Air Force attempts to address its compliance and pollution prevention efforts across the broad spectrum of its installations located around the world.

The Air Force's P2 goals, established in 1996 and shown in Table 2-1, were essentially achieved in 1999. There is an ongoing committee at the Department of Defense level to develop new environmental goals (part of which include P2 goals) (28). In the meantime, the Air Force has established metrics for measuring it environmental success.

The goals, shown in Table 2-1, focus on compliance and pollution prevention while the current Air Force metrics focus on areas including open enforcement actions (OEAs), cost of compliance penalties and fines (assessed and paid), percentage of installations in compliance with the Clean Water Act (CWA), and the weight of hazardous waste disposal. The Air Force has reduced its OEAs from 245 in 1992 to about 10, a level which has been relatively constant for the past 3 years. For fines and penalties, the Air Force only recently started tracking this metric in 1996 and it has yet to show significant trends. For the past 3 years, 90 percent of the Air Force's installations have been in compliance with CWA requirements. As for the amount of hazardous wastes being disposed, this metric has decreased annually, from 24,600 tons in 1992 to about 10,000 tons since 1997. (11)

Table 2-1. Air Force Pollution Prevention Goals as of 1996 (27)

Program Component	Baseline Year	Goal
EPA 17 Industrial Toxic Pollutants (EPA-17)	1992	15% reduction of purchases by 31 Dec 96
Hazardous Waste Minimization	1992	25% reduction in disposal by 31 Dec 96 50% reduction in disposal by 31 Dec 99
Municipal Solid Waste	1992	10% reduction in disposal by 31 Dec 93 30% reduction in disposal by 31 Dec 96 50% reduction in disposal by 31 Dec 97
Environmentally Preferable Products (Affirmative Procurement)	None	100% of all products purchased each year in each of EPA's "Guideline Item" categories shall contain recycled materials meeting EPA's Guideline Criteria
Energy Conservation	1985	10% reduction in BTU/sq ft by 1995 20% reduction in BTU/sq ft by 2000 30% reduction in BTU/sq ft by 2005
Toxic Release Inventory (TRI) Chemical Releases	1994	50% reduction of total releases and off-site transfers by 1999
Pesticide Management	1993	50% reduction in pounds of active ingredient by 2000

Environmental Funding

Pollution prevention projects are difficult to fund because of current policies and criteria for environmental funding (26:17). Since environmental compliance (EC) and P2 projects compete for the same money and compliance projects get prioritized higher, EC projects generally get funded first. The P2 program includes all work necessary to eliminate or reduce the Air Force's undesirable impacts on human health and the environment, in regards to both its processes, practices and the products it uses (8:9). The EC program includes all work necessary to ensure Air Force activities comply with applicable Federal, state, interstate, tribal, host nation, and local environmental regulations and standards as well as Department of Defense (DoD) and Air Force environmental policies (8:7).

Funding for both P2 and EC are encompassed within environmental quality (EQ). Environmental quality requirements are broken down into one category of recurring requirements and three categories of non-recurring requirements. Current Air Force policy is to only fund Level 0 and Level 1 requirements (20). This policy makes it difficult to fund many P2 requirements, as it is hard to justify P2 as a Level 1 requirement. Additionally, the 5-year payback requirement for P2 projects makes the justification all the more difficult.

Recurring (Level 0) Requirements. Recurring requirements, more commonly known as Level 0 requirements, are the annual "must-do" activities and projects necessary to execute AF EQ programs. They are required to maintain compliance, and sustain effective natural and cultural resource conservation programs. (8; 41:S-5 – S-8)

Non-recurring (Level 1) Requirements. Non-recurring level 1 requirements are the activities and projects necessary to fix non-compliance items. They are intended to either correct an out-of-compliance condition for the year in which funding is provided or prevent going out of compliance in a future year for an item. Level 1 also includes cost-effective P2 projects, with a five-year or less payback, that eliminate or reduce "extremely high" and "high" compliance burdens. (8; 41:S-5 – S-8)

Non-recurring (Level 2) Requirements. Non-recurring level 2 requirements are the activities and projects that prevent non-compliance. They address needs for programs and activities that are currently in compliance but are necessary to prevent non-compliance in a future programmed year. Level 2 also includes cost-effective P2 projects with a five-year or less payback that eliminates or reduces "medium" and "low" compliance burdens. (8; 41:S-5 – S-8)

Non-recurring (Level 3) Requirements. Non-recurring level 3 requirements are the activities and projects that enhance the environment. They are not explicitly required, but are needed to enhance the environment beyond compliance conditions or to address overall environmental goals and objectives. (8; 41:S-5 – S-8)

Air Force Compliance Through Pollution Prevention Guidance

According to the draft AFI 32-7080, Compliance Assurance and Pollution Prevention, the purpose of the Air Force's compliance assurance and P2 program is to (7):

> … sustain and enhance mission readiness by implementing sound cost-effective strategies for complying with new environmental requirements while minimizing or eliminating potential hazards to human health and the environment. Fundamentally, the Air Force's strategy is to use pollution prevention as the preferred solution for assuring environmental compliance.

Compliance Through Pollution Prevention. The Air Force funds all level 1 compliance requirements. However, there are two paths to achieve compliance as seen in Figure 2-1: the standard compliance approach ("end-of-pipe") or the long-term P2 approach ("process-oriented"). An excellent example of using the process-oriented approach was seen with the de-icing example presented earlier. The Air Force could have continued with the status quo, using existing de-icing chemicals and paying expensive compliance costs for the T&D of the vast amounts of de-icing chemicals. Instead of looking at an "end-of-pipe" solution, which would have been how to more efficiently treat the waste de-icing chemical, the Air Force chose instead to look at the entire process, thereby discovering an opportunity and taking action. Reducing the amount of de-icing chemicals required to de-ice an aircraft decreased compliance costs. Furthermore, the new system sped operations as well. (29)

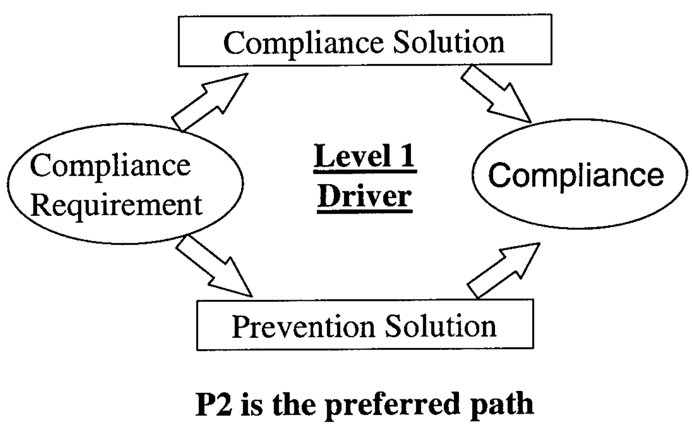

Figure 2-1. Compliance Achievement Paths (18:2)

The CTP2 process uses the environmental management hierarchy to preferentially apply P2 solutions that achieve compliance while reducing TOCs, reducing risks, improving mission performance, and reducing other compliance requirements.

Installations review their P2 and EC programs for CTP2 opportunities to reduce compliance burden by identifying cost-effective P2 solutions that are highest in the hierarchy.

Compliance Through Pollution Prevention Investment Strategy. Over the past few years, the Air Force has made great strides in the compliance arena. Figure 2-2 shows how the Air Force reduced its number of OEAs from over 240 in 1992 to a current level of 10. Since the Air Force has been effective in reducing its number of OEAs, it believes that it can continue this success in the compliance business by eliminating sources of pollution, i.e., compliance sites. The identification and tabulation of compliance sites provides the Air Force with a picture of its current vulnerabilities. Once the number of compliance sites is established, the Air Force plans to quantify its investment within each media. P2 investments are identified as either source reduction or reuse/recycling; if treatment and disposal are inherent to the process, the investment is considered a compliance cost.

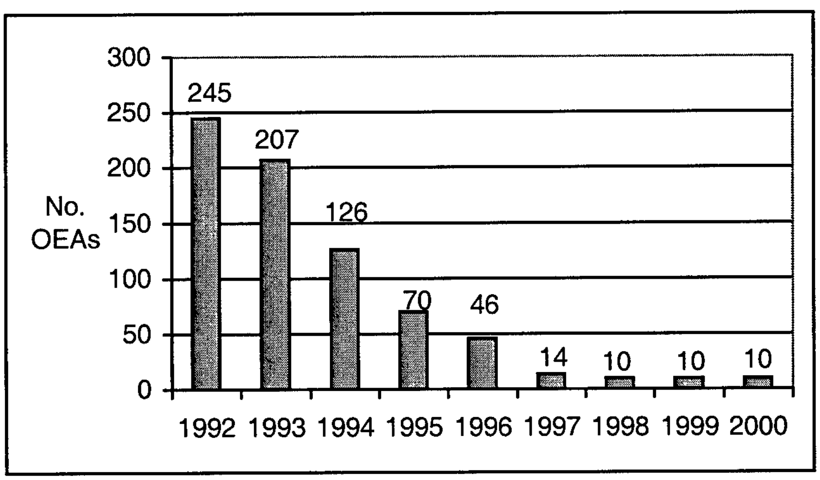

Figure 2-2. Open Enforcement Actions (11)

Compliance Through Pollution Prevention Implementation. The Air Force provided its installations guidance to implement CTP2 using a three-phase process, summarized in Figure 2-3. Phase one, which consisted of compliance site identification, was conducted in 1999. Phase two, which included prioritizing sites by compliance burden, was completed in early 2000. Phase three is currently underway and includes identifying cost effective P2 solutions. Additionally, the Air Force has reinitiated phase one for an iteration of the process, in 2001; the goal is to eventually conduct this implementation process on an annual basis.

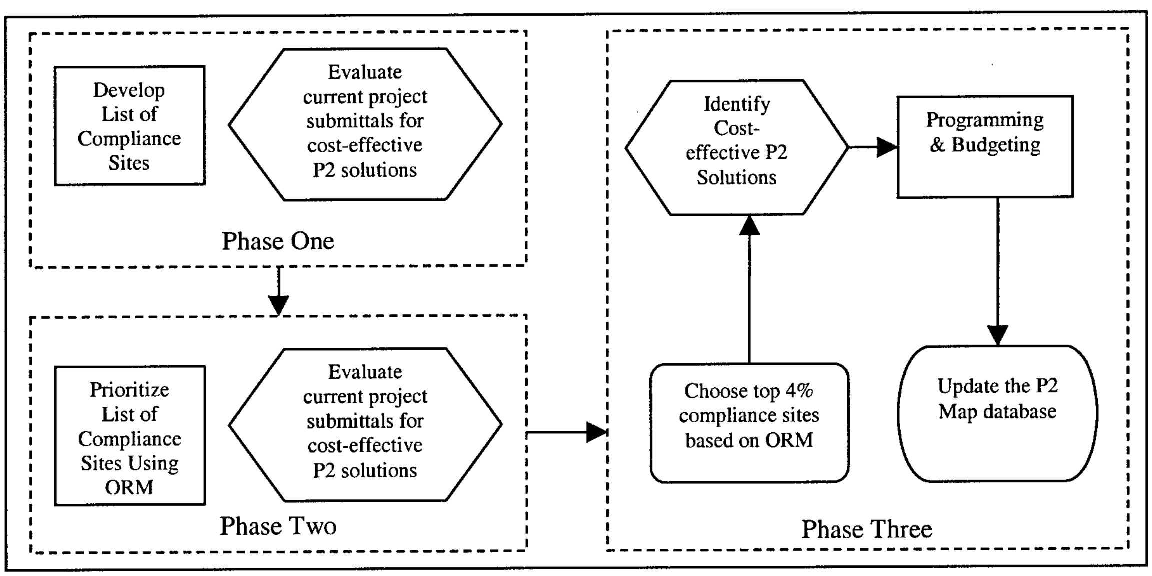

Figure 2-3. Compliance Through Pollution Prevention Implementation Process (18:5)

Phase One: Compliance Site Inventory. Air Force installations used a cross-functional CTP2 team to identify compliance sites and develop a consolidated site inventory. The major command headquarters were heavily involved and provided contract support to the bases. Within the Air Force Materiel Command (AFMC), one contractor was responsible for accomplishing the compliance site inventory (CSI) for all bases. (18:5-7)

Accomplishing the inventory was difficult because a single activity could generate multiple compliance sites. For example, an industrial activity can discharge air pollutants, wastewater, and hazardous waste, with each point of discharge constituting a separate compliance site. Additionally, multiple compliance sites can discharge into another compliance site. For instance, a hazardous waste accumulation point is a compliance site at which multiple hazardous waste generation compliance sites terminate. In other words, hazardous waste is typically accumulated at small short-term collection stations and, when enough is accumulated, transported to a large long-term collection station to be held for final treatment and disposal. Both the short-term and long-term collection stations are classified as compliance sites. (18:5-7)

Phase Two: Compliance Site Prioritization. In phase two, the compliance sites identified in phase one were evaluated and prioritized using the ORM process. Definitions were also provided to link environmental compliance costs with operational and ESOH risks to establish compliance burdens for each site. This was a four-step process that incorporated both cost and risk in establishing the compliance burden and the resulting priority order for addressing each compliance site. (18:8)

Step 1: Environmental Compliance Cost Rankings. Initially, sites were assigned an allocated cost based on environmental compliance costs which included, but were not limited to, permit, disposal, control equipment, training, energy, and other ESOH costs. After allocated costs were used to rank order the sites, the definitions of cost burdens, listed in Table 2-2, below, were used to assign a cost burden category to each site. (18:8)

Table 2-2. Cost Burden Categories (18:8)

Cost	Cost Burden
0% <= Cost <= 20%	Lowest
20% < Cost <= 40%	Low
40% < Cost <= 60%	Medium
60% < Cost <= 80%	High
80% < Cost <=100%	Highest

Step 2: Risk Assessment. The Air Force used the ORM process described in AFI 91-213, Operational Risk Management Program, and Air Force Pamphlet 91-215, Operational Risk Management Guidelines and Tools, to accomplish the risk assessment. This step begins with identifying a realistic worst-case scenario (or undesired event) for each compliance site. The probability and severity of the realistic worst-case scenario is then used to determine the hazard category and risk level for that undesired event. Minimum items considered included potential impacts on mission performance, volume and toxicity of effluent, potential or actual history of notices of violation (NOVs), and Environmental Compliance and Management Program (ECAMP) findings. The Risk Assessment Matrix, shown in Table 2-3, was used to assign each site a hazard category. To assign the severity categories shown in Table 2-3, the definitions

listed in Table 2-4 were used with the realistic worst-case scenario (or undesired event) at a given compliance site. Similarly, the probability categories shown in Table 2-3 were determined by using the hazard probability definitions shown in Table 2-5 with the realistic worst case scenario (or undesired event) at a given compliance site. (18:8-10)

Table 2-3. ORM Risk Assessment Matrix of Hazard Categories (18:9)

	Probability Categories				
Severity Categories	**Frequent**	**Likely**	**Occasional**	**Seldom**	**Unlikely**
Catastrophic	Extremely High	Extremely High	High	High	Medium
Critical	Extremely High	High	High	Medium	Low
Marginal	High	Medium	Medium	Low	Low
Negligible	Medium	Low	Low	Low	Low

Table 2-4. Hazard Severity Categories (18:9-10)

Severity Category	Loss	Definition
Catastrophic	Loss > $1M	Complete mission failure, loss of system, death, permanent total disability, or irreversible environmental damage that violates law or regulation
Critical	$200K < Loss < $1M	Major mission degradation, system damage, permanent partial disability, severe injury or occupational illness that may result in hospitalization of at least 3 personnel, or reversible environmental damage causing a violation of law or regulation
Marginal	$10K < Loss < $200K	Minor mission degradation, system damage, injury or occupational illness resulting in a lost work day, or mitigable environmental damage where restoration can be accomplished without violation of law or regulation
Negligible	$2K < Loss < $10K	Less than minor mission degradation, system damage, injury or occupational illness not resulting in a lost work day, or minimal environmental damage not violating law or regulation

Table 2-5. Hazard Probability Definitions (18:10)

Probability of Occurrence	Qualitative Definition	Quantitative Definition probability (P)
Frequent	Occurs often in the life of the system	$P > 0.1$
Likely	Occurs several times in the life of the system	$0.1 > P > 0.01$
Occasional	Will occur in the life of the system	$0.01 > P > 0.001$
Seldom	Unlikely, but could occur in the life of the system	$0.001 > P > 0.000001$
Unlikely	So unlikely you can assume it will not occur in the life of the system	$P < 0.000001$

Step 3: Compliance Burden Identification. As previously explained, compliance burden is a combination of environmental cost and risk. Cost was assigned on a percentage basis according to the categories shown previously in Table 2-2. Risk was assigned according to the matrix shown in Table 2-3. Using the compliance burden matrix in Table 2-6, the cost categories and risk levels were aggregated into a compliance burden and assigned one of four levels: low, medium, high, and extremely high. (18:10-11)

Table 2-6. ORM Compliance Burden Matrix of Compliance Sites (18:11)

	Environmental Compliance Cost Categories				
Risk Levels	**Highest (Top 20%)**	**High**	**Medium (Middle 20%)**	**Low**	**Lowest (Bottom 20%)**
Extremely High	Extremely High	Extremely High	High	High	Medium
High	Extremely High	High	High	Medium	Low
Medium	High	Medium	Medium	Low	Low
Low	Medium	Low	Low	Low	Low

Step 4: Prioritization. Once each site was assigned a compliance burden, the sites were rank ordered. The hazard categories from Table 2-4 were used to discriminate between sites assigned the same compliance burden. (18:11-12)

Phase Three: Identification of Cost-Effective Pollution Prevention Solutions. Once the compliance sites are rank ordered by compliance burden, installations use the CTP2 process in conjunction with the normal programming process to achieve or maintain compliance where feasible and cost effective. This is done by identifying cost-effective P2 solutions for the top four percent of compliance sites. Cost-effective P2 solutions are developed by focusing on process changes to either eliminate the site or reduce the risk category of each site (18:12). Referred to as process specific opportunity assessments (PSOAs), these activities evaluate a process, with the participation of the process owners, to identify cost-effective changes that will reduce environmental compliance burden and in turn reduce overall process costs (16).

Air Force Materiel Command's CTP2 Program

The Air Force Materiel Command has been at the forefront of the Air Force's CTP2 program, having conducted two previous compliance site inventories prior to 1999 (40). Although, the 1999 iteration was the first that included a prioritization of sites based on cost and risk (40). AFMC's approach to CTP2 follows that of the Air Force, but it does differ in the manner of prioritizing compliance sites. Due to the nature of AFMC operations, the command determined that the Air Force's ORM approach to prioritizing compliance sites was inappropriate due to the large number of depot facilities and uniqueness of operations (3). Therefore, AFMC developed a unique approach to compliance site prioritization (3).

Cost Burden. Costs are allocated to each site, as specified by the Air Force guidance based upon the prior year's EC obligated budget. In the case of the 1999 CSI, costs were allocated based on the 1998 obligated EC budget. The difference in the process is when AFMC prioritizes the sites. AFMC utilized a percent ranking method that assigned burden categories based on the percentiles of the quantities of sites inventoried, as opposed to assigning burden categories based on the cost values allocated to the sites. As with the Air Force guidance, sites were assigned cost burdens of lowest, low, medium, high, and highest. (13; 14)

Risk Burden. Risk burden assignment represented the most dramatic difference between the AFMC and Air Force methodologies. AFMC used a *Compliance Site Risk Assessment Protocol* algorithm to calculate a comparative risk for each compliance site based upon the core components of risk-hazard, exposure, severity, and probability. Once the comparative risks, or risk levels, were found for each site, the sites were ranked using a percent rank method, as was cost, to establish four categories of risk burden: low, medium, high, and extremely high (13;14;15). Comparative risk was calculated with the following equation (15).

$$C_{W\Sigma} \times F_{WF} \times H_{WF} \times M_{WF} \times P_{WF} \times R_{WF} \times E_{WM} \times \left(\frac{(O_{AM} + N_{AM} + L_{AM})}{3} \right) \qquad (2\text{-}1)$$

where

$C_{W\Sigma}$ = Compliance Weighing Factor (Probability risk component),

F_{WF} = Future Regulatory Impact (Probability risk component),

H_{WF} = Hazard Weighing Factor (Hazard risk component),

M_{WF} = Mobility Weighing Factor (Severity risk component),

P_{WF} = Proximity Weighing Factor (Exposure risk component),

R_{WF} = Release Weighing Factor (Severity risk component),

E_{WM} = Worker Exposure Weighing Matrix (Exposure risk component),

O_{AM} = Operational Complexity Additive Matrix (Probability risk component),

N_{AM} = Containers Additive Matrix (Probability risk component), and

L_{AM} = Containment Additive Matrix (Probability risk component).

Furthermore, the compliance weighing factor, $C_{W\Sigma}$, has five individual components that are summed in order to produce the overall factor (15):

$$C_{W\Sigma} = C_p + C_n + C_i + C_k + C_r \qquad (2\text{-}2)$$

where

C_p = Permits/Registration,

C_n = NOV has been issued,

C_i = Reportable Incident,

C_k = Inspections/Record-keeping performed, and

C_r = Reports required.

The five components in the compliance weighing factor each relate to a compliance site's history and status. The criteria for assigning scores to the components are shown in Table 2-7. Tables 2-8 through 2-13 provide the criteria for assigning scores to the core component parameters of risk-hazard, exposure, severity, and probability.

Table 2-7. Compliance Weighing Factor Component Criteria (15)

Factors	Score	Criteria
C_p Permits/Registration	2	Has more than 1 permit from a federal, state or local agency
	1	Has 1 permit or requires agency registration
	0	Otherwise
C_n NOV has been issued	4	Incurred a historical NOV or other enforcement action from any federal, state or local agency
	0	Otherwise
C_i Reportable Incident	3	Incurred an incident which was reported to an environmental agency
	0	Otherwise
C_k Inspections/Record-keeping performed	3	Agency required regular inspections and record-keeping are performed daily or more
	2	Agency required regular inspections and record-keeping are performed between daily and monthly
	1	Everything less frequent than monthly
C_r Reports required	2	Reporting is by any agency
	0	Otherwise

Table 2-8. Future Regulatory Factor (F_{WF}) Criteria (15)

Score	Criteria
5	New regulation relating to the site has been promulgated, but not yet effective
4	New regulation has been proposed, but not yet promulgated
3	New regulation is in the advance notice of rulemaking status, but not yet proposed
1	No future regulatory action known

Table 2-9. Hazard Weighing Factor (H_{WF}) Criteria (15)

Score	Criteria
5	3 or more chemicals on the EPCRA or CERCLA Reportable Quantity (RQ) lists, or the state's toxic chemical list, or RMP Level 3 designation
4	1 or 2 chemicals on the EPCRA or CERCLA RQ lists or the state's toxic chemical list or gasoline or jet fuel
3	3 or more chemicals on the EPCRA 313 TRI list or diesel fuel or risk management plan (RMP) Level 2 designation
2	1 or 2 chemicals on the EPCRA 313 TRI list or designated RMP Level 1
1	No chemicals on the above lists
Note	If the total volume of chemicals of concern is less than 10 gallons, a score of 5 is reduced to 3, 4 is reduced to 2, and 3 and 2 are reduced to 1

Table 2-10. Mobility Weighing Factor (M_{WF}) Criteria (15)

Score	Criteria
5	Liquid pollutant/contaminant impacting surface water or a gaseous pollutant/contaminant impacting the air
4	Liquid pollutant/contaminant impacting the soil
3	Liquid pollutant/contaminant impacting the air or a solid pollutant/contaminant impacting water
2	Solid pollutant/contaminant impacting the air
1	Uncontaminated air and combustion gases from propane and fossil fuel (except coal) combustion
1	All others
Note	If the total volume of chemicals of concern is less than 10 gallons, a score of 5 is reduced to 3, 4 is reduced to 2, and 3 and 2 are reduced to 1

Table 2-11. Proximity Weighing Factor (P_{WF}) Criteria (15)

Score	Criteria
5	Within 1 mile of a pristine area (such as a National Park or Forest), tribal area, AND within ¼ mile of a public receptor located either on or off the base. A public receptor can be a road, building or house where human occupancy is frequent
4	Within 1 mile of a pristine area (such as a National Park or Forest), tribal area, OR within ¼ mile of a public receptor located either on or off the base
3	Within 5 miles of a pristine area, or tribal property and within ½ mile of a public receptor on or off base
2	Within 5 miles of a pristine area, or tribal property OR within ½ mile of a public receptor on or off base
1	None of the above

Table 2-12. Release Weighing Factor (R_{WF}) Criteria (15)

Score	Criteria
5	A compliance site with a continuous process discharge. Examples are: active boilers and waste water treatment plants
4	With a batch process. Examples are: paint booths, abrasive blasting, fuel dispensing, plating shops, labs, etc
3	With a batch discharge due to filling or emptying. Examples are: storage tanks
2	With a batch discharge due to breathing losses. Examples are drums and smaller containers
1	All others

The worker exposure matrix, Table 2-13, is used to quantify the weighing factor for the level of exposure to humans. A small room is one that is either unventilated or has a floor area less than 400 square feet, indoors represents a room greater than 400 square feet or outdoors with obstructions (such as a wall) within 20 feet, and outdoors represents anything outdoors with no obstructions within 20 feet. Worker traffic quantifies the number of people within the site's physical boundary during its most active 1-hour time period during the day. (15)

Table 2-13. Worker Exposure Weighing Matrix (E_{WM}) (15)

		Boundary		
		Small Room	**Indoors**	**Outdoors**
Worker Traffic	> 5	5	4	3
	1 - 5	4	3	2
	0	1	1	1

The operational complexity matrix, Table 2-14, is used to quantify the degree of sophistication and complexity of both the compliance site operation and the individuals who perform the operations. The container additive matrix, Table 2-15, is used to quantify the number and size of containers associated with the compliance site. The containment additive matrix, Table 2-16, is used to quantify the degree of containment associated with the compliance site.

Table 2-14. Operational Complexity Additive Matrix (O_{AM}) (15)

		Automation		
		Manual	**Partial**	**Fully**
Operator Skill Level	Unskilled	5	4	3
	Skilled	4	3	2
	Trained	1	1	1

Table 2-15. Container Additive Matrix (N_{AM}) (15)

		Number of Containers		
		> 25	**11 - 25**	**10 or less**
Size of Containers	= 55 gals	5	4	3
	> 1, < 55	4	3	2
	1 gal or less	3	2	1

Table 2-16. Containment Additive Matrix (L_{AM}) (15)

		Secondary Containment		
		None	**Partial**	**Full**
Environment	Underground	5	4	3
	Outdoors	4	3	2
	Indoors	3	2	1

Compliance Burden. Once the cost and risk burdens were established, the overall compliance burden for AFMC sites was found using Table 2-6, as per the Air Force guidance. (13; 14; 18)

Summary

This chapter has provided information concerning the importance of pollution prevention and briefly discussed applicable EPA and Air Force policies. It then focused on the Air Force's program to implement P2 as a means to drive down long-term compliance costs and risk. The compliance site inventory is the tool to identify compliance sites at Air Force installations. Compliance burden, which is comprised of compliance costs and environmental, safety, and occupational health risks, is the ultimate target of reduction through P2 initiatives.

III. Methodology

Overview

Pollution prevention (P2) has now been advocated as the "right-thing-to-do" for many years and the Air Force has been trying to "do-the-right-thing" for almost ten years. There has been a tendency to see P2 only as a means to cut costs; therefore, the primary benefit is often perceived as monetary in nature. However, as shown in Chapter II, the benefits are much more. Unfortunately, no quantifiable evidence has been produced thus far to show that Air Force P2 efforts have been the "right-thing-to-do" and have shown a monetary benefit. This chapter discusses the methodology used to provide support to the argument concerning the effectiveness of Air Force P2.

As mentioned in Chapter II, the Air Force did an inventory of, and subsequently rank ordered, all compliance sites in 1999. Known as the compliance site inventory (CSI), this effort identified all compliance sites across the Air Force and ranked them based on cost and risk. Together, cost and risk comprise what is known as the compliance burden. Furthermore, it was pointed out in Chapter II that the goal of the Air Force's compliance through pollution prevention (CTP2) program is to reduce the number of compliance sites as well as the overall compliance burden. Since the objective of this research is to provide quantitative data regarding the effectiveness of the CTP2 program, it was originally thought that the database from the 1999 CSI could be analyzed for changes in the compliance burden resulting from P2 funding. Unfortunately, it was not possible to draw any meaningful conclusions from the 1999 CSI. Additionally, the current CSI compliance burden assignment process does not allow the establishment of a baseline to make comparisons of data.

Since it was not possible to draw conclusions regarding the effectiveness of Air Force P2 efforts from the database alone, a different approach will be used. The time value of money (TVM) and net present value (NPV) analyses of past Air Force environmental compliance (EC) and P2 budgets will be used to determine if the cost portion of the compliance burden is actually being reduced. Additionally, correlation calculations will be performed to show the relationship of P2 costs to EC savings.

Data Population

The objective of this research concerns the effectiveness of the Air Force Materiel Command (AFMC) CTP2 program. The analysis will focus on Wright-Patterson Air Force Base and, in a broader sense, AFMC. Wright-Patterson AFB (WPAFB) and AFMC were chosen due to their proximity and the relative ease in obtaining data. Additionally, AFMC is appropriate due to its mission; its logistics and depot functions make it the largest stakeholder in the Air Force EC and P2 programs.

Wright-Patterson AFB. Focusing on Wright-Patterson AFB made it easier to eliminate much of the "noise" within the EC and P2 budget data. For example, if the entire Air Force budget was analyzed, many other factors would have to be considered. Two of the more obvious examples of issues that would have influenced the size of past EC budgets are base closures and downsizing efforts. To identify all of the influencing factors and determine their collective impact on the budget would be a monumental task.

Air Force Materiel Command. To analyze command-wide data, project listings will be obtained from the Environmental Division of the Command Civil Engineer at Headquarters AFMC. Although EC data is available from 1993 through 2000, the 1993 and 1994 data will be discarded because it is not consistent with the 1995 to 2000 data. Prior to 1995, the conservation program was funded as a part of the EC program and the projects listings obtained from AFMC do not designate conservation projects (5).

Since AFMC encompasses many bases and laboratories, there is a much greater chance that other factors are influencing the budgets. Therefore, additional measures will be taken to ensure the validity of the analysis. First, bases scheduled for closure will be removed from the analysis. Once a base is slated for closure, the drastic changes that ensue at a base cause too many variables that could impact EC costs. To study those impacts are outside the scope of this research. Second, much of the data represents EC funds that were spent by AFMC directly on either product centers or laboratories. Although these funds represent EC costs to AFMC, they do not represent costs that are directly associated with compliance at an installation (5). Therefore, these costs will be consolidated to create a composite category of costs labeled AFMC Support. Finally, any anomalies in the data that do not represent a compliance requirement for AFMC will be deleted.

<u>Compliance Site Inventory</u>

The CSI is a tool used to inventory all Air Force compliance sites and assign each site a compliance burden. The <u>AFMC CSI Summary</u> makes the following statement about CSI (14:2):

> The CSIs provide the foundation for AFMC to identify and track progress in reducing EC cost and risk at its installations. This information provides installations with a starting point to prioritize and group sites and to determine which sites to address first. The CSIs will be maintained at the installations and updated annually, which will provide AFMC the ability to monitor and track progress on this effort.

Figures 3-1a, 3-1b, and 3-1c are a split sample of the CSI database. They show the cost and risk data for various sites on WPAFB. As described in Chapter II, the database uses EC allocated costs to assign each site a cost ranking ranging from lowest to highest. This is also referred to as the cost burden. The database then uses risk scores, calculated using the comparative risk algorithm (Equation 2-1), to assign each site a risk level ranging from low to extremely high. This is also referred to as risk burden. Figure 3-1c takes the cost values from Figure 3-1a and the risk scores from Figure 3-1b and displays their respective cost rankings and risk levels. These rankings and levels are then aggregated, using Tables 2-7 and 2-8, to produce the compliance burden level, seen in the right column of Figure 3-1c.

Table 3-1a. Sample Compliance Site Inventory Data (Cost) (3)

			EC Recurring Cost (k$/yr)					Non-EC Recurring Cost (k$/yr)		One-time EC Cost
Location	Type	Description	Assigned by Site	Assigned by Category	Annual-izable	Residual	Total	OH	Other	(k$)
31244	Air	Paint Booth	$ 0.4	$ 0.3	$ -	$ 0.1	$ 0.7	$ -	$ -	$ 0.8
31240	Air	Boiler	$ 37.8	$ 3.2	$ -	$ 0.1	$ 41.0	$ -	$ -	$ 0.8
20652 RM G15	Haz-waste Mgmt.	Initial Accum. Point	$ 0.2	$ 15.0	$ -	$ 0.8	$ 15.2	$ -	$ -	$ 0.1
NPDES 002	Waste Water / Storm Water	NPDES Outfall	$ 3.0	$ 5.3	$ -	$ 0.7	$ 8.3	$ -	$ -	$ 0.1
Public Wtr Areas A/C	Drinking Water	Water Treatment	$ -	$ 11.2	$ -	$ 0.7	$ 11.2	$ -	$ -	$ -
10878, 1000 D	Above Ground Storage Tank		$ -	$ 2.9	$ -	$ 0.8	$ 2.9	$ -	$ -	$ 0.1
34019, 30K gal Diesel	Underground Storage Tank		$ -	$ 2.1	$ -	$ 0.8	$ 2.1	$ -	$ -	$ -

Table 3-1b. Sample Compliance Site Inventory Data (Risk) (3)

			Risk Score / Rank														
Location	Type	Description	Cp	Cn	Ci	Ck	Cr	Fwf	Hwf	Mwf	Pwf	Rwf	Ewm	Oam	Nam	Lam	Score
31244	Air	Paint Booth	1	0	0	3	2	3	5	5	4	4	4	3	0	0	28,800
31240	Air	Boiler	1	0	0	3	2	3	3	5	4	5	4	1	0	0	7,200
20652 RM G15	Haz-waste Mgmt.	Initial Accum. Point	0	0	0	2	1	1	5	3	4	4	4	4	3	2	8,640
NPDES 002	Waste Water / Storm Water	NPDES Outfall	1	0	3	1	2	5	5	3	2	5	1	3	0	0	5,250
Public Wtr Areas A/C	Drinking Water	Water Treatment	1	0	0	3	2	1	5	4	4	4	3	1	0	1	3,840
10878, 1000 D	Above Ground Storage Tank		0	0	0	2	0	1	4	4	4	3	2	2	0	2	1,024
34019, 30K gal Diesel	Underground Storage Tank		1	0	0	3	0	1	4	4	4	3	2	3	0	3	3,072

Table 3-1c. Sample CSI Data (Compliance Burden) (3)

			AFI 32-7080 Reporting				
Location	Type	Description	Cost Percentile	Cost Ranking	Hazard Percentile	Risk Level	Compliance Burden Level
31244	Air	Paint Booth	0%	Lowest	100%	Extremely High	Medium
31240	Air	Boiler	100%	Highest	66%	High	Extremely High
20652 RM G15	Haz-waste Mgmt.	Initial Accum. Point	83%	Highest	83%	Extremely High	Extremely High
NPDES 002	Waste Water / Storm Water	NPDES Outfall	50%	Medium	50%	Medium	Medium
Public Wtr Areas A/C	Drinking Water	Water Treatment	66%	High	33%	Medium	Medium
10878, 1000 D	Above Ground Storage Tank		33%	Low	0%	Low	Low
34019, 30K gal Diesel	Underground Storage Tank		16%	Lowest	16%	Low	Low

Unfortunately, the CSI cannot be used to measure the Air Force's effectiveness in reducing compliance burden. Since the CSI is relatively new, there is virtually no historical data to analyze. The CSI was initiated in 1999 and the database only contains one year of information. Although annual updates are planned, the 2000 update was eliminated to allow for evaluation and modifications to the process. An update for 2001 is only in the initial phases of accomplishment. Additionally, the CSI methodology for assigning compliance burden establishes criteria for cost and risk burdens that are relative only within the respective year in which the CSI is accomplished. When assigning cost and risk burdens, the CSI database ranks the sites first by cost and then by risk. These rankings are used to assign cost and risk burdens to each site based on percentile groupings. Therefore, compliance burden is strongly determined by a site's relative ranking in any given year. Chapter IV will explore this process in more detail by analyzing what happens to the cost and risk burdens during subsequent iterations of the CSI.

First, an example, using 20 hypothetical sites, will be used to show what happens to risk burden when 2 sites are eliminated from the inventory. In this example risk burden is assigned to sites by establishing bins for the risk values based on a percent ranking of the total quantity of sites. Sites are prioritized based on their respective risk values. Then, using the 20 sites, the value for the 5th site becomes the 25th percentile, the value for the 10th site becomes the 50th percentile, and the value for the 15th site becomes the 75th percentile. The resulting four bins are the criteria for sites to be labeled as low, medium, high, and extremely high risk. Because the respective values for risk are relative with each iteration of the CSI, there is no baseline that could indicate whether or not risk is actually changing. It is possible for a site to experience a change in risk burden while having no change in risk value. To illustrate this anomaly, keeping all other variables constant, 2 sites will be removed from the database so as to reestablish the quantity of sites and thereby change the size of the bins.

Second, an example using the 1,525 sites at WPAFB will again show how the same anomalies appear when using the actual compliance sites. To show a change in the risk burden, keeping all other variables constant, select sites will be removed from the database so as to reestablish the percentiles. Again, a change in total number of sites will create a change in bin size that will cause certain sites to change burden category although their risk value never changed.

Cost Savings

Research has shown that, although CTP2 is relatively new to the Air Force, the actual effort of actively engaging P2 initiatives for the purpose of reducing costs and risks began in 1993. To show trends in the EC and P2 budgets, an analysis of the respective budgets from 1995 to 2000 will be accomplished using the TVM and NPV approaches. Additionally, correlation calculations will be used to determine if a relationship exists between P2 costs and EC savings.

Inflation. Any analysis of multi-year monetary values must account for the effects of inflation. The standard consumer price index (CPI) is a good measure of price increases for the typical consumer, but it is not a good measure for industrial price increases (32:562). A better indicator is the producer price index (PPI), shown in Table 3-2 along with inflation rates from 1994 through 2000. From available indices at the U.S. Department of Labor, Bureau of Labor Statistics, the PPI for the military aircraft industry was chosen as the best fit for Air Force EC and P2 requirements. Additionally, the annual PPI for September was used to coincide with the end of the Air Force's fiscal year.

Table 3-2. Inflation Values (38)

Year	PPI	PPI Inflation (percent)
1994	132.8	3.16
1995	137.0	2.99
1996	141.1	0.85
1997	142.3	0.21
1998	142.6	1.05
1999	144.1	4.86
2000	151.1	--

Time Value of Money. By utilizing a TVM approach, each year's EC costs can be converted to a present day value considering inflationary effects on purchasing power. The annual inflation rates shown in Table 3-2 will be used to convert past year's costs into present day costs. The following equation details the approach:

$$FV = PV(1+i)^t \tag{3-1}$$

where *FV* is *Future Value* (dollars), *PV* is *Present Value* (dollars), *i* is the *inflation rate,* and *t* is the *time period* (yrs). Therefore, given a value for a past EC cost, it can be determined what value, in current day dollars, would have the same purchasing power. For example, if inflation were 5 percent, $100 in 2000 would have an equivalent value of $105 in 2001. That is it takes $105 dollars in 2001 to purchase what $100 dollars would purchase in 2000.

In the case of this analysis, the calculations will be more difficult since the inflation rate is different for each year. Therefore, a hybrid of Equation 3-1, will be used:

$$FV = PV(1+i_1)(1+i_2)...(1+i_n) \tag{3-2}$$

where $i_j, j = 1,2,...,n$ is the inflation rate in year *j* and *n* is number of years.

Equation 3-2 is used to find the 2001 value of a $100 EC cost from 1998 considering that the inflation rates from 1998 to 2000 are 2.0, 3.0, and 2.5 percent, respectively. Using this equation, it can be shown that it takes $107.69 in 2001 to purchase what $100 would buy in 1998.

Net Present Value. Although the TVM analysis should give good insight into EC costs, a NPV analysis can provide additional insight by analyzing both EC and P2 budgets. NPV will be used to determine if the Air Force is realizing an overall cost savings in the combined EC and P2 budgets. Using 2000 as a baseline for EC and P2 funding, a NPV analysis of EC cost savings and P2 expenditures to date will be accomplished. The year 2000 is chosen because 2001 EC and P2 costs were not incurred at the time of this research.

To illustrate this methodology, the NPV of hypothetical EC costs saved from 1998 through 2000, using hypothetical inflation rates of 2.0, 3.0, and 2.5 percent, respectively, will be determined (see Table 3-3). The NPV is determined by summing the respective FV amounts. As shown in Table 3-3, the EC cost savings from 1998 through 2000 are $335.75 in year 2000 adjusted dollars. To establish EC cost savings, 1995 will be established as a baseline since it is the first year in which EC costs can be tracked with confidence.

A similar analysis will be conducted for P2 expenditures; refer to the hypothetical P2 costs shown in table 3-3. A novice comparison of the data might lead one to think that there has been an overall cost savings because total EC cost savings equal $320 and the P2 expenditures are only $319. However, when a NPV approach is used, there is a different result. As shown in Table 3-3, the P2 expenditures from 1998 through 2000 are $336.70 in year 2000 adjusted dollars. When the two NPVs are compared, it is now seen that NPV_{P2} is in reality greater than the NPV_{EC}. Although the difference in NPVs may not appear significant, it is believed that a more distinct difference will emerge once the NPV calculation is performed over many years.

Table 3-3. Net Present Value Example

Year	Inflation (percent)	EC Cost (dollars)	FV_{EC} (dollars)	P2 Cost (dollars)	FV_{P2} (dollars)
1998	2.0	90	96.92	134	144.30
1999	3.0	100	105.58	90	95.02
2000	2.5	130	133.25	95	97.38
			335.75		336.70

Correlation. Until now, the methodology has focused on (1) showing that EC costs are declining and (2) that P2 investments have been less than the suggested resultant savings in EC costs. To establish a direct linkage between P2 investments and EC costs, correlation calculations will be performed with the following equation:

$$r_{x,y} = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i - \mu_x)(y_i - \mu_y)}{s_x \cdot s_y} \qquad (3\text{-}3)$$

where

$$-1 \le r_{x,y} \le 1$$

and

r = sample correlation,

X = EC Cost Savings,

Y = P2 Expenditures,

n = number of samples,

μ = mean, and

s = sample standard deviation.

To accurately compare P2 costs to EC savings, EC savings will be attributed to prior year costs. Since it is not expected that P2 efforts would be immediately effective; correlations will be calculated for no lag, one-year lag, two-year lag, and three-year lag scenarios. Although the Air Force funding guidance requires that P2 projects show at least a 5-year payback, since the analysis will only use 6 years of data, it will not be possible to calculate correlations using 4-year and 5-year lag periods. Additionally, correlations will be calculated to find the relationships between the overall EC and P2 budgets, regardless of whether savings are realized.

Summary.

In summary, this methodology showed why the CSI database cannot be used to measure compliance burden reduction and explained the data collection necessary to analyze the EC and P2 budgets for AFMC and WPAFB. Demonstrating that P2 efforts have been effective in reducing compliance costs is a three-step process: (1) using TVM to show that EC costs are declining, (2) using NPV analysis to show that EC savings have been greater than P2 expenditures, and (3) using correlation calculations to identify any relationship between P2 expenditures and EC cost savings.

IV. Data Analysis

Overview of Compliance Site Inventory Data

The 1999 compliance site inventory (CSI) provided a complete inventory of compliance sites throughout the Air Force Materiel Command (AFMC). In all, AFMC had 17,884 sites at the 12 bases shown in Figure 4-1. Kelly Air Force Base (AFB) and McClellan AFB were not included in the inventory since they are being closed under the Base Realignment and Closure (BRAC) process. Since the respective missions at each base influence the number of compliance sites, it is not surprising that bases such as Edwards, Hill, Robins, and Tinker have the most sites (61 percent of the total). As the Air Force's Air Logistics Centers (ALCs), with the exception of Edwards AFB, these bases are considered major environmental compliance (EC) stakeholders due to their logistics and depot maintenance roles.

Figure 4-2 displays the 1999 total environmental compliance cost for each AFMC installation, with the command's total being $40.5 million. As with the previous figure, it is not surprising that the Edwards AFB and the three ALC bases experience most of the command's EC costs (52 percent of the total). Note that, with the exception of Kirtland AFB, the bases with more compliance sites also have the higher EC budgets.

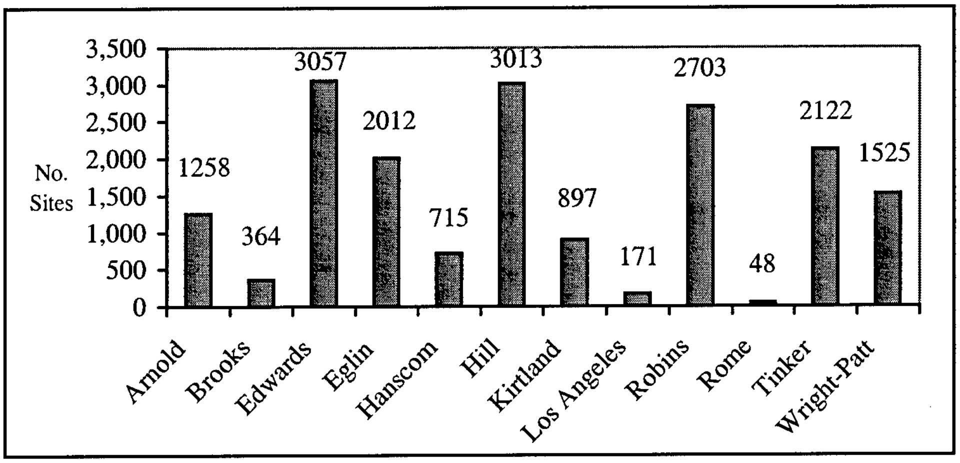

Figure 4-1. Compliance Sites Across Air Force Materiel Command (14)

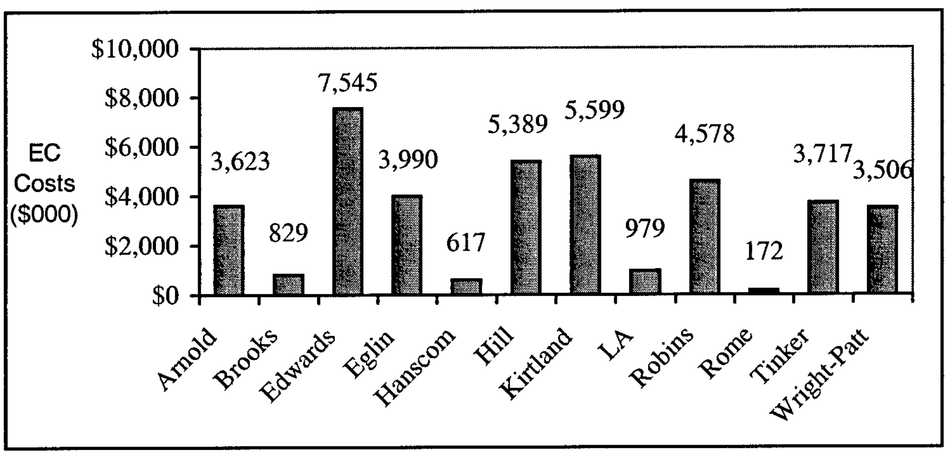

Figure 4-2. Total 1999 Environmental Compliance Cost for Air Force Materiel Command Installations (4)

Calculating the sample correlation best identifies the relationship between the number of sites and the EC costs. Using Equation 3-3, the correlation coefficient is found to be 0.83. A reasonable rule of thumb when interpreting correlation coefficients is that correlation is weak if $0 \le |r| \le 0.5$, strong if $.8 \le |r| \le 1$, and moderate otherwise (10). The primary conclusion to draw from this is that the Air Force's compliance costs are closely tied to the number of compliance sites, which are unique to each installation. This illustrates the importance of the compliance site inventory (CSI) and foreshadows its abilities as a pollution prevention (P2) opportunity identification tool and possibly a tool to measure and track the Air Force's EC and P2 efforts.

Compliance Site Inventory Data

As stated in the methodology chapter, it was originally thought that the CSI data could be used in conjunction with EC and P2 costs to determine the effectiveness of Air Force P2 efforts in reducing overall compliance burden. However, the combination of the infancy of CSI and its methodology for assigning cost and risk burdens prevent it from being used to measure P2 effectiveness. As explained in Chapter III, the CSI has only been accomplished once and the second iteration is due in 2001. Further, it was hypothesized in Chapter III that AFMC's method of assigning cost and risk burdens, in which the burdens are relative within a particular year, would yield incomparable data in subsequent iterations of the CSI. In other words, establishing cost and risk burden categories each year, without any type of baseline, makes CSI unsuitable for measuring future improvements in the compliance arena. To demonstrate the problems caused by this methodology, several examples will be discussed. Since the method for assigning risk burdens is the same as that for assigning cost burdens, the examples presented only show risk calculations.

In Chapter III, it was hypothesized that AFMC's method of categorizing risk, based on percentile rankings, restricts the use of the CSI in measuring risk burden changes during subsequent CSI iterations. As the number of compliance sites is reduced though, there is the potential that a site could show an increase or decrease in risk burden without actually showing a change in risk value. To see the impact, a simplified example using 20 hypothetical sites will be initially evaluated. An example using the 1,525 compliance sites at Wright-Patterson AFB (WPAFB) will then be used.

Table 4-1 shows the results of a hypothetical example in which risk burdens were assigned to 20 sites, and then re-assigned after two of the sites were removed. The risk value assigned to each site was randomly generated using a uniform distribution from 0 to 43,200. The high value of 43,200 was chosen because it is the highest risk value in the actual WPAFB CSI database. After the risk burden was reassigned, the risk burdens remained the same except for site 14. Even though there was no change in risk value, the assigned risk burden increased from medium to high. Logic would indicate that if the risk at a site does not change from year to year, then the risk burden should not change either. This relatively simple example demonstrates why this method of assigning risk burdens makes the CSI unsuitable for making comparisons. However, this example does not accurately portray the distribution of risk values as it uses 20 distinct values, whereas the actual 1525 sites at WPAFB have only 49 distinct values.

Table 4-1. Hypothetical Cost Burden Calculations (Eliminating 2 Sites)

Site	Risk Value	20 Sites		18 Sites	
		Risk (%)	Risk Burden	Risk (%)	Risk Burden
Site 1	802	0	Low	0	Low
Site 2	28,487	52	High		
Site 3	36,971	84	Extremely High	82	Extremely High
Site 4	12,630	26	Medium	29	Medium
Site 5	11,169	21	Low	23	Low
Site 6	42,035	94	Extremely High	94	Extremely High
Site 7	7,255	15	Low	17	Low
Site 8	23,175	42	Medium	47	Medium
Site 9	7,183	10	Low	11	Low
Site 10	33,917	73	High		
Site 11	32,860	63	High	64	High
Site 12	33,138	68	High	70	High
Site 13	6,960	5	Low	5	Low
Site 14	25,995	47	Medium	52	High
Site 15	13,967	31	Medium	35	Medium
Site 16	34,273	78	Extremely High	76	Extremely High
Site 17	29,526	57	High	58	High
Site 18	43,145	100	Extremely High	100	Extremely High
Site 19	40,504	89	Extremely High	88	Extremely High
Site 20	19,147	36	Medium	41	Medium
Histogram Data Counts					
Low		5		5	
Medium		5		4	
High		5		4	
Extremely High		5		5	
Total		20		18	

This same type of analysis can also be applied to the 1,525 sites at WPAFB. As before, the results of removing two sites selected at random will be analyzed. Figure 4-3 displays the distribution of the compliance sites before and after the elimination of the two sites. For both sets of data, the largest proportion of compliance sites is categorized with a medium burden and the smallest proportion is labeled as high. When the two sites were removed, no significant change takes place. Additionally, upon a closer examination of the actual sites, it was found that all 1,523 sites retained their initial risk burdens. This does not support the prior claim that the elimination of sites causes a change in the burden category even though the risk level remained constant.

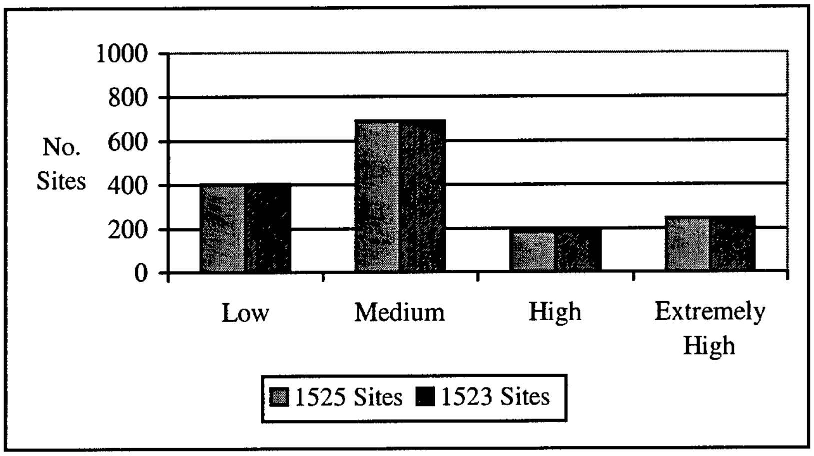

Figure 4-3. Air Force Materiel Command Compliance Sites by Risk Burden (2 Sites Removed)

The reason for no apparent change is partially attributed to the fact that there were only 49 different risk values assigned to the 1525 sites. This makes it less likely to see sites cross the 25th, 50th, and 75th percentiles as sites are removed from the inventory. However, once enough sites were removed, there was a large shift across the percentiles. For example, when 86 of the extremely high sites were removed, a large shift was observed, and when 20 each of the low and high sites were removed, a large shift was observed. Removing different combinations of sites causes movement across the boundaries when different quantities of sites are removed. To illustrate, the results of removing the 86 sites are shown in Figure 4-4, which supports the argument that the removal of sites causes a change in burden assignment. An examination of the data revealed that all 185 sites previously classified as high shifted to extremely high, even though their risk values remained the same. Again, this supports the argument that the CSI should not be used to measure reductions in compliance burden. One way to improve on the CSI database would be to establish a baseline that uses the percentiles based on the first year's data.

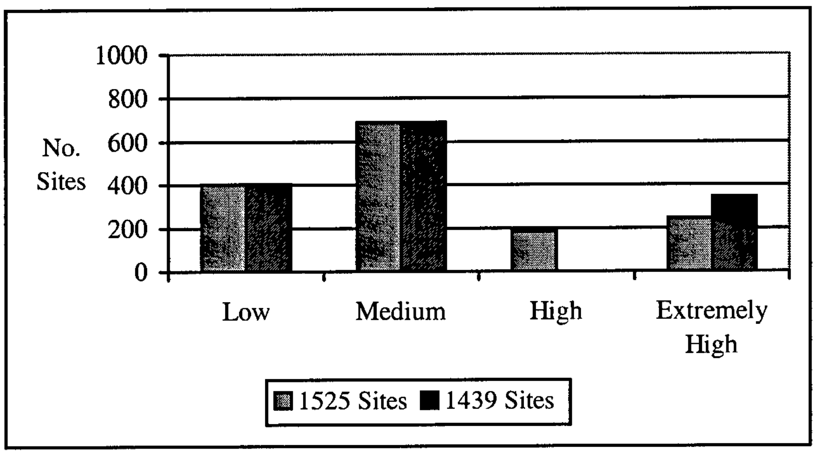

Figure 4-4. Air Force Materiel Command Compliance Sites by Risk Burden (86 Sites Removed)

Data Collection

Project listings were obtained from the Environmental Division of the Command Civil Engineer at Headquarters AFMC. The EC and P2 data collected from these listings are found in Appendices B and C. As explained earlier, only data from 1995 to 2000 was considered usable. In addition to the twelve installations mentioned earlier, there are additional organizations being allocated funding by AFMC: AFMC/CEV, numerous product centers, Kelly and McClellan AFBs (scheduled to close in 2001), and Newark AFB (closed in 1996). The blank areas in the appendices indicate that data was not available, primarily because of no funding, a name change, or a change in accounting methods (5).

To organize the data, several steps were taken. First, the Aerospace Maintenance and Regeneration Center (AMARC) is considered an anomaly in the data as AFMC seldom provides it funds (5). Since the center does not belong to AFMC, it was deleted from the data to be analyzed. There are a number of organizations within AFMC receiving P2 and EC funds for costs that are directly associated with either compliance or P2 at the base level (5). These organizations include the Armstrong Lab; the Institute for Environment, Safety, and Occupational Health Risk Analysis (IERA); and the United States Air Force (USAF) School of Aerospace Medicine (SAM); the Space and Missile Systems Center (SMC); and the Wright Lab and Aeronautical Systems Center (ASC) are at WPAFB. The costs associated with these organizations were combined with the AFMC/CEV costs to create a composite category of costs labeled AFMC Support. Since Newark, Kelly, and McClellan AFBs are all closure bases, they were not included in the analysis. Tables 4-2 and 4-3 show the resulting data sets that were analyzed using the time value of money (TVM), net present value (NPV), and correlation calculations.

Table 4-2. Air Force Materiel Command Environmental Compliance Costs (4)

Year	AFMC Support ($000)	Arnold ($000)	Brooks ($000)	Edwards ($000)	Eglin ($000)	Hanscom ($000)	Hill ($000)
1995	3,299.0	5,709.1	1,159.7	15,919.5	6,800.6	1,322.6	5,112.0
1996	973.4	4,133.0	805.8	13,518.8	7,863.2	932.1	6,378.1
1997	4,503.9	5,330.0	623.0	10,918.1	7,197.0	851.8	4,775.0
1998	3,072.6	4,493.0	484.5	7,380.7	3,957.1	637.2	5,321.0
1999	2,564.0	3,623.0	829.0	7,545.0	3,990.0	617.2	5,389.0
2000	3,216.3	3,721.6	361.0	8,491.9	5,125.0	598.0	10,650.7

Year	Kirtland ($000)	LA ($000)	Robins ($000)	Rome Lab ($000)	Tinker ($000)	Wright-Patt ($000)	Total ($000)
1995	6,730.5	1,643.0	9,105.2	3.0	8,194.1	8,030.4	73,028.7
1996	4,044.9	3,054.0	4,167.0	637.0	5,261.4	11,379.8	63,148.5
1997	5,568.6	940.0	4,469.0	523.7	3,787.5	5,281.0	54,768.6
1998	4,187.0	1,352.0	4,274.0	349.8	5,577.0	3,944.8	45,030.7
1999	5,599.0	979.0	4,578.4	172.0	3,717.1	3,505.5	43,108.2
2000	5,110.0	750.9	5,350.8	244.0	7,506.8	2,957.0	54,084.0

Table 4-3. Air Force Materiel Command Pollution Prevention Costs (6)

Year	AFMC Support ($000)	Arnold ($000)	Brooks ($000)	Edwards ($000)	Eglin ($000)	Hanscom ($000)	Hill ($000)
1995	30,332.0	907.0	8,538.0	1,605.0	4,585.0	3,396.0	9,154.0
1996	14,806.6	1,297.0	7,425.9	2,460.0	1,604.4	1,517.7	2,532.0
1997	20,860.0	2,091.0	6,132.1	1,823.0	808.0	1,844.0	2,682.0
1998	11,308.7	1,201.0	575.4	1,556.3	833.0	2,018.5	1,585.0
1999	8,294.0	909.0	892.0	2,263.0	976.0	906.0	2,636.0
2000	10,941.3	1,266.6	3,311.0	2,050.7	1,300.4	1,092.0	2,716.0

Year	Kirtland ($000)	LA ($000)	Robins ($000)	Rome Lab ($000)	Tinker ($000)	Wrigt-Patt ($000)	Total ($000)
1995	238.0	1,753.0	11,093.0		9,890.0	3,342.0	84,833.0
1996	1,597.0	1,514.5	7,373.6		3,712.4	1,118.0	46,959.1
1997	548.4	1,509.7	6,788.9	47.5	1,969.9	995.1	48,099.7
1998	409.4	699.3	2,077.3	6.0	446.0	263.7	22,979.6
1999	492.0	1,209.0	1,058.0	99.0	1,520.0	1,815.3	23,069.3
2000	676.0	418.1	3,681.5	43.8	1,993.5	2,120.0	31,610.9

Cost Savings at Wright-Patterson AFB

As previously noted, the Air Force's goal in promoting P2 is to reduce compliance costs. This section will use the TVM and NPV methods described in Chapter III to analyze past EC and P2 budgets. Table 4-4 shows the EC and P2 costs that were collected for WPAFB. As previously explained, only the data from 1995 to 2000 were used in the analysis.

Table 4-4. Wright-Patterson AFB Environmental Compliance and Pollution Prevention Budgets (4; 6)

Year	EC Costs ($000,000)	P2 Costs ($000,000)
1995	8.03	3.34
1996	11.38	1.12
1997	5.28	1.00
1998	3.94	0.26
1999	3.51	1.82
2000	3.00	2.12

Time Value of Money. Table 4-5 shows the EC cost and the cost adjusted for inflation for WPAFB from 1995 to 2000. The cost adjustment was accomplished using the inflation rates found in Table 3-2. As shown in Table 4-5, the compliance budget for WPAFB has decreased annually except in 1996; this decrease is evident in both cost columns. The magnitude of the decrease is of considerable importance as it has gone from $12.19 million in 1996 to a relatively low $3.0 million in 2000, using year 2000 dollars. This is a reduction of 75 percent over four years.

Table 4-5. 1995-2000 Wright-Patterson AFB Environmental Compliance Budget

Year	EC Cost ($000,000)	Adjusted EC Cost * ($000,000)
1995	8.03	8.86
1996	11.38	12.19
1997	5.28	5.61
1998	3.94	4.17
1999	3.51	3.68
2000	3.00	3.00

* Adjusted to Year 2000 Dollars

Net Present Value. An accurate method of gauging the effectiveness of the compliance through pollution prevention (CTP2) program is to compare total EC cost savings to P2 expenditures using an NPV approach, with 1995 as the baseline. Table 4-6 shows the EC cost savings and P2 expenditures at WPAFB from 1995 to 2000, including costs adjusted for inflation. Note that the cost savings are relatively stable during the last three years, in the $5 million range. The total NPV for the cost savings over the 6-year period is $15.63 million. The P2 costs did not show any trends. Considering TVM, P2 started with a high cost of $3.68 million in 1995, fell to a low of $280 thousand in 1998, and then rose to $2.12 million in 2000. The overall result is an NPV of $10.25 million. Therefore, over the 6-year study period, the present worth of EC cost savings is $15.63 million compared to a present worth of $10.25 million for P2 expenditures. In effect, the P2 investments resulted in an overall savings of $5.38 million over six years. These results seem to indicate that P2 expenditures are having a positive effect on reducing EC costs.

Table 4-6. 1995–2000 Wright-Patterson AFB Environmental Compliance Cost Savings and Pollution Prevention Expenditures

Year	EC Cost ($000,000)	Adjusted EC Cost ($000,000)	Adjusted Savings * ($000,000)	P2 Cost ($000,000)	Adjusted P2 Cost ($000,000)
1995	8.03	8.86	0.00	3.34	3.68
1996	11.38	12.19	-3.33	1.12	1.20
1997	5.28	5.61	3.25	1.00	1.06
1998	3.94	4.17	4.68	0.26	0.28
1999	3.51	3.68	5.18	1.82	1.91
2000	3.00	3.00	5.86	2.12	2.12
NPV			15.63		10.25

* Savings determined by subtracting the adjusted EC cost from the 1995 baseline cost

Correlating Environmental Compliance and Pollution Prevention. Although it was shown that WPAFB EC costs are declining and the P2 investments have resulted in a net savings, it has yet to be shown that there is a relationship between P2 investments and EC savings. To support this argument, the EC savings were calculated by basing each year's savings on the previous year's EC Cost. Table 4-7 shows the annual EC savings and P2 expenditures. Table 4-8 shows the correlation coefficients for various lag periods.

Table 4-7. Yearly Environmental Compliance Savings versus Pollution Prevention Costs

Year	EC Cost ($000,000)	Adjusted EC Cost ($000,000)	Adjusted Savings ($000,000)	P2 Cost ($000,000)	Adjusted P2 Cost ($000,000)
1995	8.03	8.86	--	3.34	3.68
1996	11.38	12.19	-3.33	1.12	1.20
1997	5.28	5.61	6.58	1.00	1.06
1998	3.94	4.17	1.43	0.26	0.28
1999	3.51	3.68	0.49	1.82	1.91
2000	3.00	3.00	0.68	2.12	2.10

Table 4-8. Wright-Patterson AFB Correlation Results

Relationship	Correlation
No Lag	- 0.18
1 Yr Lag	- 0.60
2 Yr Lag	0.97
3 Yr Lag	0.97
EC to P2	0.18

When a 2-year or 3-year lag was assumed between the P2 investment and resultant EC savings, there was a strong correlation of 0.97. This lends evidence to support the notion that P2 investments may cause a future reduction in EC costs. A 2-year lag appears reasonable because one would not expect the benefits from P2 initiatives to be realized any sooner. Once a P2 project is funded, it can take up to a year or more to implement the opportunity and then another year to actually observe savings in the EC budget. An obvious argument is that the two are correlated only as a result of declining Air Force budgets, with each simply taking their fair share in the cuts. However, the insignificant correlation of 0.18 between the EC and P2 budgets counters this argument. Correlations for a 1-year and no-lag scenarios were also insignificant, which makes sense as one would not expect P2 initiatives to be immediately effective.

Cost Savings at Air Force Materiel Command

The same process used to analyze the WPAFB data was also applied to the AFMC data. Table 4-9 shows the EC and P2 costs for AFMC. As mentioned earlier, only the data from 1995 to 2000 were used in the analysis.

Table 4-9. Air Force Materiel Command Environmental Compliance and Pollution Prevention Budgets (4; 6)

Year	EC Costs ($000,000)	P2 Costs ($000,000)
1995	73.03	84.83
1996	63.15	47.00
1997	54.77	48.10
1998	45.03	23.00
1999	43.12	23.07
2000	54.08	31.61

Time Value of Money. Table 4-10 shows the EC cost and the cost adjusted for inflation for AFMC from 1995 to 2000. The cost adjustment was accomplished using the inflation rates found in Table 3-2. As shown in Table 4-10, the compliance cost for AFMC has decreased annually except in 2000; this decrease is evident in both columns. The magnitude of the decrease is of considerable importance as it has gone from $80.55 million in 1995 to $54.08 million in 2000, using year 2000 dollars. This is a reduction of 33 percent over 5 years.

Table 4-10. 1995-2000 Air Force Materiel Command Environmental Compliance Budget

Year	EC Cost ($000,000)	Adjusted EC Cost * ($000,000)
1995	73.03	80.55
1996	63.15	67.63
1997	54.77	58.16
1998	45.03	47.71
1999	43.12	45.21
2000	54.08	54.08

* Adjusted to Year 2000 Dollars

Net Present Value. Similar to the WPAFB data, a good method of gauging the effectiveness of the CTP2 program for AFMC is to compare annual total EC cost savings to P2 expenditures, using an NPV approach with 1995 as a baseline. Table 4-11 shows the EC cost savings and P2 expenditures in AFMC from 1995 to 2000, including costs adjusted for inflation. The total NPV for the cost savings, over the 6-year period, is $129.94 million. Considering TVM, P2 started with a high cost of $93.56 million in 1995 and fell to $31.61 million in 2000. The overall result for P2 expenditures is an NPV of $275.14 million. Therefore, over the 6-year study period, the present worth of EC cost savings is $129.94 million compared to a present worth of $275.14 million for P2 expenditures. This analysis suggests that, unlike WPAFB, the P2 investments throughout AFMC resulted in a net loss of $145.20 million. These results seem to indicate that P2 expenditures are causing EC costs to rise for AFMC.

Table 4-11. 1995–2000 Air Force Materiel Command Environmental Compliance Cost Savings and Pollution Prevention Expenditures

Year	EC Cost ($000,000)	Adjusted EC Cost ($000,000)	Adjusted Savings * ($000,000)	P2 Cost ($000,000)	Adjusted P2 Cost ($000,000)
1995	73.03	80.55	0.00	84.83	93.56
1996	63.15	67.63	12.92	47.00	50.33
1997	54.77	58.16	22.39	48.10	51.07
1998	45.03	47.71	32.83	23.00	24.37
1999	43.12	45.21	35.33	23.07	24.19
2000	54.08	54.08	26.47	31.61	31.61
NPV			129.94		275.14

* Savings determined by subtracting the adjusted EC cost from the 1995 baseline cost

Correlating Environmental Compliance and Pollution Prevention. To test the argument that EC savings are related to P2 investments, the EC savings for AFMC were calculated by basing each year's savings on the previous year's EC cost. Table 4-12 shows the annual EC savings and P2 expenditures. Table 4-13 shows the correlation coefficients for various lag periods. For a 1-year lag, 2-year lag, and 3-year lag, the correlations were 0.78, 0.76, and 0.80, respectively. These values indicate a strong relationship between EC savings and P2 expenditures. However, contrary to the results found for WPAFB, the correlation between EC and P2 budgets was found to be 0.96 for the AFMC data. Therefore, it should be considered inconclusive that P2 investments are causing a reduction in EC costs at the major command level.

Table 4-12. Yearly Environmental Compliance Savings versus Pollution Prevention Costs

Year	EC Cost ($000,000)	Adjusted EC Cost ($000,000)	Adjusted Savings ($000,000)	P2 Cost ($000,000)	Adjusted P2 Cost ($000,000)
1995	73.03	80.55	--	84.83	93.56
1996	63.15	67.63	12.92	47.00	50.33
1997	54.77	58.16	9.47	48.10	51.07
1998	45.03	47.71	10.44	23.00	24.37
1999	43.12	45.21	2.50	23.07	24.19
2000	54.08	54.08	-8.87	31.61	31.61

Table 4-13. Air Force Materiel Command Correlation Results

Relationship	Correlation
No Lag	0.44
1 Yr Lag	0.78
2 Yr Lag	0.76
3 Yr Lag	0.80
EC to P2	0.96

Summarizing Air Force Materiel Command

When the analysis described above was applied to each individual AFMC base, there is strong evidence that some bases are effectively using P2 to reduce EC costs, while others are not; Table 4-14 shows the results for the individual bases. As previously explained, Table 4-14 does not include closure bases. Furthermore, the product centers were combined into a category called AFMC support.

Although this was the best possible known method for refining the data, it still did not account for several factors. If accounting methods changed at a base, potential existed for a product center or lab project to be assigned to a base one year and to the lab the next. Therefore, the analysis at bases that contain labs and product centers was not considered reliable. Additionally, for bases containing laboratories and product centers, attributing all costs to the base is not prudent since lab and product center work tended to be heavily weighted towards P2. This was shown in Tables 4-2 and 4-3 in which P2 costs were relatively higher than EC costs for AFMC Support. Furthermore, simply eliminating closure bases from the data does not accurately account for all base closure issues. When bases close, many activities are transferred to other bases. For example, the C-5 depot maintenance was transferred from Kelly AFB to Robins AFB. Therefore, it should be expected that Robins would see an increase in both EC and P2 costs, which it did in 2000. This analysis did not account for occurrences represented by this example.

Table 4-14. Air Force Materiel Command Correlation and Net Present Value Results

	No Lag Corr	1 Yr Lag Corr	2 Yr Lag Corr	3Yr Lag Corr	EC to P2 Corr	EC Svg ($000)	P2 Costs ($000)	Delta ($000)
AFMC Support	-0.55	0.59	-0.77	0.60	0.37	3.21	101.83	-98.62
Arnold	-0.74	-0.03	0.75	-0.93	0.30	9.12	8.10	1.02
Brooks	0.57	0.38	-0.48	-0.41	0.63	3.13	28.74	-25.61
Edwards	-0.26	0.01	0.69	-0.57	0.05	37.50	12.41	25.09
Eglin	-0.70	-0.45	0.18	1.00	0.43	7.94	10.84	-2.90
Hanscom	0.44	0.86	-0.25	1.00	0.88	3.47	11.51	-8.04
Hill	-0.01	-0.08	0.73	0.39	-0.19	-5.65	22.81	-28.46
Kirtland	0.71	-0.63	0.72	-1.00	-0.62	11.45	4.18	7.27
LA	0.13	-0.28	0.47	-0.98	0.50	1.58	7.59	-6.01
Robins	0.62	0.80	0.42	0.97	0.73	26.32	34.33	-8.01
Rome Lab	0.56	0.18	0.34	-1.00	-0.19	-2.02	0.20	-2.22
Tinker	0.60	0.59	0.55	-0.02	0.71	18.22	21.04	-2.82
Wright-Patt	-0.18	-0.60	0.97	0.97	0.18	15.63	10.25	5.38

In summary, Brooks, Hanscom, LA, and Rome Lab are installations that could have significant reliability problems due to inconsistent tracking of projects involving labs or product centers. The ALCs could also experience significant problems due to transferred mission activities from closure bases. The remaining bases are Arnold, Edwards, Eglin, Kirtland, and Wright-Patterson AFB. The results for these bases were more consistent, as shown in Table 4-15, except for Eglin AFB.

Table 4-15. Air Force Materiel Command Correlation and Net Present Value Results

	No Lag Corr	1 Yr Lag Corr	2 Yr Lag Corr	3Yr Lag Corr	EC to P2 Corr	EC Svg ($000)	P2 Costs ($000)	Delta ($000)
Arnold	-0.74	-0.03	0.75	-0.93	0.30	9.12	8.10	1.02
Edwards	-0.26	0.01	0.69	-0.57	0.05	37.50	12.41	25.09
Eglin	-0.70	-0.45	0.18	1.00	0.43	7.94	10.84	-2.90
Kirtland	0.71	-0.63	0.72	-1.00	-0.62	11.45	4.18	7.27
Wright-Patt	-0.18	-0.60	0.97	0.97	0.18	15.63	10.25	5.38

These results support the notion that P2 expenditures may be reducing EC costs. With the exception of Eglin AFB, in each case there was a net savings as P2 expenditures were less than the associated EC savings. Additionally, there was consistently moderate to high correlation between P2 and EC costs when using a 2-year lag. As final evidence, the correlation between budgets was insignificant.

Summary

This analysis showed that under the methodology for calculating CSI compliance burdens, a baseline is not established. The burden assigned to a particular site is relative only to the year in which the CSI is accomplished. During subsequent CSI iterations, the methodology may assign a different level of risk burden to a site even though the risk value remains the same. This prevents CSI from being used as a tool to measure changes in compliance burden.

This analysis also provided insight into the effectiveness of P2 expenditures in reducing EC costs at WPAFB and throughout AFMC. The results support the notion that EC costs may be reduced as a result of P2 expenditures. When the analysis was applied to AFMC, the results were not as strong; however, when bases affected by various factors were eliminated, the results were again very supportive. The results for Brooks, Eglin, Hanscom, Hill, LA, Robins, Rome, and Tinker were inconclusive, due to project accounting methods and base closure issues. Arnold, Edwards, Kirtland, and Wright-Patterson AFBs all exhibited a strong correlation between EC cost reduction and P2 expenditures.

V. Findings and Conclusions

Introduction

The intent of this research effort was to conduct a quantitative analysis of the Air Force's effectiveness in reducing overall compliance burden through pollution prevention (P2). In order to focus the effort, the analysis was conducted using data from Wright-Patterson Air Force Base (AFB) and Air Force Materiel Command (AFMC). When it was determined that the compliance site inventory (CSI) could not be used to gauge changes in cost or risk, the research took two paths. First, it illustrated why CSI was not suitable for such a task. Second, it stayed the course in attempting to quantify the Air Force's effectiveness in compliance through pollution prevention (CTP2). It showed that environmental compliance (EC) costs are indeed decreasing, that P2 efforts appear to be worthwhile when compared to the compliance costs saved, and that the EC savings are related to P2 efforts.

Compliance Site Inventory Database Methodology

This analysis illustrated that under the current burden calculation methodology, using CSI data to measure or track efforts in reducing compliance burden would be unwise. Certain anomalies occurred in subsequent iterations as a result of the cost and risk burdens being assigned based on high and low respective values. These anomalies were illustrated in examples where compliance sites were eliminated. In each case, changes to the respective risk burdens for certain compliance sites occurred even though the respective values did not change.

Cost Savings

Overall, the analysis showed that EC costs have been reduced with the implementation of P2 opportunities. The analysis showed that EC costs are falling and that savings in EC are greater than the P2 investments.

Wright-Patterson AFB. The analysis of Wright-Patterson AFB (WPAFB) provided the strongest evidence to support the argument that P2 efforts may reduce EC costs. This base showed consistent reductions in EC costs, from $12.19 million in 1996 to $3.00 million in 2000, a reduction of 75 percent over 4 years. A net present value (NPV) analysis of EC savings and P2 expenditures resulted in a net positive value of $5.38 million in overall savings for WPAFB. Additionally, the correlation between the year to year savings versus P2 expenditures using a 2-year lag period was found to be 0.97, which indicates a very strong correlation between P2 investments and EC savings.

Air Force Materiel Command. The collective analysis of AFMC provided mixed results. Overall, AFMC has also showed consistent reductions in EC costs, from $80.55 million in 1995 to $54.08 million in 2000, a reduction of 33 percent over 5 years. However, the NPV analysis of EC savings and P2 expenditures showed a net negative value. Additionally, the moderately strong correlations between EC savings and P2 were inconclusive as the correlation between EC and P2 budgets was a very strong 0.96. The mixed results, when collectively analyzing AFMC, are explained by relatively high P2 costs going to laboratories and product centers as compared to EC costs. Additionally, mission changes at the Air Logistics Centers (ALCs) due to base closures is confounding the analysis. When the AFMC analysis is focused on Arnold, Edwards, Kirtland, and Wright-Patterson AFB, where it is known that the EC and P2 expenditures being compared are purely base level expenditures, the results are conclusive that P2 is effectively reducing compliance costs. Each of these bases saw a decline in their EC costs and each had a net positive value when the NPV analysis was done on EC savings and P2 costs. Additionally, each base showed moderate to strong correlation between EC savings and P2 expenditures and no correlation between their respective EC and P2 budgets.

Recommendations

The Air Force should continue to focus on P2 as a means to drive down long-tem compliance costs. Additionally, at Arnold, Edwards, Kirtland, and Wright-Patterson AFBs, P2 appears to be effective in reducing long-term compliance costs. Therefore, the Air Force should consider funding additional opportunity assessments at these already successful bases.

Air Force Materiel Command should consider establishing a baseline for the cost and risk values which go into establishing the cost and risk burden categories. Using the 1999 CSI as the baseline would be the best alternative. It would then allow the bases to track their effectiveness in reducing risk. Additionally, if a command baseline were established it would permit the comparison of data between bases.

Future Research

Prior year EC budgets are used to allocate compliance costs to sites because they are the best measures the Air Force has regarding the cost of compliance at its installations. From year to year, budgets fluctuate and are at times cut across the board; yet, the bases find ways to stay in compliance. This leads one to question the validity of the proposed cost of compliance. An area of future research could focus on a single installation and determine its cost of compliance or create a methodology for determining cost of compliance.

The current methodology is adequate for ranking sites based on cost and risk, as it is a tool for identifying P2 opportunities. However, if the CSI is to be used as at tool to measure changes in compliance burden, a more accurate method may be required. A good area of research would be to use value focused thinking and multi-criteria decision making theories to develop a multi-attribute value function for establishing ranks. This approach could more accurately account for relative weightings of factors such as cost and risk as well as provide opportunities to conduct sensitivity analysis. It would be interesting to see if a decision analysis approach provided the same rankings as the AFMC approach to compliance site prioritization.

Appendix A. Risk Burden Calculations

Site No.	CSI No.	Site Type	Site Decr.	1525 Sites Risk Value	1525 Sites Risk (%)	1525 Sites Risk Burden	1523 Sites Risk Value	1523 Sites Risk (%)	1523 Sites Risk Burden
1	ZHTV0009	Above Ground Storage Tank		512	17%	Low	512	17%	Low
2	ZHTV0037	Above Ground Storage Tank		512	17%	Low	512	17%	Low
3	ZHTV0038	Above Ground Storage Tank		512	17%	Low	512	17%	Low
4	ZHTV0040	Above Ground Storage Tank		512	17%	Low	512	17%	Low
5	ZHTV0043	Above Ground Storage Tank		512	17%	Low	512	17%	Low
6	ZHTV0045	Above Ground Storage Tank		512	17%	Low	512	17%	Low
7	ZHTV0041	Above Ground Storage Tank		768	17%	Low	768	17%	Low
8	ZHTV0001	Above Ground Storage Tank		1,024	26%	Medium	1,024	26%	Medium
1521	ZHTV1532	Waste Water / Storm Water	Pretreatment	192	7%	Low	192	7%	Low
1522	ZHTV1533	Waste Water / Storm Water	Pretreatment	192	7%	Low	192	7%	Low
1523	ZHTV1534	Waste Water / Storm Water	Pretreatment	192	7%	Low	192	7%	Low
1524	ZHTV1535	Waste Water / Storm Water	Regional Connection	320	10%	Low	320	10%	Low
1525	ZHTV1536	Waste Water / Storm Water	Regional Connection	320	10%	Low	320	10%	Low

Calculations	1525 Sites		1523 Sites
Minimum	5		5
Maximum	43,200		28,800
Histogram Data Counts			
Low	403		403
Medium	690		690
High	185		185
Extremely High	247		245
Total	1525		1523

Appendix B: Collected Environmental Compliance Costs

Year	AFMC/ CEV ($000)	AMARC ($000)	Armstrong Lab -- IERA ($000)	USAF SAM ($000)	Arnold ($000)	ASC ($000)
1995	481.0	240.0	1,952.0	555.0	5,709.1	236.0
1996	647.6		100.0	0.0	4,133.0	225.8
1997	1,196.0		3,050.0	15.0	5,330.0	242.9
1998	923.0		1,892.8	2.2	4,493.0	254.6
1999	520.0		1,850.0		3,623.0	194.0
2000	1,461.9		1,754.4		3,721.6	

Year	Brooks ($000)	Edwards ($000)	Eglin ($000)	Hanscom ($000)	Hill ($000)	Kelly ($000)
1995	1,159.7	15,919.5	6,800.6	1,322.6	5,112.0	8,185.0
1996	805.8	13,518.8	7,863.2	932.1	6,378.1	8,866.0
1997	623.0	10,918.1	7,197.0	851.8	4,775.0	5,657.2
1998	484.5	7,380.7	3,957.1	637.2	5,321.0	3,003.0
1999	829.0	7,545.0	3,990.0	617.2	5,389.0	6,197.7
2000	361.0	8,491.9	5,125.0	598.0	10,650.7	4,082.1

Year	Kirtland ($000)	LA ($000)	McClellan ($000)	Newark ($000)	Robins ($000)	Rome Lab ($000)
1995	6,730.5	1,643.0	5,257.0	123.1	9,105.2	3.0
1996	4,044.9	3,054.0	3,692.3	572.2	4,167.0	637.0
1997	5,568.6	940.0	3,035.6		4,469.0	523.7
1998	4,187.0	1,352.0	2,082.5		4,274.0	349.8
1999	5,599.0	979.0	1,613.0		4,578.4	172.0
2000	5,110.0	750.9	1,924.1		5,350.8	244.0

Year	SMC ($000)	Tinker ($000)	Wrigt-Patt ($000)	Total ($000)
1995	75.0	8,194.1	8,030.4	86,833.8
1996	0.0	5,261.4	11,379.8	76,279.0
1997		3,787.5	5,281.0	63,461.4
1998		5,577.0	3,944.8	50,116.2
1999		3,717.1	3,505.5	50,918.9
2000		7,506.8	2,957.0	60,090.2

Appendix C: Collected Pollution Prevention Costs

Year	AFMC/ CEV ($000)	AMARC ($000)	Wright Lab ($000)	Arnold ($000)	Brooks ($000)	Edwards ($000)
1995	7,008.0	225.0	11,972.0	907.0	8,538.0	1,605.0
1996	2,787.5	65.0	7,058.1	1,297.0	7,425.9	2,460.0
1997	4,713.6	40.0	8,182.4	2,091.0	6,132.1	1,823.0
1998	4,300.1		3,581.3	1,201.0	575.4	1,556.3
1999	5,165.0		2,570.0	909.0	892.0	2,263.0
2000	5,442.3		4,045.0	1,266.6	3,311.0	2,050.7

Year	Eglin ($000)	Hanscom ($000)	Hill ($000)	Kelly ($000)	Kirtland ($000)	LA ($000)
1995	4,585.0	3,396.0	9,154.0	4,711.0	238.0	1,753.0
1996	1,604.4	1,517.7	2,532.0	3,693.8	1,597.0	1,514.5
1997	808.0	1,844.0	2,682.0	117.0	548.4	1,509.7
1998	833.0	2,018.5	1,585.0	139.3	409.4	699.3
1999	976.0	906.0	2,636.0	39.0	492.0	1,209.0
2000	1,300.4	1,092.0	2,716.0	90.2	676.0	418.1

Year	McClellan ($000)	Newark ($000)	Robins ($000)	Rome Lab ($000)	Tinker ($000)	ASC (G) ($000)
1995	7,939.9	69.0	11,093.0		9,890.0	8,780.0
1996	3,616.4	45.0	7,373.6		3,712.4	3,297.0
1997	2,469.6		6,788.9	47.5	1,969.9	2,942.0
1998	804.7		2,077.3	6.0	446.0	
1999	321.0		1,058.0	99.0	1,520.0	
2000	22.8		3,681.5	43.8	1,993.5	

Year	ASC (WP) ($000)	Wright-Patt ($000)	Total ($000)
1995	2,572.0	3,342.0	97,777.9
1996	1,664.0	1,118.0	54,379.3
1997	5,022.0	995.1	50,726.3
1998	3,427.3	263.7	23,923.6
1999	559.0	1,815.3	23,429.3
2000	1,454.0	2,120.0	31,723.9

Appendix D. List of Acronyms

Air Force .... AF

Air Force Base .... AFB

Air Force Instruction .... AFI

Air Force Materiel Command .... AFMC

Air Force Policy Directive .... AFPD

Air Logistics Center .... ALC

Clean Water Act .... CWA

Compliance Site Inventory .... CSI

Compliance Through Pollution Prevention CTP2

Comprehensive Environmental Response, Compensation and Liability Act .... CERCLA

Consumer Price Index .... CPI

Corps of Engineers .... COE

Defense Reutilization and Marketing Office .... DRMO

Department of Defense .... DoD

Emergency Planning and Community Right-to-Know Act .... EPCRA

Environmental Compliance .... EC

Environmental Compliance and Management Program .... ECAMP

Environmental Protection Agency .... EPA

Environmental Safety and Occupational Health .... ESOH

Environmental Quality .... EQ

Executive Order...EO

Federal Facility Compliance Act..FFCA

Hazardous and Solid Waste Amendment...HSWA

Headquarters, United States Air Force...Air Staff

Life Cycle Cost...LCC

Net Present Value..NPV

Notice of Violation..NOV

Open Enforcement Actions...OEA

Operational Risk Management..ORM

Pollution Prevention..P2

Pollution Prevention Act...PPA

Producer Price Index..PPI

Process Specific Opportunity Assessment..PSOA

Reportable Quantity..RQ

Resource Conservation and Recovery Act..RCRA

Risk Management Plan..RMP

Science Advisory Board...SAB

Time Value of Money..TVM

Total Ownership Cost..TOC

Toxic Release Inventory...TRI

Treatment and Disposal..T&D

Wright-Patterson Air Force Base..WPAFB

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Vita

Captain Douglas W. Gilpin was born on [redacted] in Georgetown, Texas. He graduated from Salado High School in Salado, Texas in May 1989. He entered the United States Air Force Academy in Colorado Springs, Colorado where he graduated with a Bachelor of Science degree in Civil Engineering on 2 June 1993.

His first assignment was at Kelly AFB as a Design Engineer and as then as the Chief of Maintenance Engineering in the 76th Civil Engineer Group. While stationed at Kelly, he deployed overseas in May 1995 to spend three months in Dhahran, Saudi Arabia as the King Abdul-Aziz Air Base contingency Environmental Engineer. In July 1996, he was assigned to the 31st Civil Engineer Squadron, Aviano AB, Italy where he served as the Chief of Resources and then as the Chief of Programming. In August 1999, he entered the Graduate School of Engineering and Management, Air Force Institute of Technology. Upon graduation, he will be assigned to the 554th RED HORSE Squadron at Osan AB Korea.

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14. ABSTRACT

The objective of the Air Force's compliance through pollution prevention (CTP2) program is to reduce overall environmental compliance (EC) cost and risk (compliance burden) associated with maintaining compliance at an installation through increased pollution prevention (P2) efforts. However, no quantifiable evidence has been produced that suggests P2 projects are actually reducing compliance burden. Therefore, this research attempts to determine if projects categorized as P2 truly reduce compliance burden.

This research demonstrated that, under the current burden calculation methodology, the compliance site inventory data should not be used to measure or track compliance burden reductions. The time value of money, net present value, and correlations were used to analyze the Wright-Patterson AFB (WPAFB) and Air Force Materiel Command (AFMC) EC and P2 programs from 1995 through 2000.

Overall, this research showed that CTP2 is effective because EC costs are falling, EC savings are greater than the P2 investments, and EC savings are highly correlated to P2 investments. The analysis of WPAFB provided the strongest evidence; however, the AFMC analysis provided mixed results, which were explained by relatively high laboratory and product center P2 costs and mission changes due to base closures. When the analysis focused on Arnold, Edwards, Kirtland, and Wright-Patterson AFB, the results were supportive. Each of these bases saw a decline in EC costs, had a net positive overall savings, and had a moderate to strong correlation between EC savings and P2 expenditures.

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