WMRC Reports
Waste Management and Research Center

Pollution Prevention and Business Management: Curricula for Schools of Business and Public Health, Volume 1: Modules 1-3

Thomas J. Bierma
Francis L. Waterstraat
Illinois State University

TR24
June 1995
Electronic Version

About WMRC's Electronic Publications:

This document was originally published in a traditional format.

It has been transferred to an electronic format to allow faster and broader access to important information and data.

While the Center makes every effort to maintain a level of quality during the transfer from print to digital format, it is possible that minor formatting and typographical inconsistencies will still exist in this document.

Additionally, due to the constraints of the electronic format chosen, page numbering will vary slightly from the original document.

The original, printed version of this document may still be available.

Please contact WMRC for more information:

WMRC
One E. Hazelwood Drive
Champaign, IL 61820
217-333-8940 (phone)

www.wmrc.uiuc.edu

ILLINOIS DEPARTMENT OF NATURAL RESOURCES

WMRC is a division of the Illinois Department of Natural Resources

TR-024

Pollution Prevention and Business Management: Curricula for Schools of Business & Public Health
Volume I

Module 1
Pollution Prevention and Business Competitiveness

Module 2
Pollution Prevention and Process Improvement

Module 3
Pollution Prevention and the Business Manager

by

Thomas J. Bierma,
Francis L. Waterstraat
Department of Health Sciences
Illinois State University
Normal, Illinois 61761

Prepared for

Illinois Hazardous Waste Research and Information Center
One East Hazelwood Drive
Champaign, IL 61820

Printed by Authority of the State of Illinois
95/250

This report is part of HWRIC's Technical Report Series. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

TABLE OF CONTENTS

<u>MODULE 1</u>
POLLUTION PREVENTION AND BUSINESS COMPETITIVENESS

TABLE OF CONTENTS (cont.)

MODULE 2
POLLUTION PREVENTION AND PROCESS IMPROVEMENT

TABLE OF CONTENTS (cont.)

MODULE 3
POLLUTION PREVENTION AND THE BUSINESS MANAGER

TABLE OF CONTENTS (cont.)

SUPPLEMENTAL READINGS

LIST OF TABLES

LIST OF FIGURES

PREFACE

These instructional modules are based on the premise that sustained economic development is dependent upon sustained protection of the environment. They also reflect the fact that preventing waste is far more cost effective than managing the waste once it is generated. Pollution prevention not only offers businesses a competitive opportunity, it is a natural extension of sound management practices. Incorporating pollution prevention into business management and government regulation will enhance longterm economic prosperity.

Pollution Prevention and Business Management is composed of three academic modules intended to supplement course material in schools of business and management, schools of public health with an emphasis in management and the environment, and schools of environmental studies with an emphasis in management. The modules are designed to be flexible. They may be used together, or independently. Though designed to meet the needs of graduate students, portions of the modules are appropriate for undergraduate instruction as well. Though intended to be read outside of class, and discussed in class, the modules offer many opportunities for outside and in-class activities, additional reading and research, and supplemental lecture. Most importantly, the modules are intended for participative learning. The problems and case studies which accompany each module are an integral part of the learning process, particularly if discussed in groups or by the class as a whole.

Module 1, Pollution Prevention and Business Competitiveness, is an introduction to pollution prevention and its value as a standard component of business management. It also clarifies how pollution prevention is a natural extension of sound management practice. Module 2, Pollution Prevention and Process Improvement, illustrates how waste generation is simply another form of process inefficiency, and presents methods for identifying and reducing such inefficiencies. Module 3, Pollution Prevention and the Business Manager, explores the multitude of ways in which the business manager is critical to the success of pollution prevention efforts, and how pollution prevention can be integrated into management strategy. Finally, the Supplemental Readings provide materials which complement those in the modules, as well as readings and case studies which form the basis for problems and activities at the end of each module. All copyright free supplemental readings are included in this document. Copyrighted documents are available from HWRIC as a separate booklet. The $5.00 cost of that booklet covers the copyright fees due to the original publishers. This supplemental readings booklet contains the following articles: Weinstock, M.P. "Profiting from Pollution Prevention;" Wright, D.R. "Designing a Corporate Environmental Program: The Colgate-Palmolive Approach;" Fisher, M.T. "Total Quality Environmental Management: The Procter & Gamble Approach;" Pferdehirt, W.P. "Roll the Presses But Hold the Wastes: P2 and the Printing Industry;" Willis, D.G. "Pollution Prevention Plans - A Practical Approach;" "Valley Paints, Inc.," In: <u>Curriculum for Toxics Use Reduction Planners, Third Edition</u>; White, A.L, Becker, M., Goldstein, J. "Coated Fine Paper Mill;" White, A.L, Becker, M., Goldstein, J. "Paper Coating Mill;" Whittman, M.R. "Williams Precision Valve Company, Inc.;" Whittman, M.R. "Wrayburn Jewelry Company, Inc.;" and Whittman, M.R. "Lightolier, Inc.,"

The authors hope that these modules provide an interesting educational approach to pollution prevention. We would like to know about your experiences, impressions, and questions. Please feel free to contact us at 309/438-8329.

MODULE 1
POLLUTION PREVENTION
AND BUSINESS COMPETITIVENESS

LEARNING OBJECTIVES

1. Given a business scenario, identify and explain the ways in which the business might use pollution prevention to enhance its competitive strategy.

2. Given a business scenario, identify and explain the primary areas in which waste generation and the use of hazardous substances is likely costing the company money.

3. Given a business scenario, identify and explain the primary areas in which pollution prevention is likely to produce significant savings.

4. Given a business scenario, identify and explain the significant barriers to pollution prevention and suggest ways of overcoming those barriers.

MODULE 1

POLLUTION PREVENTION AND BUSINESS COMPETITIVENESS

"Everyone thinks of waste as an environmental issue. That's a natural mistake. Waste is ... the biggest opportunity North American manufacturers have ever had to increase their profits." (1)
Charles Rooney,
Orr & Boss

Management was surprised to find out how much waste they emitted into the air.

In the late 1980's, Parker Pen USA, Ltd. found something they hadn't expected. Recent federal legislation (SARA [Superfund Amendments and Reauthorization Act] Title III) had, for the first time, required companies to identify and report to the public the quantity of wastes discharged into the environment each year. Management at the Parker Pen USA plant in Janesville, Wisconsin was surprised to find out how much trichloroethylene (TCE) they emitted into the air (2). To make matters worse they found that TCE emissions had been increasing yearly due to increased use of the solvent.

TCE was the most common of several solvents used by Parker Pen USA for degreasing, the removal of oils and other materials from metal product surfaces. Failure to reduce emissions could result in increasing public and regulatory scrutiny. A traditional approach to reducing TCE emissions would involve the environmental engineering staff designing a pollution control system to capture the emissions and dispose of the waste TCE, necessitating substantial capital and operating expenses.

Management chose to view the emissions as a production problem rather than a pollution control problem...and saved $70,000.

However, Parker Pen USA chose to view the emissions as a production management problem rather than a pollution control problem. They questioned the need for such extensive TCE use and set a goal of 50% reduction in TCE use for the plant. Research into the causes of excessive usage found that TCE could be reduced dramatically through improvements in operation of the degreasing machines, small changes in production procedures, and employee training. Instead of a substantial drain on plant resources typical of traditional pollution control programs, Parker Pen USA achieved a 54% reduction in TCE emissions in three years with a net savings of $70,000!

Parker Pen USA is not a unique example. Many companies have come to recognize that pollution is the outcome of inefficient application of corporate resources. Environmental wastes are just one among many wastes in a company, and waste reduction is a critical element in a company's competitive strategy.

This module examines the value of *pollution prevention* as an integral component of the corporate competitive strategy.

POLLUTION PREVENTION AND COMPETITIVENESS

Waste minimization as a competitive strategy.

"Companies who make the most progress toward "eco-efficiency" are positioning themselves to prevent waste from becoming an uncontrollable cost of doing business. Customers want reassurance that the products they buy cause minimal environmental harm. So by improving our "eco-efficiency," we stand to gain both competitive advantages and the customer trust.
Samuel C. Johnson, Chairman
S.C. Johnson & Son

Compliance is taking a back seat to more aggressive strategies.

Seventy-seven percent of senior management define environment as critical or important to strategic decisions according to a survey of 41 mostly Fortune 200 nonservice firms (3). Compliance with environmental laws, while still important, is taking a back seat to more aggressive environmental strategies in product design, production, and marketing. In addition, responsibility for environmental policy and programs is being diffused throughout the organization rather than resting solely with the environmental staff. Almost 60% of surveyed firms have environmental program responsibilities in manufacturing and R&D departments. Nearly 30% have established programs in their purchasing, marketing, and quality management departments. Seventy percent report establishing senior management task forces to chart corporate environmental strategy.

3M, one of the earliest companies to adopt a pollution prevention strategy, credits an aggressive waste reduction program with a substantial contribution to its competitive position. 3M estimates that their program of minimizing waste and preventing pollution at the source has saved the company $500 million from 1975-1989 (4). Thomas Zosel, Manager of 3M's Pollution Prevention Programs (3P) provides a simple justification, "the 3P Program was established because of the recognition that prevention is more environmentally effective, technically sound, and less costly than conventional control procedures."

Yet even smaller companies benefit from the preventive approach. For example, a Beloit Corporation plant in Dalton, Massachusetts, employing

400 people, found that the coolant it used in machining operations became rancid quickly, resulting in high maintenance and waste disposal costs (5). In addition, many workers complained of skin irritation (dermatitis) after working with the coolant. Company employees tried several alternative coolants and identified one, mineral oil, that both lasted far longer than the previous coolant and did not produce dermatitis. In addition, the new coolant had better cooling and lubricating properties, resulting in a dramatic increase in tool life and process rates. These changes more than doubled productivity and reduced cutting tool costs by 24% for an annual savings of $88,000.

The reason that pollution prevention is playing a larger role in corporate strategy is that it meets at least five basic corporate needs, below. Meeting each of these needs enhances the competitive position of the firm and its long-term financial health.

Reducing Costs

"It's nothing more than optimizing the process," according to Jim Conner, manager of environmental projects for Hoechst Celanese (6). Wastes leaving the plant represent lost resources as well as potential liabilities. Even wastes that are captured and reused can result in considerable capital and operating expense. Reduction in the *generation* of waste improves operating efficiency and produces the greatest potential benefits to the firm.

Wastes are lost resources as well as potential liabilities.

Meeting Customer Expectations

According to one study, 51 percent of consumers made environmentally-based purchases in 1990 across a wide range of product types (3). Procter & Gamble answered over 50,000 consumer telephone calls in 1991 concerning the environmental impact of P&G products and operations (7). Companies with a positive environmental record stand to gain considerable market power. Apple Computers devotes substantial resources to understanding the environmental expectations of its customers. In addition to customer letters and an 800-line for consumers, Apple seeks input from its dealer network, monitors the environmental activities of competitors, notes press coverage, and follows the activities of regulators and activist groups (8). One wide-spread example of industrial response to demand for a more environmentally compatible product is the movement away from inks containing organic solvents and metal pigments to those made from vegetable oils and pigments (9).

Fifty-one percent of consumers made environmentally-based purchases.

Yet Abt Associates, a corporate environmental consulting firm, offer this caution (10):

> "Companies that lack an understanding of the processes for achieving customer satisfaction have a tendency to drive satisfaction without looking at results. Often the result is programs that emphasize public relations over performance. Ultimately, such programs fail as increasingly sophisticated customers see through "green" programs that are not backed by performance."

Enhancing Harmony with the Community

"This experience had a huge effect on me."

Every company exists within a community. A firm relies upon the community to provide its workforce, its energy, its water, and many other services. Managers make their homes and raise their children within the community. Companies have increasingly recognized the impact of their environmental discharges on the community and the impact that the loss of harmony with the community can have on company operations. One example is related by Robert D. Kennedy, Chairman of Union Carbide (11):

> "About six months after Bhopal, before I became CEO, we had an accident in the U.S. A hazardous plume was emitted from a plant in a small town in West Virginia. I was told to go down there and talk to the community. The meeting was held in a local college auditorium with about 400 people attending. One old lady who lived directly behind the plant spoke up and said she was afraid to eat the okra growing in her garden. Another woman who was driving by the plant when the accident occurred said she was worried what her unborn child would look like at birth. What could I say? This experience had a huge effect on me."

Enhancing Harmony with Employees

Successful pollution prevention programs involve the efforts of the entire workforce.

Pollution prevention works hand-in-hand with worker safety since it involves gaining greater control over, and often reduction in, the use of hazardous substances in the workplace. In the Beloit Corporation example above, eliminating worker dermatitis was a top priority in identifying a new coolant.

In addition, the most successful pollution prevention programs involve the efforts of the entire workforce (12). Getting line workers involved not only generates more and better solutions, but it increases the likelihood that changes will be supported and enhances the working relationship between management and labor.

Meeting Investor Expectations

Liabilities arising out of catastrophic environmental events, such as Union Carbide's experience in Bhopal, India and the Johns-Manville bankruptcy from lawsuits over worker exposure to asbestos, readily get the attention of stockholders (13). Increasingly, however, investors are beginning to look at a company's environmental compliance record and to look for solid evidence that a company has a proactive program for taking environmental concerns beyond compliance (14). Environmental performance is becoming an increasingly common component of corporate annual reports (15).

Investors are beginning to look for companies with proactive environmental programs.

THE COSTS OF POLLUTION

Are U.S. firms wasting $400 billion per year?

"As far as we are concerned, good environmental performance is essential for the continued success of this company. If we got our environmental performance right, that will give us a competitive advantage."
Sir Denys Henderson, Chairman
ICI

To understand the value of pollution prevention as a corporate competitive strategy it is necessary to understand the costs of pollution and the costs of pollution reduction. The most obvious cost of pollution is the cost of waste disposal. But this is actually only a small fraction of pollution costs for most businesses.

Waste disposal is only a small fraction of pollution costs.

Tangible Costs

Charles Rooney, President of Orr & Boss manufacturing consultants suggests that tangible pollution costs be viewed as the sum of four elements (1):

"1. Raw material
First, there is the cost of the raw material in the waste. Manufacturers have paid for the raw material in every piece of

scrap or gallon of effluent. They intended to use it to make salable product. When the raw material becomes waste, the manufacturer loses the material's value.

"2. Labor
Nobody buys material just to throw it away. By the time it becomes waste, the factory will have worked on it. Thus, all waste contains labor. The value of that labor is also lost, as is the labor used to rework unsalable product.

Nobody buys material just to throw it away. All waste contains material and labor.

"3. Disposal
Disposal charges are clearly expenses that spring from waste. In most companies they are the only elements of waste-related expense that are recognized explicitly. As landfills close, garbage disposal costs mount. When the waste is legally hazardous, the disposal charges are exorbitant.

"4. Waste handling
This figure has two elements. First, the plant will use labor to collect and store its [waste]. It may also process its [waste], for example, by compacting solids, or distilling liquids. The expense of running these operations is a result of making waste. Secondly, disposal is tightly regulated. It imposes a costly administrative burden. This is particularly true when hazardous chemicals are involved."

These four elements alone may represent a waste of about $400 billion per year for U.S. manufacturers.

Rooney has found that these four elements are extremely expensive for most manufacturing companies, *usually exceeding a plant's entire direct labor expenses, or about $400 billion per year for U.S. manufacturers*. In addition, the vast majority of the waste-related cost is due to lost raw material. "Minimizing the cost of waste is a question of optimizing raw material utilization. (1)"

Less-tangible Costs

The costs of pollution are even greater than those identified by Rooney. Many costs are less tangible or hidden and not represented through traditional methods of financial analysis. This includes future liability, customer goodwill, employee relations and productivity, and investor confidence (16). These are potentially very large costs to a company. Liability from asbestos exposures cost the Johns-Manville Corporation $2 billion and bankrupted the company (13).

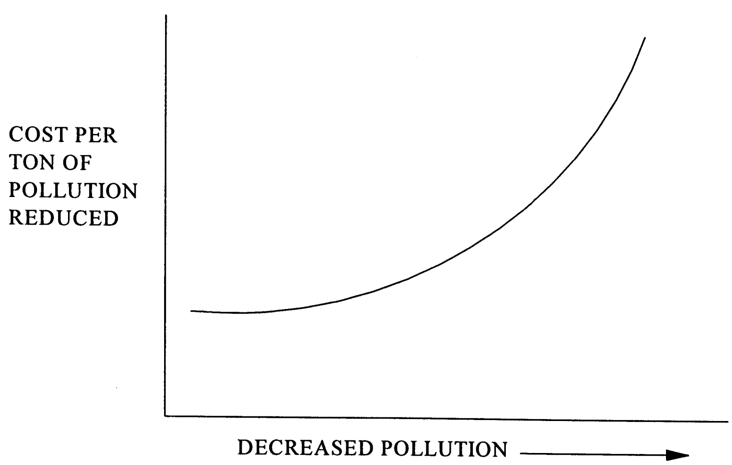
THE COSTS OF REDUCING POLLUTION

Innovation is the key to reducing costs.

"Du Pont engineers argued that reducing the pollution would be too expensive. But when they took a second look last year, they found just the opposite was true. (17)"
Wall Street Journal
June 11, 1991

In the 1970's, Japanese auto manufacturers appeared to do the impossible: they increased quality and at the same time reduced costs. Until then it was always assumed that there was a trade-off between cost and quality: one could improve quality but only with greater costs. The same thinking has been pervasive in the production of environmental quality (pollution reduction). Figure 1-1 depicts this trade-off. For example a steel mill might use a wet scrubbing system to remove dust from its exhaust gases. Moving from 30 percent reduction of dust to 60 percent reduction of dust results in an increase in costs because water and energy consumption would increase, wear on the control system would increase, and volume of liquid waste would increase.

Figure 1-1. Tradeoff between decreasing pollution and increasing cost of control

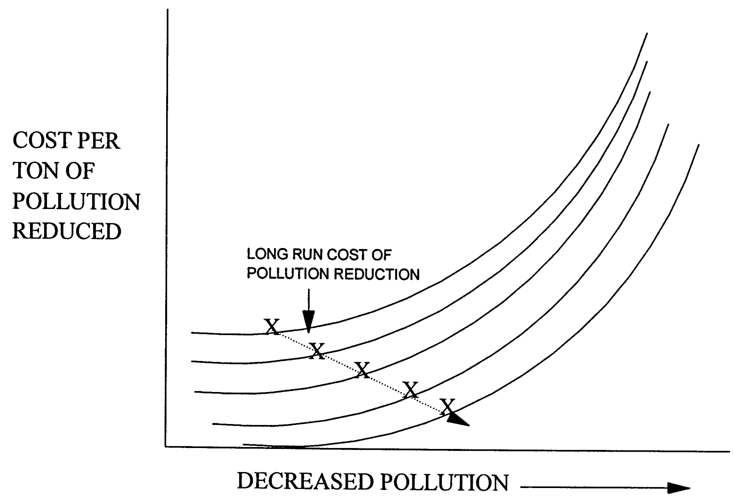


But what the Japanese learned in the 1950's, as have many U.S. companies since 1980, is that improvements in technology (knowledge) can shift the quality-cost curve to the right, allowing higher levels of quality at lower cost. The Japanese found that this could be done with

Just as some companies have found the key to improving quality* and *reducing costs, companies are now reducing both costs and pollution levels simultaneously.

small, simple, incremental improvements designed to prevent quality problems from occurring. The same concept applies to pollution prevention. Figure 1-2 reflects the series of pollution reduction-cost curve shifts that can result from incremental improvements in process operations designed to prevent wastes from occurring. These improvements can produce a long-run cost curve that is actually decreasing. This is the source of competitive advantage enjoyed by companies ranging from 3M to Beloit Corporation.

Figure 1-2. Decreasing long-run pollution control cost curve produced from innovation-driven shifts in short-run cost curves



The key to taking advantage of the decreasing long-run cost curve is time and innovation. Business is forced along a short-run curve when insufficient time is provided for compliance with a new environmental standard, or insufficient innovation is forthcoming from within the business.

Module 3 provides a more detailed discussion on performing cost-benefit analysis for specific pollution prevention projects.

POLLUTION PREVENTION OPPORTUNITIES

Moving up the waste management hierarchy.

Pollution Prevention in Perspective

Businesses have four general options available for management of their environmental wastes: Reduce, Reuse, Recycle, Dispose (Table 1-1). This is known as the Waste Management Hierarchy and each step down the hierarchy reflects an increasing long-term burden on the resources of the firm.

Table 1-1: The Waste Management Hierarchy

Reduce	This is the ultimate goal of pollution prevention, reduction or elimination of the generation of waste. This is necessary to maximize efficiency of business operations.
Reuse	In many instances waste material can be reused as raw material in production processes. Resource losses occur in the capture, transport, and reprocessing of these wastes.
Recycle	One firm's waste may be another firm's raw material, just as a household's aluminum cans become raw material for the production of new cans. Resources lost on capture, transport, and processing of the recycled material may be partially offset by purchase payments from the receiving industry. Note that when purchase payments exceed lost resources the material is no longer a waste but a product.
Dispose	Disposal options range from burial in a landfill to burning in an incinerator to direct discharge into the environment. This results in the greatest lost of resources for the firm.

Pollution prevention is often defined as only the first two of the above options: reduce and reuse. However, what is important from a business perspective is the process of moving waste management strategies up the hierarchy from disposal to reduction, with the ultimate goal of reducing all waste to zero (even if such a goal is unattainable). This definition is consistent with the need to continuously improve the efficiency of all business operations.

Movement up the waste management hierarchy can mean increasing efficiency and profit.

Companies appear to move through several phases in their pursuit of waste management efficiency (18): first, compliance with environmental laws; second, pollution reduction; third, pollution prevention; and forth, environmental strategy (Table 1-2). These also can be viewed as a hierarchy, with movement up the hierarchy resulting in increased efficiency and profit for the firm due to movement along a decreasing long-term cost curve.

Table 1-2: The evolution of waste reduction programs in a firm

Environmental Strategy	Reducing the generation of waste and maximizing "green" market potential through the redesign of product and marketing mechanisms. This includes consideration of the full environmental impact of production, use, and disposal of a product.
Pollution Prevention	Reducing the generation of waste through process redesign.
Pollution Reduction	Pursuing immediate opportunities for recycling, reuse, and reduction of wastes through better process management.
Compliance	Achieving and maintaining lawful disposal of wastes.

The Scope of Waste Reduction Opportunities

It is useful to look in more detail at the wide array of waste reduction opportunities. Below, some of these strategies are explained and examples are provided (19).

Understanding the efficient operation of equipment can reduce waste.

Improving Operational Procedures - Use the existing process more efficiently. This can include changing procedures to reduce spills or enhancing maintenance to improve operational efficiency. Understanding the efficient operation of equipment can reduce waste. In Parker Pen USA's attempt to reduce solvent losses, they discovered that degreasers were actually more effective at lower temperatures, saving both energy and evaporative solvent losses

(2). Cleaning tanks and other equipment can often be achieved using less cleaning chemical. Moline Paint Manufacturers, Inc. found they could reduce cleaning solvent use by scheduling batch operations to begin with the lightest color paints and end with the darkest color paints, which minimized the need to clean tanks between batches (20). The array of procedural improvements is as endless as the types of manufacturing processes that exist.

Modifying or Substituting Equipment - Lowell Corporation saved $26,000 annually by adding a dead-water rinse tank after its zinc coating tank (21). The zinc rinse water could be reused and reduced zinc waste by 50%, allowing Lowell to avoid far larger compliance costs. L&J of New England, Inc. installed flow control devices on several water rinse operations, reducing water use and wastewater generation without compromising cleaning quality (22).

Changing to Less Hazardous Materials - In the late 1980's, Martin Marietta Astronautics Group was faced with the necessity of dramatically reducing or eliminating two environmentally harmful solvents, TCA (trichloroethane)and MEK (methyl ethyl ketone), used to clean rocket components (23). The nature of the product, spacecraft, made performance specifications for the solvents extremely rigorous. After several years of investigation, Martin Marietta identified water-based, non-toxic, biodegradable substitutes. In many instances the new solvents performed better than the TCA and MEK that they replaced. Lampin Corporation, a small metal parts manufacturer, replaced its CFC (chlorofluorocarbons) degreasing operations with a hot water wash, saving $6,000 annually in CFC purchases (24).

Managing Inventory - The more raw material is received and stored, the more likely it is to be released into the environment through, for example, a chemical spill, leak, or other accidental release. Just-in-time (JIT) inventory techniques can reduce or eliminate on-site inventory. Better quality control on receipt and better storage and transfer procedures can reduce off-spec material losses. Better coordination between purchasing and production can reduce unneeded and outdated inventory.

The more raw material is received and stored, the more likely it is to be released into the environment through, for example, a chemical spill, leak, or other accidental release

Waste Separation - Often wastes are composed of a small quantity of hazardous material in a large volume of otherwise non-hazardous material, such as oil in water or metals in sludge. Separating the components of a waste can reduce waste volumes and may even allow reuse or recycling of some components. Poly-Plating, Inc., a small nickel- plating operation, instituted a wastewater separation unit, allowing recycling of most of the water, acid, and metal components (25). This resulted in a 96% reduction in acid purchases, a 91% reduction in waste disposal expenses, and a 98% reduction in water and sewer use. Separating wastes at the source, such as separating various grades of office paper at the point of generation, can often result in more efficient reuse or recycling.

Process Redesign - Changing the process used to produce a product can reduce waste generation. Using a dip tank instead of a spray booth may reduce paint waste. Using electronic mail can reduce paper waste.

Product Redesign - Redesigning the product and marketing mechanism has the greatest long-term potential for reducing waste. This includes consideration of the environmental impact of production, distribution, use, and disposal of a product, as well as the impact of producing the inputs to the process. For example, auto manufacturers would consider the environmental impact of producing the plastics and metals purchased by the company, the wastes generated during auto production, the emissions produced during use of the car, and the ease with which auto components could be disassembled and recycled.

Pollution prevention options are limitless. The process of identifying and selecting options is the topic of Module 2.

THE PAST AND FUTURE OF POLLUTION REDUCTION EFFORTS

The trend favors increased flexibility for business.

"Basically, you have two choices. Join the [environmental] movement or stand in the way and watch America walk over your company. (26)"
Du Pont executive

Pollution prevention as a strategy for improving efficiency and quality may appear to be so obvious as to beg the question, "Why has it taken so long?" An understanding of the origins of pollution prevention and its likely future direction can assist the business manager in identifying and making the most of pollution prevention opportunities.

"If it ain't broke, don't fix it" - production processes take a long time to "perfect" and supervisors and engineers are reluctant to make changes.

"Pollution prevention will compromise quality" - changes in processes and materials threaten the ability to produce high quality consistently.

Resistance to change can take a variety of forms.

"There is no more room for improvement" - either because of reliance on past practices or complacency born of early success, there is a tendency to resist continuous improvement.

"There are higher priorities" - pollution prevention is still seen as "just and environmental" program, unrelated to improved efficiency and quality.

"Improved efficiency means a loss of jobs" - if improvements in efficiency are going to occur through elimination of personnel (other than through attrition), employees and unions are unlikely to actively support such changes.

Lack of an Adequate Accounting System

Due to inadequate financial data, pollution prevention projects cannot compete on an equal footing with other capital investment projects.

Most companies lack either sufficient information on waste production, sufficient information on the total costs of waste production, or an adequate method of allocating costs to production sources (33). Also, short profitability time horizons of one to five years may not be sufficient to capture the longrun benefits of pollution prevention investments (33). This means that pollution prevention projects cannot compete on an equal footing with other capital investment options.

Regulatory Programs

Reactive regulations do not allow sufficient time for innovation.

Many regulatory programs continue to be inflexible or contradictory, promoting pollution prevention on the one hand and penalizing pollution prevention activities on the other (27, 32, 34). In addition laws and regulations tend to be reactive rather than proactive, minimizing time for planning and compliance. As discussed previously, the long-run waste reduction cost curve for a firm is usually downward sloping, allowing both waste reduction and cost reduction simultaneously. Reactive regulations do not allow sufficient time for innovation, forcing businesses along their shortrun cost curves with resulting inefficiencies.

Many employees of regulatory agencies may be as reluctant to change as industry. The current bureaucracies have been created around "end-of-the-pipe" control strategies, with most work organized by environmental media (air, land, water). Pollution prevention programs infer a media-integrated approach, with a reduced emphasis on enforcement, thus threatening the current administrative structure.

Lack of Management Education

Many managers are simply unaware of the potential contributions that waste minimization can make to profitability. Most lack the skills to identify and implement these opportunities. Business schools often fail to provide adequate environmental education for business students (32, 35).

Many managers are simply unaware of the potential contributions that waste minimization can make to profitability.

Lack of Financial Resources

For some firms, funds may be unavailable due to an existing debt burden or the cost of capital may simply be too high to support a given pollution prevention project.

CONCLUSIONS

Opportunity for competitive advantage.

Pollution prevention is simply part of the efficient application of corporate resources to satisfy customer needs. It is a potential gold mine, with benefits exceeding total direct labor costs for most manufacturers. Yet with all these benefits it is being adopted only very slowly by businesses. This offers tremendous competitive advantage opportunities to companies who are able to reduce wastes proactively.

Pollution prevention is simply a part of the efficient application of corporate resources to satisfy customer needs.

In Module 2 you will learn about the basic skills needed to identify pollution prevention opportunities. In Module 3 you will examine the role of the business manager in the success or failure of pollution prevention programs.

SUPPLEMENTAL READINGS

The following materials in the Supplemental Readings Booklet (available from HWRIC for $5.00) provide additional information related to topics in this Module:

1. Weinstock, M.P. "Profiting from Pollution Prevention," *Occupational Hazards*, p31-34, December, 1992.

2. Wright, D.R. "Designing a Corporate Environmental Program: The Colgate-Palmolive Approach," In: *GEMI Conference Proceedings - Corporate Quality Environmental Management II: Measurements & Communications*. Global Environmental Management Initiative, Washington, D.C. 1992.

3. Fisher, M.T., "Total Quality Environmental management: The Procter & Gamble Approach," In: *GEMI Conference Proceedings - Corporate Quality Environmental Management II: Measurements & Communications*. Global Environmental Management Initiative, Washington, D.C. 1992.

4. Pferdehirt, W.P. "Roll the Presses But Hold the Wastes: P2 and the Printing Industry," *Pollution Prevention Review*, 3:437-456, 1993.

REFERENCES

1. Rooney, C. "Economics of Pollution Prevention: How Waste Reduction Pays." *Pollution Prevention Review* 3:261-276, 1993.

2. Houseman, J.C. "Parker Pen's Total Quality Management Strategy to Prevent Pollution from Solvent's." *Pollution Prevention Review*, 3:187-195, 1993.

3. Lent, T., Wells, R.P. "Corporate Environmental Management Study Shows Shift from Compliance to Strategy." In: *Understanding Total Quality Environmental Management*, Executive Enterprises Publications Company, Inc., N.Y., 1992.

4. Zosel, T.W. "How 3M Makes Pollution Prevention Pay Big Dividends," *Pollution Prevention Review*. 1:67-72, 1991.

5. Massachusetts Office of Technical Assistance. "Coolant Management at Beloit Corporation" In: *Toxic Use Reduction Case Studies*. Executive Office of Environmental Affairs, Commonwealth of Massachusetts, Boston, MA (Undated)

6. "Prevention Takes Priority Over Cure," *Chemical Week*, p. 27, June 2, 1993.

7. Stewart, S. "Consumer Feedback and Communications: Procter & Gamble's 800-line to Consumers." In: *GEMI Conference Proceedings - Corporate Quality Environmental Management II: Measurements & Communications*. Global Environmental Management Initiative, Washington, D.C. 1992.

8. Craig. E. "Reaching for Customer Satisfaction Through Environmental Programs." In: *GEMI Conference Proceedings - Corporate Quality Environmental Management II: Measurements & Communications*. Global Environmental Management Initiative, Washington, D.C. 1992.

9. Morris, D., Ahmed, I. "Carbohydrates and Pollution Prevention: Making Chemicals and Industrial Materials from Plant Matter." *Pollution Prevention Review*, 3:383-396, 1993.

10. Wells, R.P., Hochman, M.N., Hochman, S.D., and O'Connell, P.A. "Measuring Environmental Success," In: *Understanding Total Quality Environmental Management*, Executive Enterprises Publications Company, Inc., N.Y., 1992.

11. Royal, W.F. "How CEOs See It," *ECO*, p. 6-14, June, 1993.

12. Buckbee, J.C. "Total Employee Involvement Helps the Bureau of Engraving Meet Pollution Abatement Goals," *Pollution Prevention Review*, 1:73-82, 1991

13. ReVelle, P., ReVelle, C. *The Environment: Issues and Choices for Society*, Jones and Bartlett Publishers, Boston, 1988.

14. Malone, G.W. "Corporate Responsibility and the Environment." In: *GEMI Conference Proceedings - Corporate Quality Environmental Management II: Measurements & Communications*. Global Environmental Management Initiative, Washington, D.C. 1992.

15. Schueth, S.J. "Investing in Tomorrow." In: *GEMI Conference Proceedings - Corporate Quality Environmental Management II: Measurements & Communications*. Global Environmental Management Initiative, Washington, D.C. 1992.

16. Becker, M., White, A.L. "Total Cost Assessment: An Overview of Concepts and Methods," In: *Costing and Financial Analysis of Pollution Prevention Projects: A Training Packet,* The Northeast Waste Management Officials' Association, Boston, 1992.

17. *Wall Street Journal*, June 11, 1991.

18. Bush, B. "Connecting to the Needs of Our Customers." In: *Connections for Pollution Prevention: 1993 Spring Conference Proceedings*. National Roundtable of State Pollution Prevention Programs, Washington, D.C., 1993.

19. Hunt, G. "Waste Reduction Techniques: An Overview." *Pollution Prevention Review*, 1:13-25, 1991.

20. Presentation by B. DeSmet, Moline Paint Manufacturing Company at "Practical Pollution Prevention," Illinois State University, November 23, 1992, Normal, Illinois.

21. Massachusetts Office of Technical Assistance. "Zinc Discharge Reduction at the Lowell Corporation." In: *Toxic Use Reduction Case Studies*. Executive Office of Environmental Affairs, Commonwealth of Massachusetts, Boston, MA (Undated)

22. Massachusetts Office of Technical Assistance. "Wastewater and Chemical use Reduction at L&J of New England, Inc." In: *Toxic Use Reduction Case Studies*. Executive Office of Environmental Affairs, Commonwealth of Massachusetts, Boston, MA (Undated)

23. Dykema, K.J., Larsen, G.R. "The Greening of Corporate Culture: Shifting the Environmental Paradigm at Martin Marietta Astronautics Group." *Pollution Prevention Review*, 3:197-211, 1993.

24. Massachusetts Office of Technical Assistance. "Solvent use Reduction at Lampin Corporation." In: *Toxic Use Reduction Case Studies*. Executive Office of Environmental Affairs, Commonwealth of Massachusetts, Boston, MA (Undated)

25. Massachusetts Office of Technical Assistance. "Chemical and Water Use Reduction at Poly-Plating, Inc." In: *Toxic Use Reduction Case Studies*. Executive Office of Environmental Affairs, Commonwealth of Massachusetts, Boston, MA (Undated)

26. "Can Business Save the Environment?", *E Magazine*, p. 28, November/December, 1991.

27. Freeman, H., Harten, T., Springer, J., Randall, P., Curran, M.A., Stone, K." Industrial Pollution Prevention: A Critical Review." J. Air Waste Manage. Assoc., 42:618-656, 1992.

28. Weissman, S.H., Sekutowski, J.C. "Environmentally Conscious Manufacturing: A Technology for the Nineties." In: *Understanding Total Quality Environmental Management,* Executive Enterprises Publications Company, Inc., N.Y., 1992.

29. Allenby, B. "Supporting Environmental Quality: Developing an Infrastructure for Design." *Total Quality Environmental Management*. 3:303-308, 1993.

30. Oakley, B.T. "Total Quality Product Design - How to Integrate Environmental Criteria into the Product Realization Process." *Total Quality Environmental Management*. 3:309-322, 1993.

31. Smith, J. "Overcoming impediments to waste minimization." *EI Digest*, February, 1990.

32. Minnesota Office of Waste Management. *Report on Barriers to Pollution Prevention*. March, 1991.

33. White, A.L., Becker, M., Savage, D.E. "Environmentally Smart Accounting: Using Total Cost Assessment to Advance Pollution Prevention." *Pollution Prevention Review*, 3:247-260, 1993.

34. "Fines at Pilot Plant Scare Industry Off New EPA Voluntary Compliance Plan," *Inside EPA*, June 12, 1992.

35. Post, J.E. "The Greening of Management." *Issues in Science and Technology*. p68-72, Summer, 1990.

36. Toxic Use Reduction Institute. *Curriculum for Toxics Use Reduction Planners, Third Edition*. University of Massachusetts at Lowell, Lowell, MA, 1992.

PROBLEMS AND ACTIVITIES FOR MODULE 1

1. At the business where you work, or with the permission of a local business, examine the contents of one or more "dumpsters" for holding general refuse prior to pick-up by a waste disposal company. Classify the contents into the following two categories of waste:

   - Material produced directly by the business (paper waste generated by the company, scrap product, product packaging, scrap raw materials, etc.).

   - Material generated indirectly from business operations (packaging from inputs or raw materials, paper received from others but related to business operations, junk mail, etc.).

Identify the economic impact on the company for each category of waste. Consider, at least, the following economic impacts:

   A. Waste hauling and disposal cost.
   B. Labor cost.
   C. Cost of raw materials or other inputs.
   D. Cost of product.
   E. Regulatory compliance cost.
   F. Potential liability.

(Note: if you have the opportunity, include wastes other than general refuse, including drums or tanks of waste, emissions to the air, or discharges to waterways or the sewer.)

2. Place each of the following activities on the Waste Management Hierarchy (Reduce, Reuse, Recycle, or Dispose). Identify the primary costs which could be reduced by adopting options one or two steps higher on the Hierarchy, and suggest what such options might involve. Be sure to consider employee health and safety, product safety, damage to the environment , and harm to public health through environmental exposures. (You are encouraged to use references from your library about the health and safety consequences of chemicals.) (Adapted from ref. 36)

   A. Adding water to a sodium hydroxide waste stream before releasing it to the sewer in order to meet waste water discharge concentration requirements.

   B. Burning up used motor oil in the company incinerator instead of sending the oil to a waste hauler.

   C. Burning up used motor oil in the company boilers (for space heating) instead of sending the oil to a waste hauler.

D. Replacing solvent cleaning agents with detergent and water cleaning operations to avoid the use of chlorinated organic solvents such as methylene chloride.

E. Using cadmium-based paint from one paint mixing tank in the formulation of the next batch of paint.

F. Sending used zinc electroplating bath fluids to a local commercial recycler instead of discharging to sewer.

G. Replacing the nozzle of high pressure paint applicators to better focus the chromium pigment paint spray stream.

H. Reformulating an adhesive to incorporate fewer toxic chemicals into the end product.

3. Use the Valley Paints, Inc. case in the Supplemental Readings Booklet for this role-playing activity (adapted from ref. 36). Divide the class into pairs of groups, with each group having three to five members. One group should take the role of management and the other should take the role of the pollution prevention planning group.

   The pollution prevention planning group at Valley Paints has called an initial meeting with management to convince them that the company must commit to an integrated pollution prevention program and begin implementation of some pollution prevention options immediately. The management group is generally concerned about the environment but they are not convinced that a pollution prevention program is the answer. They are concerned about additional environmental regulation. The are also very concerned about the economic impact of implementing a pollution prevention program during a down economy.

   The management group should discuss their concerns about implementing the options listed in the case. The pollution prevention planning group should prepare a presentation that will convince management that a pollution prevention program can be implemented immediately with limited risk. Once prepared, the pollution prevention planning group will make their presentation to the management group and respond to any of management's concerns.

4. Apollo Plastics is a mid-size manufacturing firm producing plastic housings for electronic equipment. Though they currently hold large contracts with several major electronics firms, contracts are up for bid approximately every two years and the bidding process is highly competitive in price, quality, and delivery. Apollo is privately owned by the company president, and has a relatively shallow management structure. Labor is non-union. The company adopted most of its production technology 15 years ago when it was formed and has made few changes since then, despite the recommendation of its design engineer.

   Product is produced by heating a mixture of plastic resins, adding coloring and conditioning agents, and then molding the plastic into the appropriate shape. The product is then finished and packaged for delivery. In the last year, Jennifer Coffee, director of manufacturing, has become concerned about not only the cost of disposing of the large quantity of solid and liquid waste generated by the plant, but also the cost of complying with the many environmental, occupational, and transportation laws to which the plant is subject. Of particular concern are the hazardous materials used as plastic additives. In addition, several industrial customers have stated that they foresee a time in the near future when they will have to take back their electronic components from consumers at the end of the product's useful life and recycle the components. They want to know how Apollo will help make this possible. They have also expressed a desire to reduce packaging waste from Apollo.

Jennifer is considering the value of a pollution prevention program at Apollo, but she has a number of questions. (A) What kinds of environment-related costs might Apollo be experiencing due to its current product design and operating practices? (B) What kinds of pollution prevention opportunities would most likely benefit Apollo? (C) In what ways would such opportunities enhance the competitive position of Apollo? (D) What barriers to adoption of pollution prevention measures is Apollo most likely to experience? Jennifer has asked for your advice in answering these questions. What would you tell her?

5. Holiday Printing, Inc. prints greeting cards, and is a subsidiary of a large greeting card company. It is located along the northern Atlantic coast. Holiday Printing is under considerable pressure from its parent company to cut costs and increase quality. The relatively large managerial sector at Holiday has been reduced 20% in the last three years, primarily through elimination and restructuring of middle management positions. The plant has been in operation since the 1920's and was a private printing business until purchased by the greeting card company in 1974. Labor has been unionized since 1956.

   Holiday uses a gravure printing process, in which multiple colored inks are applied to card stock. Toluene, a volatile organic compound (VOC), is the primary solvent used to clean presses and other equipment. It evaporates rapidly, and because it is used on equipment throughout the plant, it would be difficult and expensive to capture and control emissions.

   Andrew Larson, plant manager for Holiday recently received a memo from the health and safety supervisor at the plant stating that the state environmental **protection** agency will be doubling its air pollution permit fee and will be reducing the amount of VOCs that it will allow Holiday to emit into the air. This is because of tighter state and federal laws to control ozone concentrations in cities along the Atlantic coast. In addition, the laundry that receives Holiday's clean-up rags recently indicated that it cannot meet sewage discharge limits for toluene due to the toluene content of Holiday's rags. On top of this, a letter came last week from the marketing division of the parent company indicating that 35% of its potential customers are concerned about the environmental impact of greeting cards. In particular, these customers are looking for cards printed on recycled paper and paper that has not been chlorine-bleached. The parent company wants Holiday to use such paper for at least 50% of its product within three years without compromising quality.

Mr. Larson thinks that these developments may provide the opportunity to initiate a pollution prevention program at Holiday, but he has a number of questions. (A) What kinds of environment-related costs might Holiday be experiencing due to its current product design and operating practices? (B) What kinds of pollution prevention opportunities would most likely benefit Holiday? (C) In what ways would such opportunities enhance the competitive position of Holiday and its parent company? (D) What barriers to adoption of pollution prevention measures is Holiday most likely to experience? Mr. Larson has asked for your advice in answering these questions. What would you tell him? (For additional information on the printing industry, see the article in the Supplemental Readings Booklet: Pferdehirt, W.P., "Roll the presses but hold the waste: pollution prevention and the printing industry," *Pollution Prevention Review*, Autumn, 1993)

(Note: you may wish to visit a greeting card display in a retail store. What proportion of cards are printed on recycled or non-chlorine-bleached paper? How do they use this product attribute to their competitive advantage?)

MODULE 2
POLLUTION PREVENTION
AND PROCESS IMPROVEMENT

LEARNING OBJECTIVES

1. Given information on the types and rates of inputs received, product shipped, and waste by-product produced; perform and present a materials balance for a facility.

2. Given a facility-level materials balance, and information on the direct, tangible costs of waste generation, calculate and present a financial impact analysis of waste generation and an efficiency analysis for production.

3. Given the information below on a process and its operations, perform and present a materials balance for each operation in the process.
   a. the supply rate of materials to each operation,
   b. the production rate of product and by-product from each operation, and
   c. the rate at which any by-product is internally reused or recycled.

4. Given a process-level materials balance, and information on the direct, tangible costs of by-product generation, calculate and present a financial impact analysis of waste generation and an efficiency analysis for each operation and the process as a whole.

5. Given the information from (3) and (4), above, identify and prioritize the primary contributing factors to waste generation and waste generation costs for a company process.

6. Given a business scenario, identify the most likely significant indirect or intangible costs associated with waste generation.

MODULE 2

POLLUTION PREVENTION AND PROCESS IMPROVEMENT

Warren Johnson, Purchasing Director for the Midwest Manufacturing Company, was preparing for an upcoming meeting of directors from all of the plant's divisions. The U.S. Environmental Protection Agency had recently filed a suit against the company alleging violations of several air pollution regulations, and requested fines of over $500,000. There has already been considerable negative publicity resulting from the suit. Potential damage to the company image could easily exceed the value of the fine. The Plant Manager told the senior managers that the company is "bleeding to death from waste" and called the meeting to identify ways in which future problems of this type could be avoided. In particular, she is interested in exploring how the plant can reduce the volume of pollutants generated without compromising product quality or profitability. This will require the input of every division in the plant.

Warren has made a reputation for himself within the company as a creative problem solver. He reviewed in his mind the six steps he uses in solving a problem: 1. Define the problem, 2. Analyze the root causes of the problem, 3. Identify alternative solutions, 4. Select an alternative and plan its implementation, 5. Implement the solution, and 6. Evaluate and improve the solution. Based upon these, Warren wrote down five questions to introduce at the meeting. He knew that it would be necessary to answer these questions before the company could effectively reduce pollution. But as he looked over his list of questions, he wasn't sure how to find the answers.

His questions were:

1. *How can we identify the extent of the waste generation problem?*

2. *How can we identify the important root causes of waste generation at the plant?*

3. *How can we identify the impact of waste generation on the financial health of the company?*

4. *How can we identify potential solutions to important root causes of waste generation?*

5. *How should we select the potential solutions we want to implement?*

This Module explores each of these five questions.

Hewlett-Packard's circuit board plant in Sunnyvale, California faced strict limits and high treatment and disposal costs for its nickel wastes due to the sensitivity of the San Francisco Bay ecosystem. The plant operated two nickel plating lines. Waste bath solution and rinse water were treated to remove nickel. The sludge was then sent off-site for metal reclamation. After studying the process, staff were able to make a number of changes. Improved monitoring and maintenance allowed an increased production rate while maintaining product quality. A new control system allowed different types of boards to be produced without interrupting production flow, further increasing production efficiency. Line maintenance was moved to off-shift times instead of shutting one line down during the day shift. Finally, instead of two lines operating simultaneously during one shift, one line could be operated over two shifts. These process improvements not only reduced sludge production by over 50 percent but saved the plant $110,000 per year. The savings resulted not from major technological innovation, but from a number of small improvements resulting from a careful analysis of the process (1).

MATERIALS BALANCE FOR PROBLEM IDENTIFICATION

What goes up must come down, and what goes in must come out.

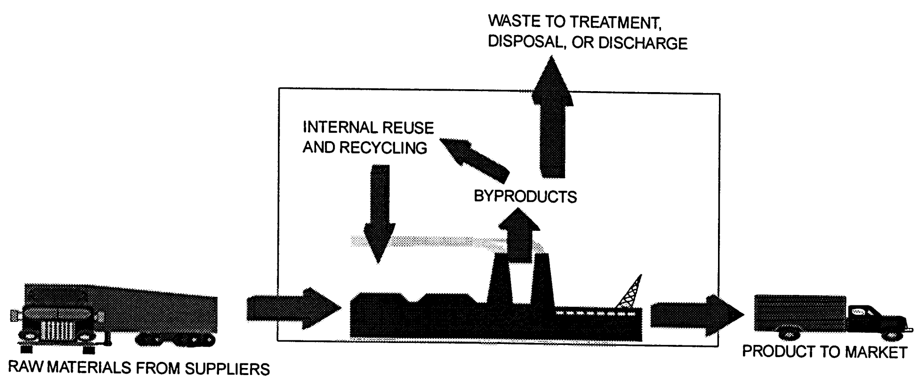
Introduction

In the 14th century an Italian monk named Piccoli recognized that financial resources may enter a firm or leave a firm, but are neither created or destroyed within the firm. The nature of the resources may change, but they must remain in balance. Assets must balance liabilities plus retained earnings. Piccoli's Financial Balance Sheet is today a basic tool of business management, giving managers the opportunity to identify sources of potential danger in the financial health of the firm.

A Materials Balance is like a financial balance sheet for materials.

Similarly, mass can be neither created nor destroyed (ignoring some rather extreme atomic processes). *Inputs* entering a facility are converted into *products* or *by-products* and must either come out of the facility or accumulate within it (inventory). If we picture a production facility as a box with inputs and outputs, it would look something like Figure 2-1. Products are those items from which the firm derives its profits; that is, products have a market value greater than the sum of resources expended by the firm to create them. By-products, on the other hand, have a market value less than the sum of resources expended to create them. In fact, many by-products have a zero or negative market value! For example, the firm may have to pay to have the by-product removed, or the by-product may produce a legal liability. When a by-product leaves the company it is called a *waste*. However, some by-products may remain in the plant to be recycled, allowing some of the value of the by-product to be reclaimed by the firm.

Figure 2-1: Conversion of raw materials into products and by-products.



By-products are a drain on the resources of the company. They represent lost materials, wasted labor, liabilities, and other expenses. Reducing by-product losses can significantly improve the financial position of the company. Such losses can be reduced either by decreasing the amount of by-product produced (increasing production efficiency), increasing the market value of by-products, or reclaiming a greater proportion of the value of by-products. This module focuses on identifying and reducing by-product generation.

The purpose of a Materials Balance conducted at the facility level is to guide by-product reduction efforts to the highest priority wastes. To illustrate how a Materials Balance is performed and how it can be used to guide by-product reduction efforts, let's consider the case of Warren Johnson's company from the opening of this Module.

The purpose of a Materials Balance is to guide by-product reduction efforts to the highest priority wastes.

Assume that the Midwest Manufacturing plant uses only two raw materials , A and B, to produce its product, AB (a process flow sheet is presented in Figure 2-2). Records indicate that last year the company received 1,000 tons of A and 500 tons of B, and shipped 1,200 tons of AB. If AB is composed of 2/3 A and 1/3 B, this means 800 tons of A and 400 tons of B were shipped as product. Assume records also indicate that inventory of product and raw material B were unchanged, while inventory of raw material A increased 100 tons over the year. This suggests that 100 tons of A (1,000 tons received minus 800 tons in product, minus 100 tons as inventory) and 100 tons of B (500 tons received minus 400 tons as product) were lost as by-product during the year. Plant records indicate that a solid waste by-product containing 50 tons of A and 25 tons of B were removed by a waste disposal firm last year. Additional by-product containing 50 tons of A and 25 tons of B were discharged into the air. This leaves 50 tons of B which must be accounted for. Further investigation found that this 50 tons was disposed of a "contaminated" raw material B. These figures are displayed in balance sheet format in Tables 2-1 and 2-2.

Table 2-1: Materials Balance for material A, year ending December 31.

Material In		
Raw Material A Received		1000 tons[a]
Material Out		
Material A in Shipped Product	800 tons[b]	
Material A in AB By-product solid waste	50 tons[c]	
Material A in AB By-product air emissions	50 tons[d]	
Material Accumulated		
Raw material A inventory change	100 tons[e]	
Total of Material Out Plus Material Accumulated		1000 tons

a - from shipping papers
b - from product shipping papers. Product composed of 2/3 A according to production specifications.
c - from waste hauling receipts
d - from engineering estimates of air emissions
e - from inventory audit, December 31

It is important to note, however, that information is often imprecise or missing. Measuring and accounting for material can be difficult and prone to error. For example, air emissions are difficult and often estimated from studies done at other plants, which may involve other materials or processes. Even waste hauling receipts may be imprecise. When dealing with tens or hundreds of tons, it is not uncommon to fail to account for hundreds of pounds of materials.

Table 2-2. Materials Balance for Material B, year ending December 31

Material In		
Raw Material B Received		500 tons[a]
Material Out		
Material B in Shipped Product	400 tons[b]	
Material B in AB By-product solid waste	25 tons[c]	
Material B in AB By-product air emissions	25 tons[d]	
Material B "contaminated"	50 tons[e]	
Total of Material Out Plus Material Accumulated		500 tons

a - from shipping papers
b - from product shipping papers. Product composed of 2/3 A according to production specifications.
c - from waste hauling receipts
d - from engineering estimates of air emissions
e - from waste hauling receipts

Materials Balance can be used to estimate production efficiency.

A Materials Balance analysis at the facility level can also be used to estimate the efficiency with which the process converts inputs into product. In the example above, the efficiency with which Warren Johnson's company converts A into product is 80 percent (800 tons in product/1,000 tons raw material). The efficiency with which B is converted into product is also 80 percent (400 tons in product/500 tons raw material). Process efficiency less than 100 percent represents wasted materials, labor, and other resources. Improvements in process efficiency are a source of potential profits.

Table 2-3 summarizes both a more simple (Waste Audit), and more complex (Mass/energy Balance) version of the Materials Balance. The Waste Audit may be useful if time or resources are not available for a Materials Balance. The Mass/energy Balance, on the other hand, may be needed to achieve efficiency improvements beyond those attainable with a Materials Balance.

MATERIALS BALANCE TO IDENTIFY ROOT CAUSES

Applying Materials Balance to individual processes and operations.

Introduction

Any facility contains one or more processes, each of which completes a series of sequentially related operations. Each operation involves the conversion of inputs into outputs. For example, a painting operation converts an unpainted product and paint into a painted product and paint waste. A drilling operation in a metal fabricating process may convert a sheet of metal and a drill, into a sheet of metal containing 10 holes plus

Table 2-3: Three types of facility-level analyses

Waste Audit	Focuses only on the output side and only on those wastes subject to environmental regulation, such as wastes legally designated "hazardous" under the Resource Conservation and Recovery Act (RCRA), wastes subject to the Clean Air Act, Clean Water Act, and Title III of Superfund Amendments and Reauthorization Act (SARA). Discharge data are usually available within the company for compliance purposes. Wastestreams can be prioritized relatively easily by volume or costs of compliance. Many wastes, however, are not subject to regulation and may not be reported. Useful if time and organizational commitment are limited and if the primary intent is to reduce the facility's regulatory burden. Not an effective approach to improving operational efficiency. Regulatory agencies may recommend this approach since their work is oriented to the individual chemicals and wastestreams exiting the facility. However more thorough analyses will lead to more significant process improvements.
Materials Balance	A balance of the primary inputs, outputs, and accumulations within the plant. Uses company records to identify the primary raw material inputs to the process; the use of environmental reports or permits to estimate the amount of raw materials present in gaseous, liquid, and solid wastes from the process; and product specifications testing information to estimate the amount of raw materials in final product. An example of this materials balance approach is provided in Appendix A for a facility with a single, simple process. Most facilities would be more complex but the same approach to performing the facility-level analysis is used.
Mass/energy Balance	This approach begins with a detailed accounting of all material and energy inputs, usually obtained from purchasing records. All inputs must ultimately be accounted for in the outputs, either products or waste. Usually a very involved, engineering activity, but provides the most valuable information on wastes and process efficiencies.

waste metal. In a letter-producing operation, a secretary may convert paper, envelope, stamp, printer and printer ribbon into a letter and waste ribbon (though all of the components of the letter may become the receiver's waste).

Applying Materials Balance concepts to individual processes within a plant, and to individual operations within each process, can both further define the problem and begin to uncover its root causes. Just as "what goes in must come out" applies to a facility as a whole, it applies to each process and operation.

Just as "what goes in must come out" applies to a facility as a whole, it applies to each process and operation.

Process Flow Sheets

The Materials Balance begins by identifying the processes within a facility. This is, to some extent, an arbitrary decision, since one process may flow directly into another. It is useful, however, to divide the overall process into smaller processes in order to keep the analysis manageable. Look for natural breaks in the overall process, such as temporary storage or longer transports, or where products from several small processes come together. Be sure to include materials storage and transport in a process. Appendix A (Standard Metal Products, Co.) provides an example of a process so simple that no subdivision is required. However, the example in Appendix B (Fred's Foundry) required breaking the overall process into five smaller processes.

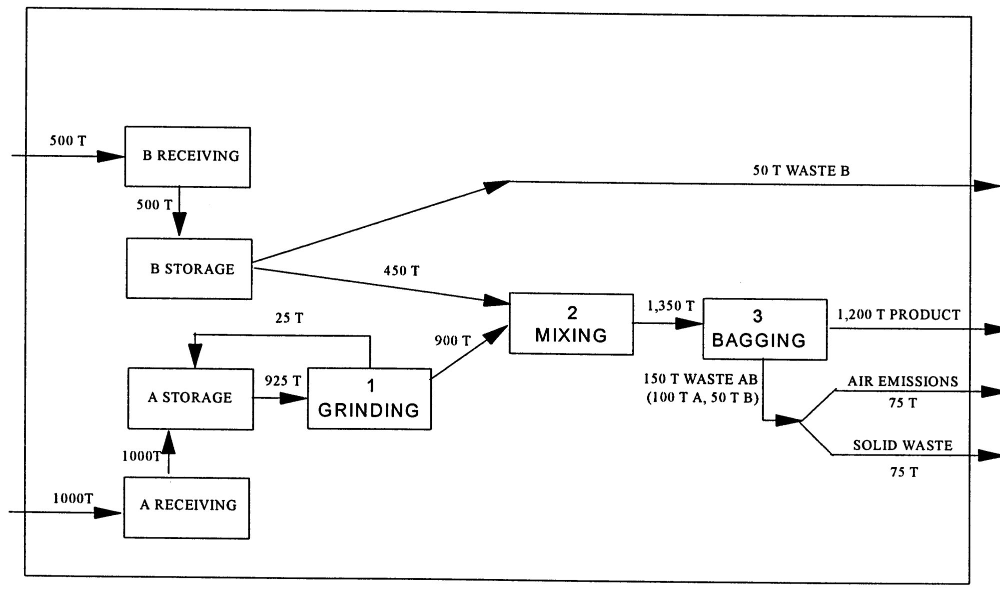
Once the smaller processes in a plant have been identified, a diagram of the process, called a process flow sheet, should be created showing each operation in the process and the flow of product through the process. The input of materials at each operation should then be added. Finally the outflow of materials from each operation should be added. Remember, outflows may be product (intended for further processes and ultimate sale) or by-products. By-products are simply non-product material that has not yet left the plant. For example, in a plastic press operation, off-spec product is a by-product. It may be ground and recycled, and, therefore, not a "waste". If the plastic were contaminated or improperly formulated, however, it may not be recyclable and would be disposed off-site, becoming a "waste". The distinction between waste and by-product is useful since there may be many ways to use by-products within a plant (see examples in Appendices A and B).

A Process Flow Sheet shows the flow of materials through a process.

For Midwest Manufacturing production of AB occurs in one process, having three operations. In Operation 1, A is finely ground; in Operation 2, A and B are mixed and dried to make AB; and in Operation 3 AB is bagged for shipment. This is represented in the process flow sheet in Figure 2-2.

Note also the flow of materials in Figure 2-2. We already know the amounts of A and B received. Assume, from production records, we find that 925 tons of A were fed to Operation 1. Twenty-five tons of A is emitted to the air in Operation 1, but is captured by air pollution control equipment and reused by returning it to storage. This, combined with the 75 tons of unused A, results in our reported increase of 100 tons in inventory of raw material A.

Figure 2-2: Process flow sheet for Midwest Manufacturing Company.



Applying Material Balance at the facility level identified the sources of each by-product and the fate of by-products that do not become waste.

Production records indicate that 900 tons of A and 450 tons of B were fed to Operation 2. This implies that 50 tons of B were stored or wasted between receiving and Operation 2. Investigation finds that 50 tons of "contaminated" B were removed from raw material storage. Further investigation also finds that most of the losses of raw material B occur from off-spec material received from the supplier and is simply discarded as "contaminated".

Operation 3 received 1,350 tons of AB, indicating no loss of material in Operation 2. However, Operation 3 produced only 1,200 tons of bagged product, resulting in a loss of 150 tons. Further investigation finds that the losses occur from spillage during bagging. Seventy-five tons of spillage are collected from the production floor and discarded as solid waste. The other 75 tons are airborne dust. Emissions from bagging would be difficult and expensive to collect and control. No air pollution control equipment is currently used at Operation 3 and all 75 tons are discharged into the atmosphere.

Further investigation found that the spillage at Operation 3 is due to 1) agitation used to keep the powdered product flowing, 2) the free fall of product into the bags, and 3) the bag remaining completely open on top during filling.

FINANCIAL IMPACT OF WASTE GENERATION

Integrating cost data into the Materials Balance.

Using Direct, Tangible Costs

There are many types of costs which should be considered in estimating the financial impact of waste generation.

Materials Balance information can be used to estimate waste costs at the facility level as well as at each process and operation. There are many types of costs which should be considered in estimating the financial impact of waste generation. As indicated in Module 1, the primary costs of waste are lost raw materials, labor costs, disposal costs, and waste handling costs. Though other costs associated with wastes, such as future liability, can be significant, the intent of this section is to demonstrate how simple financial analyses can be conducted using the most tangible costs.

For Warren Johnson's company, assume that raw material A costs $1,000/ton and raw material B costs $2,000/ton. Disposal costs for waste A, B, or AB by-product are $400/ton. At the facility level, this implies that the costs of waste generation were at least $350,000 during the last year (see Tables 2-4a and b).

Applying the same principles at the process level provides a better picture of the costs of waste generation. The Cost Accounting Department estimates that receiving, transporting, and sorting off-spec or contaminated B costs about $80/ton in labor and energy. Recycling A from Operation 1 costs about $70/ton in labor and energy. By the time AB passes through Operation 3, bagging, about $600/ton in value from labor and energy have been added. Cost analysis tables can be constructed for each operation in the process. Tables 2-5 though 2-7 present analyses for Receiving and Transporting Raw Material B, Operation 1, and Operation 3, respectively. Estimates of waste generation costs increased to $411,750 when examining costs from a process level. The increase is primarily due to consideration of labor and energy expenditures on wasted material.

The analyses also help to prioritize the waste streams.

Note that in addition to providing an estimate of the direct tangible costs associated with waste generation, the analyses also help to prioritize the waste streams. Clearly, by-product generated during Operation 3 has the greatest financial impact on the firm.

Indirect and Intangible Costs

Air emissions had no disposal costs but <u>had</u> resulted in a $500,000 fine.

Waste generation can result in substantial indirect and intangible costs. These range from worker protection to administrative fines and future environmental liabilities. For example, Warren Johnson's company has no disposal costs associated with air emission losses from the bagging operation. However, this grossly underestimates the financial impact of such emissions on the company. Failure to control these emissions has already resulted in a fine of $500,000. The potential legal liability from damage to the surrounding population and environment may be even greater.

Capturing these indirect or intangible costs in a financial analysis is difficult, and depends largely on the interest and ability of management. As such, this topic is developed in greater detail in Module 3, Pollution Prevention and the Business Manager. Yet it is important, when conducting analyses using direct, tangible costs, to keep in mind the potentially significant costs that do not appear in the results.

When Costs are Hard to Estimate

Some firms have sought ways to prioritize waste streams using non-financial data. The most common approach is to use some estimate of waste toxicity, that is, the ability of the waste to produce illness in exposed persons. Multiplying the volume of waste produced by the toxicity results in an index representing the potential liability of the waste to the firm. (2)

Others have used more sophisticated schemes, including consideration of the extent of worker exposure, the method of waste disposal, the fate of the waste in the environment, and other factors (3). As these techniques are improved, they will become more commonly used in business.

Table 2-4a: Process efficiency and by-product composition for year ending December 31.

	Material A	Material B
Input Amount (tons)	1,000	500
Product Amount (tons)	800	400
Process Efficiency	80%	80%
By-Product Amount (tons)		
AB solid waste	50	25
AB air emissions	50	25
B solid waste		50

a - as AB solid waste
b - as AB air emissions
c - as B

Table 2-4b: Direct costs of by-products for year ending December 31. (entries are in $1,000's)

Cost	AB Solid Waste (By-Products)	AB Air Emission (By-Products)	B Solid Waste (By-Products)	Total
Lost Material	100[a]	100[b]	100[c]	300
Disposal	30[d]	0[e]	20[f]	50
Total	130	100	120	$350

a - $1,000/ton x 50 tons A, $2,000/ton x 25 tons B
b - $1,000/ton x 50 tons A, $2,000/ton x 25 tons B
c - $2,000/ton x 50 tons B
d - $400/ton x 75 tons
e - no direct tangible costs for air emissions
f - $400/ton x 50 tons

Table 2-5a: Process efficiency and by-product composition for Receiving, Handling and Storage of Raw Material B for year ending December 31.

	Material B
Input Amount (tons)	500
Product Amount (tons)	450
Process Efficiency	90%
Waste Amount[a] (tons)	50

a - as "contaminated" B solid waste

Table 2-5b: Direct costs of by-products for Receiving, Handling and Storage of Raw Material B for year ending December 31 (entries are in $1,000's).

Cost	B Solid Waste
Lost Material	100[a]
Labor/energy	4[b]
Disposal	20[c]
Total	120

a - $2,000/ton x 50 tons
b - $80/ton x 50 tons
c - $400/ton x 50 tons
d - $400/ton x 75 tons
e - no direct tangible costs for air emissions
f - $400/ton x 50 tons

Table 2-6a: Process efficiency and by-product composition for Operation 1, Grinding of Raw Material A, for year ending December 31.

	Material A
Input Amount (tons)	925
Product Amount (tons)	900
Process Efficiency	97%
By-product Amt.[a] (tons)	25

a - as A, returned to storage for reuse

Table 2-6b: Direct costs of by-products. for Operation 1, Grinding of Raw Material A, for year ending December 31 (entries are in $1,000's)

Cost	Reused A
Lost Material	0[a]
Labor/energy	$1.750[b]
Disposal	0[c]
Total	$1.750

a - all material is reused
b - $70/ton x 25 tons
c - all material is reused

Table 2-7a: Process efficiency and by-product composition for Operation 3, Bagging of Product, for year ending December 31.

	Material A	Material B
Input Amount (tons)	900	450
Product Amount (tons)	800	400
Process Efficiency	89%	89%
Waste Amount (tons)		
AB solid waste	50	25
AB air emissions	50	25

Table 2-7b: Direct costs of by-products for Operation 3, Bagging of Product, for year ending December 31 (entries are in $1,000's).

Cost	By-Products: AB Solid Waste	By-Products: AB Air Emission	Total
Lost Material	100[a]	100[b]	200
Labor/energy	30[c]	30[c]	60
Disposal	30[d]	0[e]	30
Total	160	130	$290

a - $1,000/ton x 50 tons A, $2,000/ton x 25 tons B
b - $1,000/ton x 50 tons A, $2,000/ton x 25 tons B
c - $600/ton added value x 75 tons
d - $400/ton x 75 tons
e - no direct tangible costs for air emissions

IDENTIFYING POLLUTION PREVENTION SOLUTIONS

Creative ways to reduce costs and improve competitiveness.

Once pollution prevention priorities have been selected, methods for reducing waste must be identified. There appear to be two common approaches. Some firms use a small group of individuals specializing in pollution prevention, typically associated with engineering units. The second approach involves a variety of employees, including the line workers and supervisors of the process in question. In the first method, solutions may be implemented more quickly. However, in the second case, solutions may be more effective since they are created by those who must implement them.

In some firms, solutions are generated in engineering units, while other firms involve a variety of employees.

No matter which approach is used, it is advantageous to consider a wide variety of options. Brainstorming is particularly useful at this point (4). Some authors suggest using a list of pollution prevention strategies, such as those in Table 2-8, to be sure that all such options are explored by the group. It is important to minimize evaluation of suggestions at this point. Often apparently impossible options turn out to be quite feasible, and sometimes initially outrageous ideas can trigger a very practical idea. Care should be taken not to discourage creative thinking.

It is advantageous to consider a wide variety of options. Often apparently impossible ideas turn out to be quite feasible.

The group should also seek information from others. A large number of case studies are available in the published literature. Case studies are also available via computer database. USEPA and your state pollution prevention assistance agency should be contacted for updated databases. In addition, public and private consulting services can provide practical examples. Many states offer free or low-cost consultation through non-regulatory agencies. Your state pollution prevention assistance agency can direct you to such services if available.

Benchmarking represents another way to identify pollution prevention options. Benchmarking involves learning from others who are considered "best in class" at dealing with a specific pollution prevention program. Benchmarking competitors can be difficult since it requires collaboration. However, in many cases non-competitors may have similar operations. Degreasing operations, for example, are used in many industries. Office waste is generated in every business. "Best in class" companies can sometimes be identified through word of mouth, trade associations, suppliers, or the published literature.

Table 2-8: Selected pollution prevention strategies for waste by-product losses through reduction, reuse, or recycling. (4, 6, 7)

Reduction
- Inventory management
  Inventory reduction
  Materials handling and storage
- Process modifications
  Operating procedures
  Maintenance procedures
  Material change
  Equipment modification or modernization
- Volume Reduction
  Waste separation
  Concentration
- Process redesign
- Product redesign

Reuse

Recycling
- On-site
- Off-site

SELECTING A POLLUTION PREVENTION SOLUTION

Meeting your needs and those of your customers.

Selecting one pollution prevention option from among a list of options can be difficult. The selection criteria should be clear and agreed upon by the personnel involved. Several common criteria are listed in Table 2-9.

In many cases, it will not take a detailed analysis to identify the relatively few feasible options, and further analysis can be narrowed to these. However, the quality movement in business has established a very important fact: MANY THINGS WHICH APPEAR TECHNICALLY OR ECONOMICALLY INFEASIBLE CAN BE MADE FEASIBLE, given time, creative thinking, and focused effort. If a pollution prevention option has very great benefits but appears infeasible, don't dismiss the option, but continue to work on its feasibility over the long-term.

Table 2-9: Common evaluation criteria for pollution prevention options (2, 4).

1. Technical feasibility
2. Amount and timing of costs
3. Amount and timing of benefits
4. Effect on product quality
5. Effect on worker health and safety
6. Effect on productivity
7. Effect on other portions of the process
8. Effect on employee morale
9. Effect on product sales
10. Effect on company image
11. Consistency with expertise and culture of th organization

Proper economic analysis of pollution prevention options is critical at this stage. Not only is it important to identify the best options, but it is also critical to assure that the selected option is considered fairly as it competes with other uses of company resources. "Total Cost Accounting" (TCA) is a method for accurately reflecting the impact of pollution prevention options on the long-term profitability of the firm. Proper methods for TCA are still a subject of debate and are presented in greater detail in Module 3. Examples in this Module are simplified, and the reader is referred to Module 3 for a more thorough discussion of TCA issues.

A proper economic analysis helps to identify the best options, but also assures that pollution prevention strategies compete fairly with other investment alternatives.

A key consideration in capital budgeting is return on investment (ROI), using indicators such as net present value (NPV), profitability index (PI) or internal rate of return (IRR). In using any indicator, two factors are particularly important (see Module 3). First, consider all costs and benefits that can reasonably be attributed to the project. Pollution prevention options often involve significant indirect costs and benefits, and failure to consider these can make as much as a two-fold change in projected return on investment (5). Second, use a time frame long enough to adequately capture the costs and benefits. Many savings associated with pollution prevention, such as reduced waste disposal or energy costs, continue, or even grow, long into the future. Short time horizons of 2-5 years can significantly underestimate the benefits accruing to the firm from pollution prevention programs.

Pay-back period is a simple and popular way to examine return on investment, but is fails to consider the time value of money.

A capital budgeting indicator that is widely used, yet inferior to NPV, PI, or IRR, is the pay-back period. Undoubtedly, its popularity is due to its intuitive appeal: How quickly can the investment return its value to the firm? An investment of $10,000 returning a benefit of $2,000 per year has a payback period of five years. The appeal is obvious, but so is the drawback; payback fails to consider the time value of money. Ultimate decisions about implementation of pollution prevention options should not be made without consideration of one of the indicators employing the time value of money.

Some costs or benefits may be difficult or impossible to accurately quantify, particularly those related to environmental and worker risks or consumer and community goodwill. Even if not quantifiable, estimates of projected impact should accompany option assessments to alert decision makers to all costs and benefits.

Module 3 provides a more detailed discussion of financial analysis and includes examples of capital budgeting decisions.

MONITORING AND IMPROVING POLLUTION PREVENTION PROJECTS

Assuring success through continuous improvement.

Pollution prevention projects must be monitored after implementation to both assure that the program is successful and to provide the information needed to make future improvements. Accurate data must be collected to insure that pollution prevention and financial goals are met. Failure to meet these goals should lead to re-evaluation of projects. In fact, the data needed for project monitoring is generally the same data needed for the original project analysis. Often, the needed data are not available, and a pollution prevention project may include the establishment of certain data collection and reporting programs. The types of data needed for program analysis and monitoring are discussed in greater detail in Module 3.

CONCLUSIONS

Warren Johnson's firm targets pollution prevention priorities.

At the meeting of division directors, Warren Johnson introduced the idea of a Materials Balance for the plant and for each of the plant's processes. The other directors agreed. The results clearly identified several wastegenerating operations which were not only causing environmental problems for the firm, they were costing thousands of dollars yearly in lost materials and labor.

The directors selected the bagging operation as the top priority. Using a team comprised of personnel from manufacturing, engineering, marketing, and other divisions, a variety of options were developed for reducing emissions during bagging. One option suggested by a line worker was to attach a long tube to the bagging machine so that product could be delivered directly to the bottom of the bag instead of dropping in a free fall. The team decided to try the idea. The modification cost less than $1,000 but reduced emissions during bagging by 75%.

Encouraged by their success, the team continued to work on additional ideas to control waste from the bagging operation as well as other operations throughout the plant.

SUPPLEMENTAL READINGS

The following materials in the Supplemental Readings Booklet (available from HWRIC for $5.00) provide additional information related to topics in this Module:

1. Pferdehirt, W.P. "Roll the Presses But Hold the Wastes: P2 and the Printing Industry," *Pollution Prevention Review*, 3:437-456, 1993.

2. Willis, D.G. "Pollution Prevention Plans - A Practical Approach," *Pollution Prevention Review*, 2: 347-355, 1991.

3. "Valley Paints, Inc.," In: Curriculum for Toxics Use Reduction Planners, Third Edition. Toxic Use Reduction Institute, University of Massachusetts at Lowell, Lowell, MA, 1992.

4. White, A.L, Becker, M., Goldstein, J. "Coated Fine Paper Mill," In: *Alternative Approaches to the Financial Evaluation of Industrial Pollution Prevention Investments*, New Jersey Department of Environmental Protection, Trenton, NJ, 1991.

5. White, A.L, Becker, M., Goldstein, J. "Paper Coating Mill," In: *Alternative Approaches to the Financial Evaluation of Industrial Pollution*

Prevention Investments, New Jersey Department of Environmental Protection, Trenton, NJ, 1991.

6. Whittman, M.R. "Williams Precision Valve Company, Inc.," In: *Costing and Financial Analysis of Pollution Prevention Projects: A Training Packet*, Northeast Waste Management Officials' Association and Massachusetts Office of Technical Assistance, Boston, MA, 1992.

7. Whittman, M.R. "Wrayburn Jewelry Company, Inc.," In: *Costing and Financial Analysis of Pollution Prevention Projects: A Training Packet*, Northeast Waste Management Officials' Association and Massachusetts Office of Technical Assistance, Boston, MA, 1992.

8. Whittman, M.R. "Lightolier, Inc.," In: *Costing and Financial Analysis of Pollution Prevention Projects: A Training Packet*, Northeast Waste Management Officials' Association and Massachusetts Office of Technical Assistance, Boston, MA, 1992.

REFERENCES

1. Malachowski, M. "Hewlett-Packard's Sunnyvale Facility is a Leader in Waste Minimization." *Pollution Prevention Review,* 1:405-410, 1991.

2. Hanlon, D, Fromm, D. "Waste Minimization Assessments," In: *Hazardous Waste Minimization,* H.M. Freeman, ed., McGraw-Hill, NY, NY, 1990.

3. Rice, D.A., Hopkins, M.A. "A Preliminary Screening Tool for Ranking Pollution Prevention Analysis at Department of Defense Facilities," In: *Proceedings of the Air and Waste Management Association 85th Annual Meeting,* Air and Waste Management Association, Pittsburgh, PA, 1992.

4. Toxics Use Reduction Institute, *Curriculum for Toxics Use Reduction Planners*, University of Lowell, Lowell, MA, 1992.

5. White, A.L., Becker, M., Savage, D.E. "Environmentally Smart Accounting: Using Total Cost Assessment to Advance Pollution Prevention" *Pollution Prevention Review*, 3:247-260, 1993.

6. Hunt, G.E., "Waste Reduction Techniques and Technologies," In: *Hazardous Waste Minimization,* H.M. Freeman, ed., McGraw-Hill, NY, NY, 1990.

7. US Environmental Protection Agency, *Facility Pollution Prevention Guide*, EPA/600/R-92/088, Office of Research and Development, Washington, D.C., 1992.

PROBLEMS AND ACTIVITIES FOR MODULE 2

1. Almost everyone has ridden in cars as they move through automatic (brush or brushless) car washes. The car wash is a fairly simple linear and continuous process. Yet, if you attempt to develop a process flow diagram you may see that there is more to the production than hits the windshield. (Adapted from ref. 36).

   A. Develop a complete process flow diagram of an automatic car wash. Be sure to account for all materials input and materials output (qualitatively).

   B. Identify all points of chemical use, by-product generation and releases into the air, sewer, land, or reuse/recycling.

2. The next time you prepare a salad, casserole, pie, or other dish requiring the input of several food items, create a process flow diagram for the activity. Be sure to include all points of food input, by-product generation and the fate of those by-products (garbage, sewer, inadvertent consumption, etc.), and final product. Don't forget food packaging, and any preparation, such as washing, of food inputs as well as the fate of generated by-products (including evaporation). If you have access to a food scale, try to quantify by-products as best you can, including weight loss during cooking (what by-product was generated and where did it go?). (Adapted from ref. 36).

3. The production manager of a small auto parts manufacturer noted that the company had used 200 tons of plastic polymer last year, after adjusting for inventory. They had made 300 tons of final product during that same time period. The final product was 50% plastic by weight. The process involves 1) receiving and storing polymer, 2) molding, where the polymer is heated and molded into correct shape using molding machines, 3) trimming, where excess plastic is removed from the molded parts, and 4) assembly, where the plastic parts are assembled with the non-plastic components to create the finished product. What is the overall efficiency of the process with regard to turning the received polymer into product? If you were production manager, where would you suspect that you may be losing polymer from the process?

4. Refer to the Holiday Printing case in the Problems and Activities section of Module 1 and the article on the printing industry (Pferdehirt, W.P, "Roll the presses but hold the waste: pollution prevention and the printing industry," Pollution Prevention Review, Autumn, 1993) in the Supplemental Readings Booklet. In an attempt to reduce toluene emissions from clean-up operations, Andrew Larson and a team of production and maintenance personnel have identified several options:

A. Improve toluene use and management procedures, particularly several items listed in Table 3 of Pferdehirt's article under "Good Housekeeping" and "Cleanup".
B. Install an automated washing system (e.g., automatic blanket washes).
C. Use a detergent and water cleanup solution.
D. Use a methyl alcohol cleanup solution.

Identify the criteria that the team might use to determine the superior alternative. To the best of your ability, rate each alternative on the criteria you create (this may involve additional research on the printing industry and the hazardous nature of chemicals).

5. Using the Standard Metal Products Company case in the Supplemental Readings Booklet, answer the following questions:

A. Develop a process flow diagram for the production of electrical switch boxes. Be sure to include all flows of raw materials, products, and by-products. (see Figure 2-2 as a guide)

B. Develop materials balance tables for each of the four materials used in the process. (see Tables 2-1 and 2-2 as guides).

C. Estimate process efficiency for the use of sheet metal and paint, and describe the composition of each by-product stream using a table similar to Table 2-4a. Standardize all units to a "per 1,000 lb. of product" basis. (For example, sheet metal input is 1,250 lb. per 1,000 lb. of product)

D. Estimate direct, tangible costs of by-products for each operation in the process. (see Tables 2-5b, 2-6b, and 2-7b as guides). Express all costs on a "per 1,000 lb. of product" basis.

i. What is the total cost of by-product generation over the last 12 months?

ii. Which operations and by-product streams are the greatest contributors to this loss?

iii. Are these losses due primarily to lost materials, disposal costs, or both?

iv. What other tangible costs might exist which were not included in this analysis and how would they likely effect the outcome?

v. What intangible costs might exist which were not included in this analysis and how would they likely effect the outcome?

vi. What other factors would be most important to consider in selecting priority by-product streams and how would they likely effect the outcome?

E. Perform a present value analysis of cost for the two systems, using a 12% cost of capital estimate. Use the Sample Table, below, for guidance. Which option should Wilson select? Why?

Sample Table: Present value analysis of Aquaclean and Enviroclean systems using 12% cost of capital. (Costs in $1000)

		AQUACLEAN SYSTEM			ENVIROCLEAN SYSTEM		
YEAR	PV DISCOUNT FACTOR	ANNUAL COST	PV COST	CUMULATIVE PV COST	ANNUAL COST	PV COST	CUMULATIVE PV COST
0							
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

6. Using the Fred's Foundry case in the Supplemental Readings Booklet, answer the following questions:

A. From this information, develop a process flow diagram for the production of cores. Be sure to include all flows of raw materials, products, and by-products. (see Figure 2-2 as a guide)

B. Develop materials balance tables for each of the three materials used in the process. (see Tables 2-1 and 2-2 as guides).

C. Estimate process efficiency for the use of the three inputs , and describe the composition of each by-product stream using a table similar to Table 2-4a. Standardize all units to a "per ton. of product" basis. (For example, sand received is 1.150 tons per ton of product). You may ignore catalyst in broken core.

D. Estimate direct, tangible costs of by-products for each operation in the process. (see Tables 2-5b, 2-6b, 2-7b as guides). Express all costs on a "per 1,000 lb. of product" basis.

i. What is the total cost of by-product generation over the last 12 months?

ii. Which operations and by-product streams are the greatest contributors to this loss?

iii. Are these losses due primarily to lost materials, disposal costs, or other costs?

iv. What other tangible costs might exist which were not included in this analysis and how would they likely effect the outcome?

v. What intangible costs might exist which were not included in this analysis and how would they likely effect the outcome?

E. What is the playback period for the new sand handling system selected by the pollution prevention team using only direct, tangible costs (you may also wish to perform a present value analysis)? Does this analysis alone support their recommendation? Considering other potential benefits of the system, do you believe the team made a wise decision? Why or why not?

F. Perform a present value analysis of the changes made to reduce core breakage in temporary storage, using a 10% cost of capital estimate. Use the Sample Table, below, for guidance.

i. Do the changes in the storage area have a positive financial impact? Why?

ii. What other tangible or intangible costs or benefits might exist which were not included in this analysis and how would they likely effect the outcome?

Sample Table: Present value analysis of net savings from changes in temporary storage area using 10% cost of capital. (Costs in thousands of dollars)

YEAR	PV DISCOUNT FACTOR	ANNUAL COST	REDUCED CORE BREAKAGE	REDUCED OVERTIME	NET SAVINGS (COST)	PV SAVINGS	CUMULATIVE. PV SAVINGS
0							
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

G. The company developed solutions to sand transport spillage and core breakage during temporary storage. What by-product stream would you recommend they focus on next? Why? Do you have any suggestions for what they might do to reduce the generation of this by-product?

MODULE 3
POLLUTION PREVENTION AND THE BUSINESS MANAGER

LEARNING OBJECTIVES

1. Given a business scenario, identify and explain the role of the manager in integrating pollution prevention into business operations.

2. Given a business scenario, write an appropriate organizational policy for pollution prevention.

3. Given a business scenario, identify and explain the ways in which management philosophy can aid or inhibit the success of pollution prevention efforts.

4. Given a business scenario, identify and explain the ways in which organizational structure can aid or inhibit the success of pollution prevention efforts.

5. Given a business scenario, identify and explain the most important modifications to the business plan (marketing, operations, finance, personnel) to enhance the success of pollution prevention efforts.

6. Given a financial analysis of a pollution prevention option, identify strengths and weaknesses in the analysis and recommend improvements consistent with Total Cost Assessment.

MODULE 3

POLLUTION PREVENTION AND THE BUSINESS MANAGER

Warren Johnson, Purchasing Director for a manufacturing plant in the Midwest, had just returned from a meeting of directors from all of the plant's divisions. The meeting had been called to discuss how to react to a recent suit and $500,000 fine from the U.S. Environmental Protection Agency (EPA) for alleged violations of air pollution regulations. Damage to corporate image from this suit may be extensive and costly. It became clear from the meeting that at least some of the pollution problems of the company could be solved through better control and coordination of the manufacturing process, preventing the generation of pollutants in the first place. Process improvements not only could reduce pollution problems, but could save the company money through reduced loss of product and raw material, and reduced compliance-related costs.

Yet it was also evident from the meeting that achieving pollution prevention would not be easy for the company. Much of the meeting had involved transferring blame among division directors. Many directors argued that the changes needed to reduce waste generation would frustrate the objectives of their division. No one believed that the information currently available in the company adequately captured the nature and extent of waste generation or its impact on the company's longterm financial health. The marketing director could not assess the likely impact of the suit on customer perceptions, nor could she identify the nature of customer environmental concerns with regard to the use and disposal of the company's product.

The CEO concluded that the EPA suit represented an opportunity for the company to rethink its approach to pollution, waste generation, and the environment. He asked the division directors to meet again in one week to discuss their ideas about how the company should change to avoid such problems in the future, and how the company might actually capitalize on waste reduction to its competitive advantage.

As Warren returned to his office, he considered what the role of the business manager should be in preventing pollution. He realized a tool which guides daily managerial decisions is the business plan. He also realized that the formation and conduct of the business plan is influenced by the management philosophy, or culture, of the firm, as well as company policy and organizational structure. When Warren reached his desk, he quickly jotted down the following questions which needed to be answered before the next meeting:

1. *What company policy should be written to guide managerial and employee decisions toward better pollution prevention?*

2. *How does our current management philosophy affect our success in pollution prevention, and how could our philosophy be improved?*

3. *How does the organizational structure of the company affect success in pollution prevention and how could it be improved?*

4. *How can the business plan (marketing, production, finance, and personnel) be used to drive pollution prevention success?*

This module explores each of these four questions.

> "Every day, business managers make countless decisions that affect the environment...Every aspect of modern business - including financial policy, marketing, competitive strategy, and research and development - is increasingly influenced by environmental considerations."(1)
> James E. Post
> Corporate Conservation Council

POLLUTION PREVENTION AND THE BUSINESS MANAGER

Managers control the system in which decisions are made.

It is the business manager who is responsible for insuring the success of a pollution prevention strategy employed to achieve a competitive advantage.

Pollution prevention can be a component of an organization's competitive strategy. It is a key element in an organization's efforts to meet its customers' needs and reduce costs through the elimination of waste. It is the business manager who is responsible for insuring the success of a pollution prevention strategy employed to achieve a competitive market advantage for the organization. Yet gaining a competitive advantage through pollution prevention is neither simple nor assured. It requires a conscious and continuous effort to achieve an integrated management approach.

The most important factors contributing to a successful pollution prevention program have been identified in a study by The Business Roundtable, an association of business executives from major American corporations (2). These factors were identified through a study of facilities with outstanding pollution prevention programs, including Proctor and Gamble, Intel, Du Pont, Monsanto, 3M, and Martin Marietta. The results, presented in Figure 3-1, are grouped into three classes of factors contributing to success.

Note that all of the factors in Figure 3-1 are under either the direct or indirect control of management. Thus, the single most important factor contributing to the successful use of pollution prevention as a competitive strategy is *good management*.

This Module focuses on four areas of management which encompass most of the factors in Figure 3-1: 1) Management Policy, 2) Management Philosophy, 3) Organizational Structure, and 4) The Business Plan (marketing, operations, and finance).

MANAGEMENT POLICY

"Organizational policies are a broad guide to thinking". (3)

The first logical step in implementing a successful pollution prevention program is to develop an organization-wide pollution prevention policy. Organization-wide environmental policies function as a guide for employee decision-making and therefore represent important drivers for successful pollution prevention programs. In addition, written policies provide important communication mechanisms for presenting an organization's position to external constituents such as customers, the community, stockholders, banks, insurers and the media.

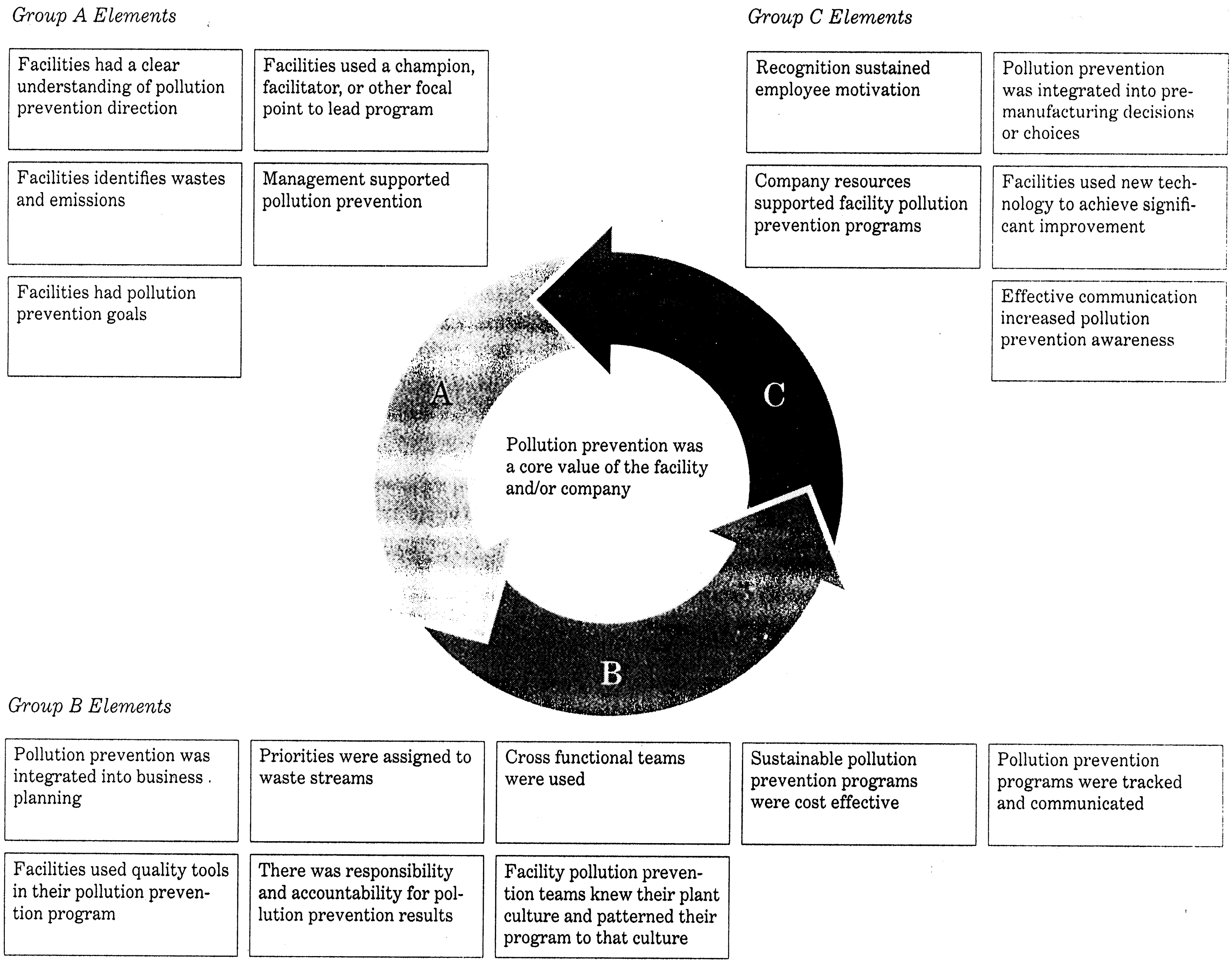
Appropriate management policy contributes to a number of factors from Figure 3-1:

- Management supports pollution prevention.
- Facilities have a clear understanding of pollution prevention direction.
- Facilities have pollution prevention goals.
- Priorities are assigned to waste streams.
- Pollution prevention programs are tracked and communicated.
- There is responsibility and accountability for pollution prevention results.
- Recognition sustains employee motivation
- Company resources support facility pollution prevention programs.

Companies with an explicit pollution prevention policy experienced greater employee and management acceptance.

Ninety-five percent of U.S. multi-national corporations responding to a 1990 survey stated that they had written environmental policies (4). Developing a sound environmental policy is the first priority in the International Chamber of Commerce's Business Charter for Sustainable Development. The Global Environmental Management Initiative (GEMI) and the chemical industry have also listed a written environmental policy

Figure 3-1: Critical and essential elements of a manufacturing facility pollution prevention program (2).



as top priority in their recommended organizational self-assessment program (5, 6). A 1993 survey of a wide variety of industries, from 40 to over 500,000 employees, found that those companies which had explicit pollution prevention policies experienced less employee resistance to change, were more satisfied with employee pollution prevention progress, and observed greater growth in upper management support for pollution prevention than companies without an explicit corporate pollution prevention policy statement (7).

Organizational policy should extend beyond simple compliance with environmental law. To seize a competitive advantage from pollution prevention opportunities, organizational policy should drive the organization toward proactive improvement of environmental performance which exceeds legal requirements - not just meet them. Pollution prevention policy should be comprehensive, addressing every aspect of the manufacturing process from product design to the recycling of products when the consumer is through with it (5). At a minimum, pollution prevention policy statements must answer the following questions (8):

- **What** should the organization do?
- **Why** should the organization do it?
- **Who** in the organization should do it?

To seize a competitive advantage, organizational policy should drive the organization toward proactive improvement of environmental performance.

Well written policy statements provide an organization's employees with clear answers to the what, why and who of the pollution prevention program; but determining "how should pollution prevention be achieved" is the responsibility of the employees, and may change from day-by-day, operation-by-operation, and product-by-product.

MANAGEMENT PHILOSOPHY

What is the purpose of a manager in an organization?

There are probably as many organizational management philosophies as there are managers in business. Organizations can likely achieve some level of pollution prevention success under almost any management philosophy. Yet, because the management philosophy defines the role of the manager in an organization, some philosophies will achieve greater success than others. Management philosophies likely to provide a competitive advantage are those which can best promote employee harmony and involvement, continuous improvement, decision-making based on systematic analysis, customer harmony, and community harmony. These are discussed in greater detail below.

Appropriate management philosophy contributes to a number of factors from Figure 3-1:

- Facility uses a champion, facilitator, or other focal point to lead the program.
- Cross-functional teams are used.
- Facility pollution prevention teams know their plant culture and patterned their program to that culture.
- Facilities use quality tools in their pollution prevention program.
- Recognition sustains employee motivation.
- Effective communication increases employee awareness.

[Total Quality Management (TQM), a recent alternative to traditional Western management philosophy, is summarized in a paper entitled "Management Practices - U.S. Companies Improve Performance Through Quality Efforts," available in the Supplemental Readings Booklet. Many books are currently available to the interested student on TQM and W. Edwards Deming.]

Employee Harmony and Involvement

Disharmony is expensive and due largely to a failure of the management philosophy.

Disharmony among the employees of an organization occurs when personal goals are inconsistent with the goals of others and the goals of the organization. Symptoms include lack of cooperation, "turf" protection, blame, secrecy, and outright contempt. Disharmony is expensive and due largely to a failure of the management philosophy. Successful organizations maintain a positive work relationship among employees and involve employees in the decision making process.

Pollution prevention activities typically affect many divisions within a company and require the knowledge, skills and cooperation of individuals at many levels in the organization. Involving employees in the decision process results in greater employee commitment to the success of the final decision. Lack of employee harmony or involvement places the company at a disadvantage in attaining successful waste reduction.

Continuous Improvement

Successful organizations focus on continuously improving systems and processes, which results in improved product quality and cost reductions. Continuously improving manufacturing systems and processes is an essential component of a successful pollution prevention strategy.

Decision-making Based on Systematic Analysis

Waste reduction can be achieved through careful, systematic study of the manufacturing process. Decisions that are not based on a thorough understanding of the facts risk wasting time and resources on ineffective and inefficient activities. The corporate culture in some companies may not allow managers the time and resources to thoroughly study a process, or may not provide employees with the basic knowledge and skills to perform systematic analyses.

Customer Harmony

Successful organizations strive to work in *harmony* with their customers. Organizations develop harmonious customer relationships by identifying the customer needs through the marketing function. These customer needs are addressed through changes in the products, services, and distribution systems of the company as well as in the future design and manufacturing of products.

Corporate cultures which are not customer-driven will not recognize, and therefore cannot meet, the environmental needs of its customers. These unmet needs (from reduced packaging to the use of less hazardous materials) may provide ripe opportunities for competitors seeking greater market share. (See Fisher, M.T., "Total Quality Environmental Management: The Procter & Gamble Approach," in the Supplemental Readings Booklet for examples of how Procter & Gamble's culture resulted in profitable environmental marketing opportunities.)

Community Harmony

Successful organizations maintain a strong "good neighbor" image in their respective communities. The "good neighbor" image enhances the reputation and goodwill of the organization. These are intangible benefits that are difficult to value, but there are bottom-line financial impacts that can result from a loss of harmony. Failure to address potential pollution problems may result in community-led product boycotts and class action legal claims against the organization. These community actions can be financially draining for an organization to fight or overcome. Some communities are actually seeking judgments against the officers' and board members' personal assets when a company has endangered a community. A Wall Street Journal article stated:

These are intangible benefits that are difficult to value, but there are bottom-line financial impacts.

> *"The recent proliferation of regulations protecting the environment and workers' rights has lead many courts to tear down the shield of owners regarding claims in these areas... Shareholders of closely held companies face increased liability for environmental, pension and other claims against the corporation.'"* August 13, 1993. (9)

These community actions are the result of poor product environmental quality and a failure to meet the communities' needs. Maintaining a harmonious relationship with the community is the best way to prevent such losses.

ORGANIZATIONAL STRUCTURE

Pollution prevention crosses organizational and managerial bounds.

Pollution prevention efforts may produce conflict, but cooperation is the key to success.

A key to success in pollution prevention is cooperation. Pollution prevention affects every department in an organization including marketing, finance, manufacturing, shipping, personnel, and accounting. Cooperation across organization boundaries can lead to several of the critical factors in Figure 3-1 for successful pollution prevention programs:

- Management supports pollution prevention.
- Cross-functional teams are used.
- Facility pollution prevention teams know their plant culture and pattern their program to that culture.

Organizational divisions, whether vertical or horizontal, promote the adoption of division-specific goals and inhibit cooperation. Each organizational entity tends to focus on its own business operations and needs at the expense of other operating areas. For example, marketing may be concerned with product quality and production delays associated with implementing a pollution prevention improvement program. The production department may find it difficult to cost-effectively comply with demands for improved environmental performance of a product. Finance may dislike a longer lag time for realizing the benefits from a pollution prevention project.

Conflicts may also exist between line and staff positions (4). Staff positions, such as those in environmental control or facilities engineering, are often given the task of driving pollution prevention efforts. This brings them into direct conflict with line managers, particularly those in production, who must expend additional time and resources to undertake pollution prevention projects.

In multi-facility companies, particularly corporations with large corporate staffs, multiple facilities, or numerous product lines, conflicts can arise between the production facilities and corporate headquarters (4). The additional layers of management can hinder the improvement process. Production facilities may often resist specific process or product changes initiated by those in upper management who are unfamiliar or perceived to be unfamiliar with the production facility.

In smaller companies, or in larger companies with relatively autonomous facilities, cross-divisional and management-staff cooperation may be easier to achieve since the personnel in different divisions are more likely to know each other and work together on other projects. Organization's employees will also have a better perspective of the entire manufacturing process. The benefits to the facility of pollution prevention projects will be more apparent, making cooperation easier. But a small size does not guarantee success. In smaller organizations managers and employees wear "multiple hats" because they have a wider range of responsibilities. In the initial stages of a pollution prevention program in a small company managers may have to work harder than their counterparts in a larger organization, but the potential for success is much greater.

Overcoming these conflicts requires that management develop and implement a management philosophy, management policies, and organizational structure to maximize cooperation and minimize internal competition. The structure of the organization itself, and how management chooses to use that structure, is a key factor in overcoming divisional barriers.

Overcoming these conflicts requires that management create a management philosophy, management policies, and organizational structure to maximize cooperation.

Different organizations use different approaches to promote cooperation. Some companies use cross-disciplinary teams to coordinate different organizational units. Other companies alter the organization itself, using standing committees for decision-making rather than individual managers in the traditional hierarchy of authority. To increase success in pollution prevention efforts, managers must seek to remove structural barriers to cooperation and install those structures that will promote cooperation. Because pollution represents operational inefficiency and lost market potential, some companies reduce the line/staff conflict by placing pollution prevention responsibilities on line management, allowing the environmental control staff to serve as a resource to line management (10). Environmental control staff function in a support role, much like that of an information systems department. To minimize headquarters/facility conflicts, some companies have used corporate headquarters to articulate pollution prevention goals but allowed facilities to find their own method of achieving them (4)

THE BUSINESS PLAN

Integrating pollution prevention into daily operations.

Only when pollution prevention is fully integrated into the business plan can a company reap its full competitive benefits.

The business plan drives the daily activities and decisions in pursuit of the company's objectives. The manager is involved not only in creating a business plan, but is an essential participant in carrying it out. Only when pollution prevention is fully integrated into the marketing, operations, finance, and personnel components of a business plan can a company reap its full competitive benefits.

Including pollution prevention into the marketing, operations, and financial planning of an organization contributes to a number of factors from Figure 3-1:

- Pollution prevention is integrated into business planning.
- Facilities identify wastes and emissions.
- Priorities are assigned to waste steams.
- Sustainable pollution prevention programs are cost-effective.
- Pollution prevention programs are tracked and communicated.
- Pollution prevention is integrated into pre-manufacturing decisions.
- Facilities use new technologies to achieve significant improvement.

The impact of integrating pollution prevention into the marketing, operations, and financial components of the business plan is discussed below.

Marketing

The business manager can incorporate pollution prevention into the marketing function in at least four important ways: marketing intelligence, understanding the environmental impact of your products and processes, new product development, and "green" marketing opportunities.

Know the environmental needs of your customers.

Marketing Intelligence. Know the environmental needs of your customers. Environmental perceptions and concerns should be a routine part of marketing intelligence collected from current and prospective customers. The commitment to understanding customer needs and exceeding customer expectations is an important component of a business plan. Even companies whose customers are other companies often find that environmental performance is an important part of the customer/supplier relationship.

Similarly, marketing intelligence on the extent to which competitors are meeting the environmental needs of the market, can be valuable information. This may identify opening market niches or increasing competitive threats.

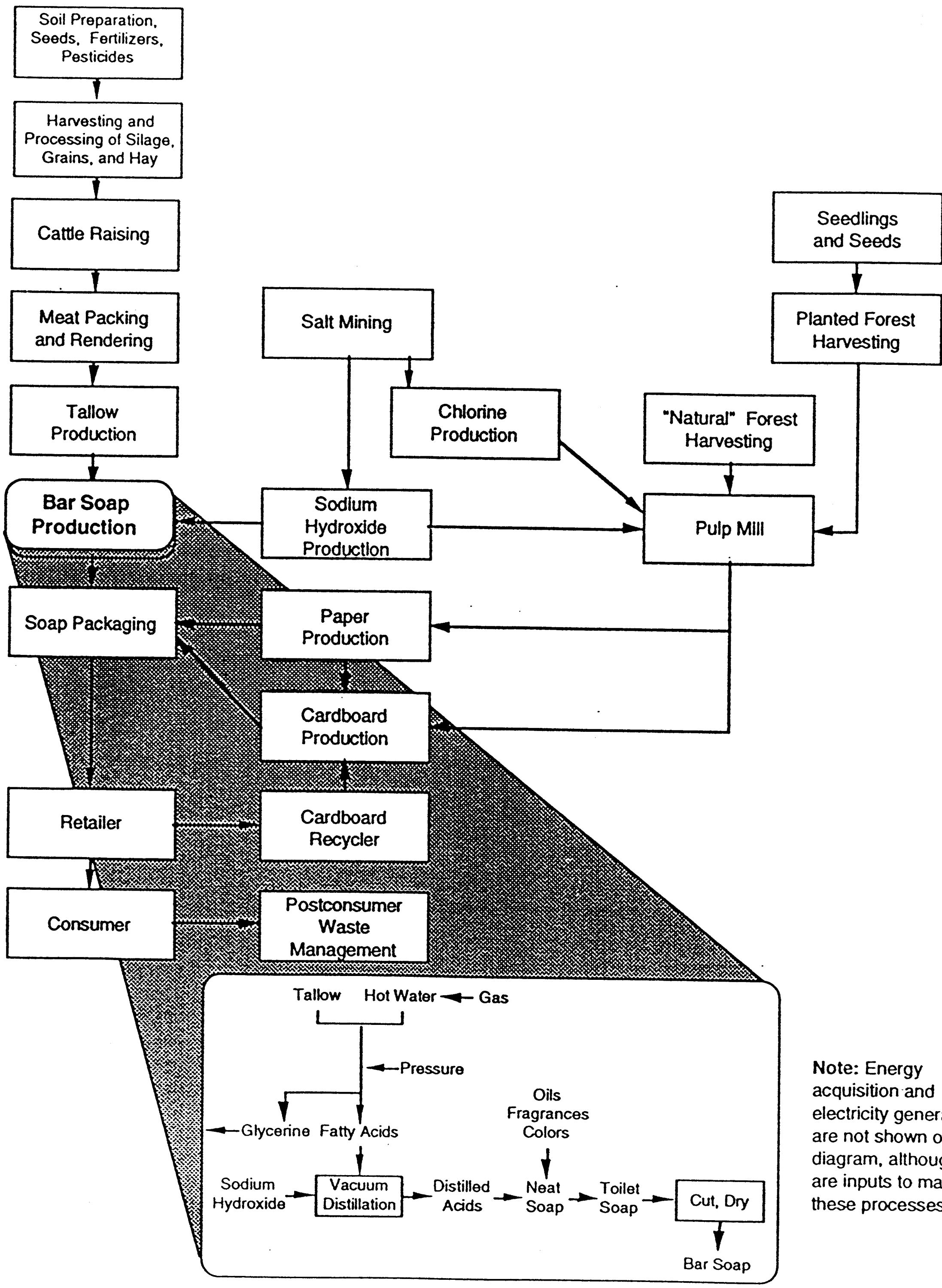
Understand the environmental impact of your products and processes. Module 2 provided some guidance to estimating the waste generated in the production process. However, the impacts of a product can begin with environmental damage caused by suppliers (such as forest destruction, wastewater from mining operations, or air pollution from manufacturing) and can continue through damage due to the ultimate "disposal" of the product by the consumer (such as ground water pollution from landfilling, or air pollution from incineration). As the environmental interests of consumers increases, the scope of environmentally damaging activities perceived to be associated with a product will also increase.

One way that many companies are attempting to understand the full environmental impact of their products and processes is a technique called *Life Cycle Analysis.* Life cycle analysis examines the impact of a product from the origins of its raw materials to the environmental fate of its components following "disposal". Figure 3-2 provides an example of activities which would be included in the production of bar soap (11). These range from agricultural production of livestock from which the soap will be made, to post-consumer waste management. Life Cycle Analysis can be a complex and expensive undertaking, but environmental damage at any step in the life cycle represents both a marketing and legal liability. It is far better to recognize these liabilities before your customers do. Small changes in the product or by suppliers may be sufficient to reduce environmental concerns. Some companies are beginning to design their products for disassembly and recycling after use (12).

Life Cycle Analysis examines the impact of a product from the origins of its raw materials to the environmental fate of its components following "disposal".

New product development. New product development is a critical part of business planning process. The product development cycle is the optimal time to build environmental performance into a product with the purpose of reaping the greatest benefits in cost reduction and competitive advantage. Life cycle analysis and an understanding of customer environmental needs, as discussed above, should be part of the foundation for developing new products. An organization must plan for adequate time and resources in R&D process to insure that pollution prevention concepts can be integrated into the product manufacturing process. Ideally, representatives from the environmental, occupational health, and safety departments are included in product development teams.

Figure 3-2: Detailed system flow diagram for bar soap (11).



Note: Energy acquisition and electricity generation are not shown on this diagram, although they are inputs to many of these processes.

Green marketing opportunities. An alert business manager may have previously overlooked market opportunities. In the past, few companies considered themselves manufacturers of environmental products. Yet the increase in consumer environmental interest has opened market opportunities that did not exist in the past. The proliferation of "green" computers and the pursuit of a recyclable automobile demonstrate that both high-tech growth industries as well as stodgy rust belt industries are being affected by the world's focus on pollution and its prevention. Wall Street has found the "green" concept to be very profitable as evidenced by the number of investment firms that have created "environmental friendly" mutual funds which only purchase stocks of organizations that pursue positive environmental policies and practices

Operations

The business manager can integrate pollution prevention into the operations function through creation of an environmental performance tracking system, improving existing processes, and planning new processes.

Good data on environmental performance are essential for good decision making.

Environmental performance tracking system. "[Knowledge] is very expensive, yet ignorance costs more than you can imagine." (13). Good data are critical to good decision-making. Management must collect data on waste generated in every area of their organization to insure that their decisions are based on data and not guess work. Data on waste generation provide valuable information for three critical activities: identifying pollution prevention opportunities, prioritizing those opportunities, and monitoring progress in meeting pollution prevention objectives.

Module 2 discusses relatively simple ways in which managers can identify and prioritize pollution prevention opportunities. Table 3-1 summarizes some pollution prevention performance indicators that can be used in these relatively simple methods. The indicators range from measure of facility-wide waste generation to production specific waste generation measures. Facility-wide waste generation measure may be valuable for public reporting and prioritization, but are relatively useless as control and feedback monitors in production management since they are not related to specific processes, changes in production levels, or changes in operations. Waste generation measurements can be improved for production purposes by expressing them in terms of units of production. As production levels change, waste generation will change, but waste generation per unit of product will provide a more accurate picture of pollution prevention performance. Table (3-1) displays some of the common sources of information for many of the indicators.

However, all of these indicators miss the most important objective of pollution prevention: improved efficiency of a process which converts inputs into products. Tracking this requires an ongoing materials and energy balance. That is, the system must identify all inputs to a process and track these inputs to their ultimate destination (waste, reuse, inventory, shipped product, etc.). This can be an expensive operation, though it is likely to pay for itself quickly in efficiency improvement.

Table 3-1: Common measurements of pollution prevention performance and possible information sources. (8, 14, 15)

Pollution Prevention Measurement	Information Source
Quantity of by-product produced	Materials balance
Quantity of by-product reused or recycled	Materials balance
Quantity of waste shipped off-site	Waste hauling records or compliance records
Quantity of waste treated on-site	Process measurements
Quantity of waste discharged into the environment (air and water)	Materials balance or compliance records
Toxicity of chemicals used	Purchasing records
Employee exposure to hazardous substances	Industrial hygiene records
Lost time from employee illness or injury	Personnel and medical records
Water consumption	Utility records
Energy consumption	Utility records

Lack of an adequate environmental performance tracking system is one of the greatest barriers to pollution prevention

Lack of an adequate environmental performance tracking system is one of the greatest barriers to pollution prevention (2). This poses a dilemma for managers. Environmental performance data are often needed to persuade upper management to commit resources to pollution prevention. Yet, without such commitment from upper management, the resources needed to collect environmental performance data may not be available. It may be necessary to begin with low cost information systems to demonstrate the greatest pollution prevention opportunities. Subsequent upper management interest may then provide opportunities for more expensive tracking systems.

Improve existing processes - Most organizations experience strong resistance to change. Yet in today's economic environment change is essential to survival. Once some form of environmental performance tracking system is in place, the business must plan for process improvement. This means insuring adequate time, resources, personnel, and coordination to make continuous process improvements.

Technical assistance for process improvement is available from private and public organizations. But your best resource may be your own people.

Technical assistance for process improvement is available in many forms. Many environmental consulting firms now provide pollution prevention services. In addition, the USEPA and most states have extensive collections of case studies and other technical literature. Many states offer free technical assistance, particularly to small businesses (contact the National Pollution Prevention Roundtable, 202/543-P2P2, for sources of assistance in your state). However, most companies find ample technical expertise among their own employees. Cross functional teams can be valuable in reducing waste from activities ranging from purchasing to packaging.

Production planning - Once a new product has been planned or an existing process is to be redesigned, production planning is an excellent opportunity to minimize waste. The environmental waste tracking system and life cycle analyses can provide the foundation for such plans. Operations from materials purchasing to product packaging, inventory, and shipping should be included. Be sure to include environment, occupational health, and safety representatives in production planning teams. There must be a long term organization-wide commitment to pollution prevention. Effective pollution prevention programs are seldom profitable in the short term.

Finance

With proper financial analysis, environmental programs can compete for resources with other profit-adding and market-expanding opportunities.

Sound financial information is critical to decision-making throughout the firm, from process control to capital investment. To maximize benefits from pollution prevention, managers should build three features of financial information into the financial business plan: total cost accounting, long-term analysis, and activity-based cost allocation

Expenditures for environmental control have traditionally been viewed as *profit sustaining*, or "must do"; that is, such expenditures are necessary to maintain production. This approach has blinded companies to the profit-adding and market expansion capabilities of proactive environmental programs (16). With the three improvements in financial analysis discussed below, environmental programs are increasingly being viewed as profit-adding, and at times, market-expanding opportunities.

Total Cost Accounting. To make the best investment decisions, managers must have information on the contribution of each investment alternative to the long-term profitability of the firm. Historically, pollution control investments have been viewed outside of the regular capital budgeting process. This is because most of the benefits of such projects were beyond the conventional accounting system and have a high degree of uncertainty, yet the investments were considered "must-do" projects to assure regulatory compliance (16).

To make significant progress in pollution prevention, projects should be considered as an investment opportunity which must compete with other company-wide investment opportunities. This requires a change in traditional conceptions of project costs and benefits. Total Cost Accounting (TCA) is a financial management tool intended to capture the true financial contribution of a pollution prevention project to the long-term profitability of the firm. It is directly applicable to pollution prevention It involves not only traditional accounting measures such as materials, personnel, and efficiency, but captures the hidden or less-tangible financial effects of waste generation, such as future liability or consumer goodwill.

Total Cost Accounting captures not only the traditional accounting measures, but also hidden or less tangible financial effects of waste generation.

Work is underway by a number of groups to define TCA practices. Most agree that, ideally, TCA should contain at a minimum the cost components in Table 3-2. Direct costs are those considered in a traditional project cost analysis. Indirect costs (or "hidden" costs) are those environmentally-related costs incurred by companies in the normal course of business but not normally linked to a specific process or project. This includes many legally mandated activities such as obtaining operating permits and completing other paper work. Such costs are typically noted as "overhead".

Liability costs are legal obligations which may arise in the future due to current activities, typically through enforcement actions or civil suits. Reports of liability from pending legal action follow standard accounting procedure in public financial statements. But reporting liability from *possible future* actions is highly uncertain and no standard procedure yet exists. Failure to account for likely liabilities can result in over-investment in costly projects. Yet over-estimates of liability can result in lost profit opportunities and an undervaluing of the firm.

Less-tangible benefits may be substantial for a firm since they may represent increased customer loyalty, increased sales, and increased productivity. Yet it is difficult to both predict and quantify such benefits accurately.

At the present time there are a number of methods for estimating pollution prevention costs and benefits (17), but they all have substantial limitations.

USEPA has suggested a four-tiered model in which the four categories of costs and benefits are considered hierarchically. If direct costs are sufficient to warrant the project, no estimates need be made for the other categories. If direct costs are not sufficient, indirect costs are estimated. If the project is now justifiable, no further estimates are made. Otherwise, liabilities are estimated, and so on. This approach offers the advantage of beginning with the most supportable cost estimates and minimizing the time that must be spent deriving highly uncertain estimates.

Two case studies at the end of this Module, "Coated Fine Paper Mill" and "Paper Coating Mill", provide examples of detailed TCA applications.

Table 3-2. Cost components in a Total Cost Assessment (USEPA)

Direct Costs
Capital Expenditures
- Buildings
- Equipment and Installation
- Utility Connections
- Project Engineering

Operating and Maintenance Expenses or Revenues
- Raw Materials
- Labor
- Waste Disposal
- Water and Energy
- Value of Recovered Material

Indirect Costs
Administrative Costs
Regulatory Compliance Costs
- Permitting
- Record keeping
- Monitoring
- Manifesting

Insurance
On-site Waste Management
On-site Pollution Control Equipment Operation

Liability Costs
Penalties
Fines
Personal Injury
Property Damage
Natural Resources Damage Clean-up Costs
- Superfund
- Corrective Action

Less-Tangible Benefits
Increased Sales Due to
- improved product quality
- enhanced company image
- consumer trust in green products

Improved Supplier-Customer Relationship
Reduced Health Maintenance Costs
Increased Productivity Due to Improved Employee Relations
Improved Relationships with Regulators

Many benefits of pollution prevention may not arise until three or more years after the project.

Long-term analysis - For many pollution prevention projects, costs and benefits may accrue long into the future. Liabilities and less-tangible benefits may not arise until three or more years after the project. Capital budget assessments using three or even five year time horizons may not capture the impact of a project on the long-term profitability of the firm.

When waste generation costs are allocated to overhead, it makes it difficult to assess the value of pollution prevention.

Activity-based cost allocation - Indirect costs such as those associated with environmental staff time or on-site waste treatment are typically considered overhead and may be allocated to production units on a basis unrelated to waste generation, such as a percentage of direct costs or sales. This approach to environmental overhead allocation produces two problems. First, it makes it difficult to assess the value of pollution prevention projects, since the impact of a process on company costs is not expressed. Second, it reduces managerial incentives for waste reduction since savings in overhead would be distributed to all production units while the direct costs of the project would accrue to one unit only.

Allocating indirect costs to those units responsible for their creation is not simple. As noted earlier, detailed data by process on the production of by-products rarely exists. In addition, costs must be allocated on the basis of waste generation so that reductions in waste produce reductions in allocated costs.

Personnel

Pollution prevention programs can impact personnel planning and *vice-versa*. Staffing levels, staff organization, and the reward system are three areas of personnel planning, that managers should address in the revising the personnel function in the business plan.

Pollution prevention can improve efficiency. But concern over subsequent staff reductions may pose a significant barrier to employee cooperation.

Staffing levels - Most pollution prevention projects produce an increase in production efficiency. Either directly or indirectly, efficiency improvements often result in decreased staffing needs. Though reductions in staff represent an important savings for the company, the likelihood of staff reductions can be a significant barrier to staff cooperation in identifying and implementing pollution prevention opportunities. Managers should develop a staff reduction or reallocation plan to insure pollution prevention opportunities do not constitute a threat to the organization's employees. Long range staff reduction strategies must be separated from pollution prevention activities and achieved through non-threatening methods such as attrition or reassignment to other areas or divisions.

Staff organization - Recognizing pollution prevention opportunities and implementing successful waste reduction programs requires the cooperation of staff from all parts of the organization. Though improvements might be possible through the efforts of a small number of technical staff, such improvements cannot compete with organizations capable of obtaining the commitment of all their employees who must participate in the implementation of pollution prevention programs. The best organizational pollution prevention strategy is clearly achieved through interdisciplinary teamwork (3). Managers must insure that communication systems and organization structures are in place to facilitate a teamwork atmosphere. Failure to do so could achieve benefits in one area of the production process that squandered in other areas.

Reward system - For organizations using a formal personnel evaluation system for monetary and promotional rewards, pollution prevention, and participation in pollution prevention activities should be a part of the performance review. This might involve targets or measurable goals for pollution prevention progress. Though some organizations have found formal personnel evaluation systems to be counter-productive, all organizations can benefit from informal rewards and recognition to promote the cooperation necessary for continuous improvement in waste minimization.

The reward system should recognize participation and teamwork.

CONCLUSIONS

Warren Johnson prepares to make changes.

Warren Johnson has prepared a number of proposals for the next director's meeting. He will begin by proposing a company policy on waste minimization, setting out not only the longterm goal, but also some specific objectives for the coming years. Next, to encourage cross-functional cooperation, he will propose a purchasing advisory team, including representatives from operations, environment, health, and safety to help identify ways of reducing waste by working with suppliers. He will encourage other directors to do the same. He will also recommend a community advisory panel to work with the company on environmental issues and other concerns of surrounding residents. This will be needed quickly to minimize fear generated from the USEPA suit.

Warren Johnson decided to propose a few, basic changes to put management on the course of pollution prevention.

Warren has also decided on three changes in the business plan to propose initially. First, he will recommend the creation of an environmental performance tracking system to provide better information on waste generation and production efficiency. Second, he will propose that the operations portion of the plan be revised to accomplish a dramatic pollution prevention effort in the next 12 months. Finally, he will recommend the adoption of an expanded cost accounting system that provides activity-based cost data on both direct and indirect costs related to waste generation.

This is an aggressive agenda, but the company can afford neither the current level of waste nor the reputation as environmentally insensitive. Competition in the market is fierce and other companies could easily capitalize on weakened customer loyalty.

If Warren is successful in promoting these initial measures, there are many others that he would like to see adopted. In his view, pollution prevention is a natural fit in the continuous quality improvement objectives of the firm.

SUPPLEMENTAL READINGS

The following materials in the Supplemental Readings Booklet (available from HWRIC for $5.00) provide additional information related to topics in this Module:

1. Weinstock, M.P. "Profiting from Pollution Prevention," *Occupational Hazards*, p31-34, December, 1992.

2. Wright, D.R. "Designing a Corporate Environmental Program: The Colgate-Palmolive Approach," In: *GEMI Conference Proceedings - Corporate Quality Environmental Management II: Measurements & Communications*. Global Environmental Management Initiative, Washington, D.C. 1992.

3. Fisher, M.T., "Total Quality Environmental Management: The Procter & Gamble Approach," In: *GEMI Conference Proceedings - Corporate Quality Environmental Management II: Measurements & Communications*. Global Environmental Management Initiative, Washington, D.C. 1992.

4. *Management Practices - U.S. Companies Improve Performance Though Quality Efforts*, GAO/NSLAD-91-190, U.S. General Accounting Office, Washington, D.C., 1991. (Executive Summary and Introduction only).

REFERENCES

1. Post, J.E. "The Greening of Management," *Issues in Science and Technology*, p68-72, Summer, 1990.

2. The Business Roundtable, *Facility Level Pollution Prevention Benchmarking Study.* Washington, D.C., 1994.

3. Haimann, T. *Supervisory Management for Health Care Organizations,* Catholic Health Association of the United States, St. Louis, MO, 1984.

4. Rappaport, A., Flaherty, M.F., *Corporate Responses to Environmental Challenges: Initiatives by Multinational Management*. Quorum Books, NY, 1992.

5. Data Measurement Workgroup, *Environmental Self-Assessment Program*. Global Environmental Management Initiative, Washington, D.C., 1993.

6. Chemical Manufacturers Association, *Responsible Care: A Public Commitment - Pollution Prevention Code of Management Practices.* Washington, D.C. September, 1991.

7. Graham, A.B. "The results of PPR's 1993 Survey: Industry's pollution prevention practices." *Pollution Prevention Review*, 3:369-382, 1993.

8. Office of Research and Development, *Facility Pollution Prevention Guide*. EPA/600/R-92/088, U.S. Environmental Protection Agency, Washington, D.C., 1992.

9. March, B. "Suits Go After Personal Assets of Firm Owners," *Wall Street Journal*, August 13, 1993.

10. Thomlison, B.M. "From a Culture of Fixing to a Culture of Prevention at Arm & Hammar Brand," In:. *Understanding Total Quality Environmental Management*. Executive Enterprises Publications, NY, 1992.

11. Vigon, B.W., Tolle, D.A., Cornaby, B.W., et al. *Life-Cycle Assessment: Inventory Guidelines and Principles*, EPA/600/R-92/245, USEPA Risk Reduction Engineering Laboratory, Cincinnati, OH, 1993.

12. Buchholz, R.A., *Principles of Environmental Management: The Greening of Business*. Prentice Hall, Englewood Cliffs, NJ, 1993.

13. Walton, M. *Deming Management at Work*. New York, Putnam, 1990.

14. FitzGerald, C. "Selecting measures for corporate environmental quality: Examples from TQEM companies." *Understanding Total Quality Environmental Management*. Executive Enterprises Publications, NY, 1992.

15. Wells, R.P., Hochman, M.N., Hochman, S.D., O'Connell, P.A. "Measuring Environmental Success," *Understanding Total Quality Environmental Management*. Executive Enterprises Publications, NY, 1992.

16. White, A.L., Becker, M., Savage, D.E. "Environmentally Smart Accounting: Using Total Cost Assessment to Advance Pollution Prevention," *Pollution Prevention Review*, 3:247-260, 1993.

17. White, A.L., Becker, M., Goldstein, J. *Alternative Approaches to the Financial Evaluation of Industrial Pollution Prevention Investments.* New Jersey Department of Environmental Protection, Trenton, NJ, 1991.

PROBLEMS AND ACTIVITIES FOR MODULE 3

1. For each of the following scenarios, identify who should be involved in the investigation and change-over. (From Ref. 17)

   A. An oil-based cutting fluid is currently being used to produce metal parts on the company's CNC turning lathe. The operators are having several problems: frequent tool breakage, parts out of specification due to heat stress, oil spills and leaks on the floor and foul odors from the cutting fluid. Who would investigate the possible changeover to a more cost-effective and cleaner alternative?

   B. A grocery store chain learns that the cost of having a trash collector to pick up their cardboard boxes is going to increase. It is suggested that the truckers pick up the boxes on the return trip to the warehouse instead of going back with an empty trailer. The boxes would then be sold to a paper recycling plant for a profit. Who should be involved in this program?

   C. A company that paints its final product has discovered problems with its conventional air atomized spray equipment. As little as 30% of the paint sprayed actually reaches the target object and this adds to the high cost of solvent-based coatings. Several suggestions have been made to solve the problem. These include: installing electrostatic spray equipment to increase the efficiently of paint transfer (this will save the company money through reduced paint costs and disposal charges) or using water-borne paints to replace solvent-borne paints and installing a paint recovery system in the plant. Determine which individuals should participate in this investigation.

2. For the following questions, refer to the Procter & Gamble and Colgate-Palmolive corporate policies (see Wright, D.R. "Designing a Corporate Environmental Program: The Colgate-Palmolive Approach" and Fisher, M.T., "Total Quality Environmental management: The Procter & Gamble Approach" in the Supplemental Readings Booklet.

   Procter & Gamble and Colgate-Palmolive are both large consumer product organizations with corporation-wide pollution prevention policies. Each organization has taken a decidedly different approach in developing their pollution prevention policy statements.

   A. Compare and contrast each organization's approach to environmental policy.

   B. Which organization has the best approach? Support your answer.

   C. P&G has characterized the concept of "product stewardship" as a new "consumer need". What is meant by the term "product stewardship"?

D. In your judgment, how has Procter & Gamble's environmental policy influenced the following aspects of the organization?.

- management philosophy
- organizational structure
- business plan

3. Lightolier, Inc. (see Whittman, M.R. "Lightolier, Inc." in the Supplement Readingsbooklet).

A. Using the organizational chart, discuss the role of the following personnel in determining the success of the pollution prevention effort:

Controller
Senior industrial engineer
Senior design engineer
Senior manufacturing engineer
Plant manager
VP of Manufacturing

B. Draft a "corporate environmental statement" for Lightolier, Inc. consistent with both the guidelines of the text and the case. Draft an environmental statement for the APC plant, consistent with both the case and the text.

C. Assume that you are the Plant Manager for the APC and you are in the process of modifying the business plan with Lightolier Corporate Headquarters. Michael Cahill of Manufacturing Engineering has strongly encouraged you to incorporate pollution prevention into the business plan, consistent with the Corporate Environmental Statement. Suggest ways in which you could modify the APC Business Plan in the areas of marketing, finance, operations, and personnel, in order to facilitate pollution prevention.

D. Financial Analysis

i. The "Company Analysis" and TCA ("Discounted cash flow project analysis") estimates for the proposed project differed very little. Why was this? In what ways were the analyses different?

ii. Do you believe it was worth the time to complete the TCA in this case? Why or why not?

iii. No estimate was made of future liability resulting from the continued use of TCE (which would be avoided with the proposed project). Do you believe this omission would significantly alter the decisions to be made about pollution prevention investments? Explain.

iv. Cahill noted that the current TCE system could fail in the near future, disrupting production. This was not directly factored into either cost assessment. What are the likely implications of such a failure and how should APC include them in their project evaluation?

4. Williams Precision Valve Company, Inc. (see Whittman, M.R. "Williams Precision Valve Company, Inc." in the Supplement Readings booklet).

   A. Draft a "corporate environmental statement" for Williams Precision consistent with both the guidelines of the text and the case. Compare and contrast this with your statement for Lightolier, Inc.

   B. Based upon the case, characterize the management philosophy at Williams Precision, and identify the likely impact of this on the implementation of pollution prevention (be sure to consider management philosophy on employee harmony and involvement, continuous improvement, decision-making based on systematic analysis, customer harmony, and community harmony). Compare and contrast this with your answer for Lightolier, Inc.

   C. . For Williams Precision and Lightolier, compare and contrast the role of company personnel and organizational policy in justifying funding for pollution prevention initiatives.

   D. To what extent is pollution prevention integrated into the business operations of each of these two companies? What mechanisms or structures exist in each organization for this purpose?

5. Wrayburn Jewelry Company, Inc. (see Wittman, M.R. "Wrayburn Jewelry Company, Inc." in the Supplemental Readings Booklet).

   A. In your opinion, why was the proposed purchase of the ethyl acetate recovery still "languishing" in Wrayburn's corporate headquarters? Why might the new financial analysis speed-up approval?

   B. Draft a "corporate environmental statement" for Wrayburn consistent with both the guidelines of the text and the case. Compare and contrast this with your statements for Lightolier, Inc. and Williams Precision

   C. Based upon the case, characterize the management philosophy at Wrayburn, and identify the likely impact of this on the implementation of pollution prevention (be sure to consider management philosophy on employee harmony and involvement, continuous improvement, decision-making based on systematic analysis, customer harmony, and community harmony). Compare and contrast this with your answers for Lightolier, Inc. and Williams Precision.

D. For Wrayburn, Williams Precision and Lightolier, compare and contrast the role of company personnel and organizational policy in justifying funding for pollution prevention initiatives.

E. To what extent is pollution prevention integrated into the business operations of each of these three companies? What mechanisms or structures exist in each organization for this purpose?

6. Coated Fine Paper Mill (see White, A.L., Becker, M., Goldstein, J. "Coated Fine Paper Mill" in the Supplement Readings booklet).

   A. Compare the "Company" and TCA financial results. Identify where they differ and explain the basis for this difference. Which costs are not included in the Company Analysis?

   B. The Coated Fine Paper Mill does not have a corporate pollution prevention policy. What type of long term problems might the company encounter if it fails to address the waste water issues in its strategic business planning?

   C. Write an appropriate pollution prevention policy for the Coated Fine Paper Mill Company. Review the pollution prevention strategies for Williams Precision, Wrayburn and Lightolier for possible ideas.

United States General Accounting Office

GAO

Report to the Honorable
Donald Ritter, House of Representatives

May 1991

MANAGEMENT PRACTICES

U.S. Companies Improve Performance Through Quality Efforts

GAO/NSIAD-91-190

Executive Summary

Purpose

Achieving high levels of quality has become an increasingly important element in competitive success. In recent years a number of U.S. companies have found that they could not accomplish world-class quality by using traditional approaches to managing product and service quality. To enhance their competitive position, some American companies have reappraised their traditional view of quality and have adopted what is known as the "total quality management" model in running their businesses.

Congressman Donald Ritter, with the endorsement of 29 other members of Congress, asked GAO to determine the impact of formal total quality management practices on the performance of selected U.S. companies. This report discusses (1) what was achieved by adopting these practices, (2) how improved quality was achieved, and (3) what lessons may be applicable to U.S. companies in general.

Background

For many years the traditional way to achieve quality was through systematic final inspection. This approach is referred to as "inspecting in quality." Intense foreign competition in general, and Japanese competition in particular, has led some U.S. companies to adopt total quality management practices that are prevention based. This approach is often referred to as "building in quality."

The most widely accepted formal definition of what constitutes a total quality management company exists in the criteria for the Malcolm Baldrige National Quality Award. This annual award, given by the U.S. Commerce Department since 1988, recognizes U.S. companies that excel in quality achievement and quality management.

Results in Brief

GAO's review of 20 companies that were among the highest-scoring applicants in 1988 and 1989 for the Malcolm Baldrige National Quality Award indicated the following:

- Companies that adopted quality management practices experienced an overall improvement in corporate performance. In nearly all cases, companies that used total quality management practices achieved better employee relations, higher productivity, greater customer satisfaction, increased market share, and improved profitability.
- Each of the companies studied developed its practices in a unique environment with its own opportunities and problems. However, there were

common features in their quality management systems that were major contributing factors to improved performance.

- Many different kinds of companies benefited from putting specific total quality management practices in place. However, none of these companies reaped those benefits immediately. Allowing sufficient time for results to be achieved was as important as initiating a quality management program.

GAO's Analysis

Performance indicators in each area GAO studied showed an overall average annual improvement from the time companies adopted total quality management to the publication of the latest available data.

Companies provided data in varying degrees based on their availability and company policy concerning the release of proprietary data. While these data were sufficient to evaluate performance trends, they were not sufficient to conduct a statistically rigorous analysis of the companies' performance under total quality management. Therefore, GAO's conclusions are based on a combination of an evaluation of performance trends of the available data and the information derived from on-site visits.

What Was Achieved?

GAO analyzed data in four key areas of corporate operations and found the following:

- Somewhat better employee relations were realized. Employees in the companies GAO reviewed experienced increased job satisfaction and improved attendance; employee turnover also decreased. Eighteen companies reported a total of 52 observations (performance measures) in this area. Thirty-nine out of the 52 improved, 9 declined, and 4 were unchanged.
- Improved quality and lower cost were attained. Companies increased the reliability and on-time delivery of their product or service and reduced errors, product lead time, and their cost of quality. Twenty companies reported a total of 65 observations. Fifty-nine out of the 65 improved, 2 became worse, and 4 were unchanged.
- Greater customer satisfaction was accomplished. Seventeen of the 20 companies provided data on customer satisfaction based on the companies' survey results of their consumers' overall perceptions about a product or service, the number of complaints received, and customer retention rates. Twenty-one out of the 30 reported observations improved, 3 became worse, and 6 were unchanged.

- Improved market share and profitability were attained. As measured by several ratios widely used in financial analysis, the impact of an organization's quality management practices was improved profitability. Fifteen companies reported a total of 40 observations in this area. Thirty-four of the 40 increased and 6 declined.

How Was Quality Achieved?

Companies used no "cookbook" approach in implementing a successful total quality management system, but GAO identified some common features that contributed to the companies' improved performance. For example, corporate attention was focused on meeting customer requirements: senior management led the way in building quality values into company operations; all employees were suitably trained, empowered, and involved in efforts to continuously improve quality and reduce costs; and systematic processes were integrated throughout the organization to foster continuous improvement.

Quality Management Practices Are Widely Applicable

Some lessons learned from GAO's study are applicable to a wide variety of organizations.

- The diversity of companies studied showed that quality management is useful for small companies (500 or fewer employees) as well as large and for service companies as well as manufacturers. The companies GAO reviewed began to focus on quality in the mid-1980s; their quality efforts are still evolving. Nevertheless, these companies improved their performance on average in about 2 1/2 years. Management allowed enough time for results to be achieved rather than emphasizing short-term gains.

Recommendations

This report contains no recommendations.

Agency Comments

Much of the data in this report were provided by the private sector and, therefore, GAO did not request formal comments from any federal agency. As requested, GAO did not discuss the results in this report with officials of the companies studied.

Introduction

Providing excellent product and service quality has become a key to success in competitive international markets. The level of quality expected by many consumers continues to increase as leading competitors raise their standards of quality. In response to the demand for higher quality products and services, a number of U.S. firms are adopting new management practices. The term "total quality management" is often used to describe these practices.

What Is Total Quality Management?

Total quality management (TQM) is a relatively new approach to the art of management. It seeks to improve product quality and increase customer satisfaction by restructuring traditional management practices. The application of TQM is unique to each organization that adopts such an approach. However, based on a review of current management literature and on our observation of the practices of a number of U.S. companies that have adopted TQM, it appears that a consensus has formed around the attributes that are common to all TQM organizations. This consensus is also reflected in the criteria used in the Malcolm Baldrige National Quality Award.

The Malcolm Baldrige National Quality Award

On August 20, 1987, the President signed Public Law 100-107, the Malcolm Baldrige National Quality Improvement Act. This law established the Malcolm Baldrige National Quality Award, named for a former Secretary of Commerce, the late Malcolm Baldrige. The award is designed to recognize companies that have successfully implemented total quality management systems.

The Baldrige Award is managed by the U.S. Department of Commerce's National Institute of Standards and Technology and is administered by a consortium that includes the American Society for Quality Control and the American Productivity and Quality Center.

The award is presented annually to up to six companies (two each in three categories: manufacturing, service, and small business) that pass a rigorous examination process. Applicants are evaluated by teams comprised of leading quality experts from companies, government, and academia. The exact criteria used to evaluate companies have been refined slightly each year, with the trend toward requiring more detailed information in fewer, but more important, areas.

Increasingly, companies view the criteria outlined in the Baldrige Award application as useful diagnostic tools for evaluating the effectiveness of their management practices. One indicator of the interest in TQM practices is that in 1990 over 180,000 applications were requested. Corporate executives also see the process of applying for the award as a way of improving their corporate knowledge of quality management principles and practices.

Features of Total Quality Management

Companies participating in the Baldrige Award process submit applications for examination that document their total quality management systems. The application cites several features that are deemed essential to instituting successful TQM systems. A company must demonstrate the presence of each feature to score well in the examination process. Each of these features is discussed below.

Customer-Driven Quality

An essential attribute of TQM is the general understanding that the customer is the final arbiter of quality. TQM is based on the premise that quality is driven by and defined by the customer. Product and service attributes that create a perception of quality on the part of the customer will increase customer satisfaction and, ultimately, increase customer demand.

Strong Quality Leadership

Strong quality leadership is a key attribute of TQM. Many of the management practices and principles that are required in a TQM environment may be contrary to long-standing practice. Only a strong leadership team focused on quality improvement can overcome the inevitable inertia and resistance to change by creating clear quality goals and developing the systems and methods for achieving these goals.

Continuous Improvement

Continuous improvement, a fundamental attribute of TQM, arises from a philosophy that all business operations and work activities can be done more efficiently. It requires the development of a management approach that encourages identifying and seizing on-going opportunities to improve.

Action Based on Facts, Data, and Analysis

Another important attribute is a willingness to measure quality constantly and to identify and correct conditions causing poor quality. TQM is predicated on decision-making that uses reliable information and analysis. A number of statistical techniques have been adopted to support this process.

Employee Participation

TQM environments allow all employees to participate in helping achieve organizational quality goals. All employees are held accountable for quality and are given tools and training to fulfill this responsibility. TQM is based on the assumption that the employees closest to a particular organization's daily operating procedures are in the best position to understand and improve the quality of those procedures.

Brief History of Total Quality Management

Quality has always been an important element of competitive success. U.S. companies have traditionally used a combination of final inspections and post-production adjustments to ensure quality. Quality was generally not viewed as the responsibility of all employees, however. Specialization within U.S. companies separated the quality function from such areas as planning, design, production, and distribution.

Quality Management in Post-War Japan

In contrast to the specialized approach traditionally used in the United States, a number of Japanese companies, rebuilding from post-war devastation, adopted an innovative, integrated approach to achieving quality. Several leading applied statisticians and quality experts—most notably Drs. W. Edwards Deming and Joseph M. Juran—introduced quality management principles to Japanese industry. The Union of Japanese Scientists and Engineers, a private organization formed by engineers and scholars, provided a forum for the widespread dissemination of statistical quality control techniques. In 1951 the group established the Deming Prize, with the intention of raising the quality levels of Japanese industry. Many of the management techniques developed since then form the foundation of the TQM principles that are gaining popularity in the United States today.

Total Quality Management in the United States

Using an integrated approach to quality, a number of Japanese firms sharply improved their quality levels and began to penetrate U.S. markets. In the late 1970s and early 1980s, this enhanced competition stimulated attention in the United States to the role of TQM systems in activating quality improvement. U.S. companies began to seek out quality management experts to try to understand what was happening and to fashion an appropriate response. Many U.S. experts contributed to the understanding of quality management. Among these experts were Deming, Juran, Armand V. Feigenbaum, and Philip B. Crosby. We noted the increasing interest in TQM in our March 1988 analysis of the growing

Japanese presence in the U.S. auto industry.[1] In that report we noted that U.S. auto manufacturers, "reacting to competitive pressures . . . began to change the way they were doing business . . . . Many of the features which made the Japanese model a success are now being tried and implemented by U.S. automakers."

The increased interest in Japanese management methods was also accompanied by research in the United States that documented that firms can reduce their costs by improving quality. Quality management practitioners began citing the large, hidden costs that companies were incurring due to producing substandard products and services. These costs, known as the "cost of nonconformance," included appraisal, inspection, rework, and warranty fees as well as the cost of replacing customers driven away by poor quality. Some experts estimated that manufacturing costs could be reduced by over 30 percent simply by eliminating scrap and rework that occurs from correcting defects in the manufacturing process.

Other Studies of TQM's Impact on Corporate Performance

During the 1980s the increasing importance of quality has been highlighted in some studies of total quality management efforts. Examples of these studies include the following:

- The Conference Board, Inc., New York, a business research group, surveyed senior executives at 800 large U.S. corporations about their quality management practices.[2] Of 149 firms that responded, 111 reported that they had a quality management program in place. Thirteen of the remaining 38 said they were planning to institute TQM. Sixty-two respondents reported that they measured the impact of quality on profitability. Of these, 47 reported "noticeably increased" profits due to quality management, while only 1 firm reported decreased profits due to "the increased costs of providing higher quality products and services."

  The Conference Board also interviewed senior quality executives at 12 U.S. companies recognized for the excellence of their products and services and found a consensus on the following points:

[1] Foreign Investment: Growing Japanese Presence in the U.S. Auto Industry (GAO/NSIAD-88-111, Mar. 7, 1988).

[2] Current Practices in Measuring Quality, The Conference Board, Inc., Research Bulletin No. 234 (New York: 1989).

1. Total quality is the "strategy of choice" for assuring the economic position of U.S. firms in the global marketplace.

2. Quality improvement is a long-term process.

3. At many companies, concerns remain over the lack of top-level involvement in quality programs.[3]

- PIMS Associates, Inc., a subsidiary of the Strategic Planning Institute, Cambridge, Mass., maintains a proprietary data base of 1,200 companies and studies the impact of product quality on corporate performance.[4] To date, PIMS researchers have found the following:

  1. Product quality is an important determinant of business profitability.

  2. Businesses offering premium quality products and services usually have large market shares and were early entrants into their markets.

  3. Quality is positively and significantly related to a higher return on investment for almost all kinds of products and market situations.

  4. A strategy of quality improvement usually leads to increased market share, but at a cost in terms of reduced short-run profitability.

  5. High quality producers can usually charge premium prices.

- General Systems Company, Inc., Pittsfield, Mass., a prominent quality management consulting firm, maintains a proprietary data base for its clients that documents that firms with total quality management systems in place consistently exceed industry norms for return on investment. This higher return on investment was attributed to three factors.

  1. TQM, by improving the quality of products and services, reduces the direct costs associated with poor quality: inspection, rework, warranties, etc.

  2. Improvements in quality tend to lead to increases in productivity.

[3]The Road to Total Quality, The Conference Board, Inc., Research Bulletin No. 239 (New York: 1990).

[4]The PIMS Letter on Business Strategy, The Strategic Planning Institute, Number 4 (Cambridge, Mass.: 1986).

3. The combination of improved quality and increased productivity leads to increases in market share.

- The American Society for Quality Control, Milwaukee, Wis., commissioned the Gallup Organization in 1989 to survey 601 senior corporate quality executives concerning their perceptions of quality.[5] Among the respondents, 54 percent said they were pleased with the results of their quality improvement efforts, with half of these reporting "significant results, including increased profitability and/or increased market share." Many of the remaining respondents either "weren't aware of" or had not implemented quality improvement programs. Of all respondents, 51 percent believed that "the United States is gaining on foreign competition in terms of quality."
- The Union of Japanese Scientists and Engineers published a study by Dr. Noriaki Kano and others on the Japanese companies that won the Deming Prize between 1961 and 1980.[6] The study considered the earnings rate, productivity, growth rate, liquidity, and safety of the companies and concluded that most companies had an upward trend in or maintained a favorable level of business performance. A few companies showed a temporary upturn in performance, then maintained a performance level above the industry average.
- Ernst & Young, Cleveland, Ohio, an international accounting and consulting firm, is conducting a cross-cultural study of quality management practices in the United States, Japan, and Germany. In each country it will study four industries: computers and telecommunications equipment, automobiles, banking, and health care. The objective of this study is to "establish a new, multidimensional, integrated body of knowledge" regarding quality management.

Objectives, Scope, and Methodology

Congressman Donald Ritter, with the endorsement of 29 colleagues, requested that we determine the impact of total quality management practices on the performance of U.S. companies. Our report discusses (1) what was achieved by adopting these practices, (2) how improved quality was achieved, and (3) what lessons may be applicable to U.S. companies in general.

[5] Quality: Executive Priority or Afterthought? American Society for Quality Control (Milwaukee, Wis.: 1989).

[6] Noriaki Kano et al., Quality, Union of Japanese Scientists and Engineers (Tokyo: Apr. 1, 1983).

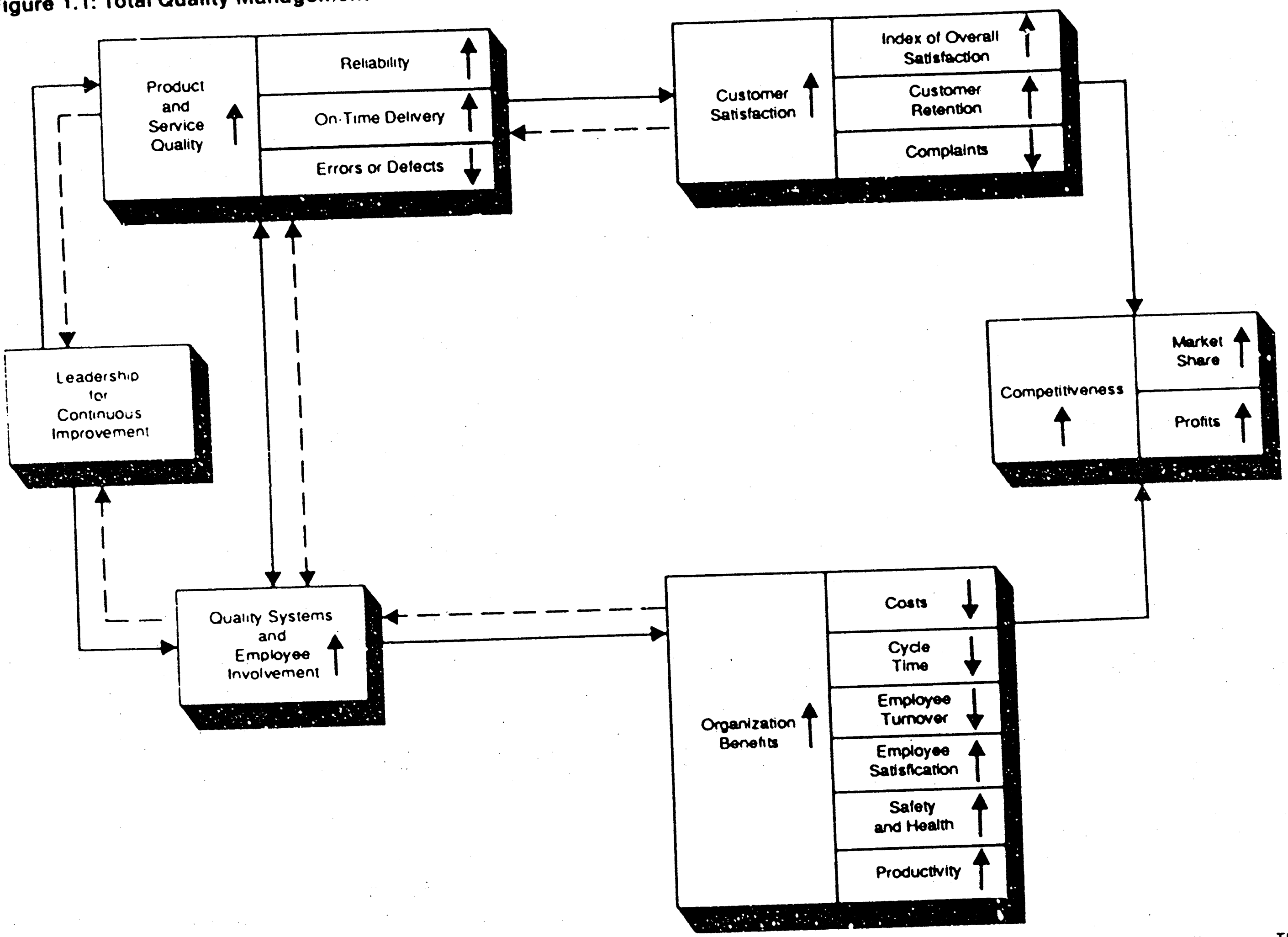
To develop our methodology, we interviewed experts from industry, professional and trade associations, universities, and government agencies. We also conducted a comprehensive review of quality management literature and reviewed prior GAO work that addressed TQM issues.

As a result of this effort, we decided to rely on criteria from the Malcolm Baldrige Award in our study. We also decided to use as our sample those companies that received the highest score on the written portion of the Baldrige examination (and as a result qualified for Baldrige site examinations, the final process prior to winning the award). The specific companies (see app. I) were identified through contacts in private industry. The advantage of this approach was that the criteria were developed through the consensus of experts, and our sample companies were recognized by industry experts as demonstrating superior TQM practices.

Nonetheless, other more comprehensive methodologies were considered. For example, a more rigorous statistical based methodology would incorporate an evaluation of a variety of TQM companies, whether or not they were Baldrige applicants, as well as comparable companies that did not pursue TQM. In addition, it would consider general economic conditions as well as economic conditions within each particular industry. We did not pursue such alternative methodologies because they would necessitate collecting extensive proprietary data at the company or subsidiary level that is generally not publicly available.

To provide a general framework for examining the impact of total quality management practices in diverse organizations, we developed a model based on our understanding of the principles of total quality management as well as our discussions with recognized experts (see fig. 1.1). With the model in mind, we based our conclusions on analysis of the data we collected as well as on our personal observations of company operations.

Figure 1.1: Total Quality Management Model



Note The solid line shows the direction of the total quality processes to improve competitiveness The dotted line shows the information feedback necessary for continuous improvement The arrows in the boxes show the expected direction of the performance indicators

To determine the impact of TQM on corporate performance, we analyzed empirical data in four broad areas: (1) employee relations, (2) operating procedures, (3) customer satisfaction, and (4) financial performance. The first three areas are major sections in the Baldrige application. In each broad area, we identified, with the help of experts, a number of indicators that could be used to measure performance.

Twenty-three individual companies, or divisions of companies, received Baldrige site examinations during 1988 and 1989. The possible sample size was 22 since 1 company received a site visit in both years. We contacted each company and requested its participation in our study. To alleviate concerns the companies may have had about releasing proprietary business information, we obtained a written statement of confidentiality from the requester. We agreed that all data would be treated confidentially within GAO and would not be published separately or otherwise disclosed outside GAO. We shared this confidentiality agreement with the companies.

Twenty of the 22 companies participated in our study to varying degrees, with some providing extensive, detailed operating information and others providing data in summary form. Several companies let us review information contained in their Baldrige Award application. We also evaluated the companies' financial data when available. However, we were unable to obtain sufficient data to conduct a statistically rigorous analysis of the companies' performance under TQM. Not all companies provided complete data, and the data were not available from other sources for all years since the companies had implemented their TQM systems. Several companies, both those privately owned and others, would not release certain proprietary information. Because of these data gaps we do not have a complete statistical picture for every indicator in every company. Therefore, our conclusions are based on a combination of an evaluation of performance trends of the available data and the information derived from on-site visits.

Nevertheless, for each participating company, we did collect a significant amount of available data in each of the four performance areas identified earlier. In judging whether these performance measures were favorable or unfavorable, we considered the direction of the trend over time and its relationship, where available, to some predetermined standard or industry average. For a variety of reasons, companies tended to measure their performance by changes in indicators from their company's past performance rather than by industry averages.

To compensate for the fact that the companies began applying TQM at different times, we calculated an annual average percent change (increase or decrease) for each company for each performance indicator. To do this we used data from the time a company reported the initiation of TQM to when the most recent data became available. We then calculated for each indicator a single average based on the individual company data. We reviewed available company documents, studies, and records that supported the data, such as the results of employee and customer surveys and the companies' Baldrige application. The company data were provided voluntarily by the companies; we did not have unlimited access to all supporting documentation.

In addition to examining individual data elements to determine the impact of TQM on corporate performance, we also generalized the experiences of all the companies to determine common features of effective TQM efforts.

We conducted our work between June 1990 and February 1991 in accordance with generally accepted government auditing standards.

We did not request formal comments from any federal agency, since all data in our report were provided by the private sector. As requested, we did not discuss the results in our report with officials of the companies studied.

FRED'S FOUNDRY
(a mock industrial process)

Thomas J. Bierma and Francis L. Waterstraat
Illinois State University

Don Basset took over his father's foundry ten years ago. His father, Fred, had build up the foundry's business to over $3 million annually. The decline in American heavy industry has led to more intense competition among foundries, and sales for Fred's Foundry have declined to only $1.5 million last year resulting in the layoff of over 20% of the foundry employees. Basset considers his workforce his most valuable asset and wants to look for improvements in efficiency without further layoffs. Basset decided that a pollution prevention program might help improve efficiency, improve morale, and reduce risks. From various departments, he assembled a pollution prevention team to evaluate the sources of waste in the foundry and recommend appropriate solutions.

Figure 1 presents a simple process flow diagram for the foundry. Cores and molds are made from sand and binder. The cores are then fitted into the molds and molten metal is poured into mold/core combinations. The casting is then cleaned and finished before shipping.

Basset decided to begin with the core making process (cores produce the hollow interior portions of a casting). Sand, binder and catalyst are received and stored. As needed, sand and binder are transported to a mixer and the mixture is then fed into the molding press. The press impresses the image of void for the metal piece to be poured. A catalytic agent is then injected to harden the binder and create the core. Cores are then moved to a temporary storage area. Specific types of cores are retrieved from temporary storage as needed and transported to the mold area to continue the process of making the casting.

Last year's production records indicate that 1,000 tons of core were delivered to the mold area, or about 4 tons per day. Core material contains 95% sand and 5% binder (catalyst represents an insignificant proportion). During this period, 1,150 tons of core sand, at $100/ton, were received from the supplier according to receiving records. Fifty-five tons of Binder was delivered in 100 lb. bags, at $40/bag. Catalyst gas, 2,700 lbs. last year at $50/lb., was received from tank trucks and pumped to a storage tank.

Sand is unloaded from trucks using a conveyor belt system, resulting in considerable spillage and dust. From storage, sand is transported to the mixer in hoppers carried by lift-trucks. Again, considerable spillage and dust occur. Little spillage seems to occur at the mixers. .Unloading and transport occur in an open air area. The team decided to allocate all sand lost prior to mixing to the receiving, storage, and transport of sand. Binder is loaded into the mixer directly from the bags, resulting in negligible losses (packaging waste can be ignored in this analysis).

During last year, 1,100 batches of sand/binder mix were created. The weight of each batch is carefully controlled to weigh 1 ton and contain 95% sand and 5% binder. Once sand

and binder are mixed, little loss of this material occurs through the core pressing and polymerization steps. In polymerization, catalyst is pumped to the core machines on demand. During the two-week plant shut-down last year it was noted that the catalyst storage and piping system lost about 2 lbs./day, apparently through leaks in the piping system. This averages about 0.5 lb./ton of core. Of the 2.2 lbs./ton delivered to the core machine, Engineering estimates that about 0.7 lbs./ton reacts with the core mix and the remainder is off-gassed. The catalyst is highly toxic so the off-gassed catalyst is captured in a hood and ducted to a water scrubber, which removes 90% of the catalyst. The water is chemically treated and discharged to the sewer. Cost for removal, treatment, and discharge of catalyst is $10/lb. The remainder of catalyst is exhausted to the atmosphere.

Basset noted that though 1,100 tons of core mix was made last year, only 1,000 tons reached the mold area. To better identify the source of this loss, core area employees kept track of core breakage for two weeks. For these weeks, 40 tons of core were made and 3.6 tons of broken core were discarded. Ninety percent of this breakage occurred in temporary storage. A shortage of space has caused crowding in the storage area and cores are broken while being moved. Cost accounting estimates that about $600 in labor, energy, and capital has been applied to each ton of core by the time it is in short-term storage. The remaining 10% of breakage occurred while removing the core from the core machines (following polymerization). Approximately $500 in labor, energy, and capital has been applied to each ton of core by this point. Waste core material cannot be reused and must be landfilled at $50/ton.

An audit of inventories identified no net changes for sand, binder, or catalyst over the year.

POLLUTION PREVENTION OPTION SELECTION

To select the priority areas for pollution prevention in the core making process the team decided to consider the threat of by-products to both workers and the environment, in addition to the direct costs of the by-products. The team was concerned about worker exposure to sand lost during transport. Sand losses during transport was selected as top priority due to the very heavy exposures to workers and the potential relationship of such exposures to lung disease.

The literature suggested a number of options for sand transport, two of which, compressed air and vacuum systems, held promise for reducing sand losses. The foundry's sand supplier suggested that the team visit a nearby glassworks which successfully uses a vacuum system. The team found that the system was easy to use and produced little visible emission of sand. The system's manufacturer estimated that foundry losses would be reduced by 95%. The cost of the system was estimated at $200,000 with annual operating costs similar to those of the existing conveyor system. The team considered the potential liability of worker exposure to be great. Employee morale gains from the new system might also be significant. Based upon this the team recommended the vacuum system.

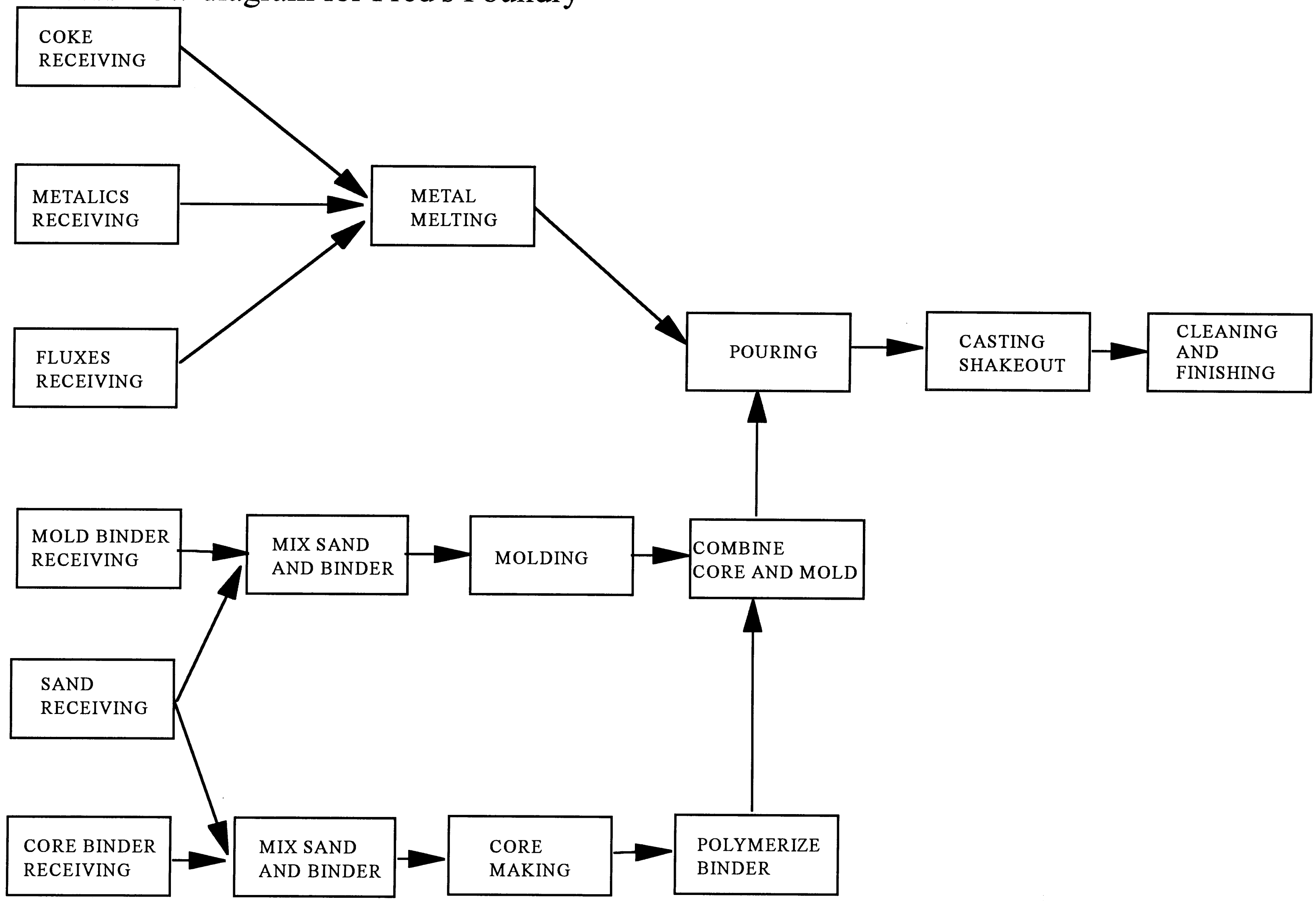
The loss of cores during temporary storage was also selected as a top priority due to high direct, tangible costs. The team decided to study the storage process to determine the causes of core breakage. They found that most breakage occurred when cores were moved around to gain access to particular cores that were needed for pouring in the next several hours. This problem seemed to be due to two factors. First, the storage area was poorly organized, with no plan as to where certain types of cores should be placed. Second, the weekly pouring schedule, which was used to plan the week's production of cores, frequently changed in response to last minute order changes from customers. Core making was notified of these changes but because the core machines required several hours to change over to a new core type the foundry relied upon an excess of many types of cores in temporary storage to cover changing needs in pouring. The scheduling problem had gotten worse in recent years as the foundry tried to be more responsive to customer needs.

Working with the employees in core making, two changes were recommended. First, the storage area was organized to group core types together and place the most frequently used cores closest to the exit area. The arrangement also maximized access for lift trucks. In the first month of using this new arrangement, core losses dropped from 0.09 tons/ton to 0.03 tons/ton. It also reduced the time it took to retrieve cores.

The second change involved the changing time for core machines. Working with core machine employees the team studied the changing process and also made a trip to a metal fabricating plant which had dramatically reduced the time it took to change its stamping presses. After three months, the team was able to reduce changing time from 150 minutes to just 20 minutes. With production schedule updates twice daily, core making was better able to adapt to demand for cores, reducing inventory in temporary storage by 20%. This reduced core losses to 0.008 tons/ton.

The team estimated that approximately $50,000 in personnel time was spent developing and implementing these improvements. No other costs were involved. Savings included not only the reduction in core waste but approximately $10,000 annually in reduced overtime due to improved efficiencies.

Process flow diagram for Fred's Foundry



STANDARD METAL PRODUCTS COMPANY

(mock industrial process)

Thomas J. Bierma and Francis L. Waterstraat
Illinois State University

PROCESS AND BY-PRODUCT STREAM ANALYSIS

Standard Metal Products Company is a small metal parts fabricating facility, producing a variety of electrical switch box housings. Due to concerns about the costs of waste disposal and out of interest in improving process efficiency, the company president, Jody Wilson, conducted a materials balance for the facility. Company records indicate that during the last 12 months the company produced 400,000 lbs. of product, operating 5 days per week, 50 weeks per year. An insignificant fraction of this product weight is paint, the rest is sheet metal. Purchasing records indicate that 500 rolls of sheet metal, each weighing 1,000 lbs., were used. Each roll cost $1,000.

The process has four basic processes. First, sheet metal is cut an drilled into appropriate shapes. The sheet metal contains a thin film of oil to protect the metal from corrosion and to add lubrication during machining. However, a cutting fluid is also used to minimize machine wear and heat build-up. Second, the metal is folded into a box of proper dimensions. Then the machining oil is removed in the degreasing operation. Finally, the bare metal is then spray painted and is ready for shipment as final product.

Scrap metal from cutting and drilling is picked-up by a local scrap dealer at no charge. In the last 12 months, records indicate that 100,000 lbs. of scrap metal was collected. Records also indicate that 10,000 gallons of cutting fluid were used in the cutting and drilling operations, at $8/gallon. Nine-thousand five-hundred gallons of waste cutting fluid was chemically treated and released into the municipal sewage system at a cost of $1/gallon. Forty-thousand gallons of cleaning solvent were used in degreasing prior to painting, at $10/gallon. Thirty-thousand gallons of waste cleaning solvent were shipped to a solvent reclaimer at a cost of $2/gallon The remainder was unaccounted for and was probably emitted into the air. Five-thousand lbs. of paint were used, at $1/lb. Of this, approximately 1,500 lbs. remains on the product. Of the remaining 3,500 lbs. of overspray, approximately 1,750 lbs. is collected on fabric filters and disposed of by a hazardous waste hauling company at $2/lb., and 1,750 lbs is released from the plant as an air pollutant. (The fabric filters are both low weight and low cost and can be ignored in this analysis.)

POLLUTION PREVENTION OPTION SELECTION

Wilson asked the operations manager and the line workers to examine means of reducing or eliminating TCA waste, and possibly TCA itself, from the cleaning operation.

Following a brainstorming session, the team identified the following short-list of options.

1. Enclose cleaning operation to minimize evaporative emissions of TCA.
2. Purchase a still to reclaim some of waste solvent in- house.
3. Find an alternative cleaning solvent.
4. Find an alternative cleaning process.

Option 1 was not considered a priority since it would address only evaporative losses, which were a minor component of total solvent waste. Based upon materials supplied by still manufacturers, Option 2 offered the possibility of reclaiming as much as 80% of the solvent in-house, though capital and operating costs were substantial. The team was uncomfortable about still operation. The firm did not have experience in chemical processing, and even though the still was automated it would require regular monitoring, adjustment, and maintenance.

The team contacted the TCA supplier for advice. The supplier indicated that TCA was an "ozone depleting chemical" and was being phased out. This, and the toxicity of TCA, further reduced the attractiveness of Options 1 and 2 since these options relied upon the continued use of TCA or a similar solvent. The supplier was already carrying a substitute, Aquaclean - a water-based solvent - and was helping customers make the transition. The team contacted other suppliers and found another promising substitute, Enviroclean. Both products required the purchase of new cleaning equipment for the production line.

Through a contact with the state pollution prevention assistance office a company was identified which was using a pressurized air cleaning process prior to painting metal parts. The operations manager visited the plant and brought several of the switch boxes produced at Standard Metal. He found that the pressurized air was not sufficient to clean the oily residual on the metal. The residue was machine oil present on the supplied metal. As a very small customer, Standard Metal did not feel it had the market power to demand elimination of the oil from its supplier.

The search was focused on the two water-based degreasing options. Standard Metal's parts were tested in both systems and were cleaned as well or better than with the current TCA system. The local sewage district found that both solvents were very biodegradable and, given the limited volume to be used, could be discharged into the sewage system without additional charge. The difference between the systems was in equipment.

Aquaclean used a recirculation system but eventually the spent solvent must be flushed and new solvent added. The team estimated that this would require about 5 gallons per 1000 lbs of product. The cost for the system was $50,000 and had a life expectancy of 15 years. The team estimated that it would consume about $5 in electricity per 1000 lbs of product. The solvent costs $18/gallon.

Enviroclean used a recirculation and separation system that removes most contaminants from the solvent. The sludge (removed contamination) can be discharged to the sewer. The system would use only about 0.5 gallons per 1000 lbs of product, but would consume $15 in electricity per 1000 lbs of product. The cost of the system is $100,000. The solvent costs $20/gallon.