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Clean Technology:

An Integrated Approach to Environmental Management of Industrial Development

Prepared by:

Dr. Smita K. Siddhanti
Paul Leamon
Booz Allen & Hamilton
and
Dr. Abdul Shibli
Stonehill College

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Preface

This concept paper brings together some of the industrial environmental man agement concepts currently in vogue among various national and international agencies and institutions active in environmental policymaking. In addition to discussing current definitions and multiple perspectives on these concepts, the paper integrates the individual concepts into the larger framework of environmental management.

The concept paper arose out of a need to clarify a number of issues in industrial environmental management and illustrate best practice and technology in light of U.S. experience in sustainable industrial development. By highlighting U.S. experience, the paper contributes to achieving US-AEP goals and objectives, which include helping the U.S. private sector take advantage of "the significant opportunity for the United States to extend the reach of its own experience, best practice, and technology to Asia" and define "the United States as the referent for environmental quality over the longer term." Although the paper focuses on U.S. experience, it also presents good management practices in other countries and various global initiatives.

This concept paper also serves as background for US-AEP's Clean Technology initiative. Within this context, the purposes of the paper are to *(a)* provide an integrated framework to support US-AEP's strategic objective (increasing efficient and less polluting industrial regimes in Asia), *(b)* provide a common understanding of the terms listed in US-AEP's industrial technology and environmental management "ladder" to facilitate effective communication among environmental professionals, industry, government, and the public, and *(c)* discuss the various environmental management concepts within the framework of a menu of options. The environmental ladder is a flexible tool or menu and not a preferred hierarchy. Not only does the need exist to use a range of these concepts as environmental management tools within an organization, but other concepts, not addressed in this paper, could be more applicable and effective in the many varying circumstances faced by organizations.

The development of this concept paper was a team effort led by the staff at Booz Allen & Hamilton in partnership with staff of International Resources Group (IRG). Dr. Smita Siddhanti and Paul Leamon of Booz Allen & Hamilton researched and wrote the paper under U.S. Agency for International Development (USAID) contract AEP/0015G0050-1400 and subcontract number 1147-95-03 with Dr. Abdul Shibli from Stonehill College as a consultant to IRG. The authors wish to thank John Butler and Malcolm Baldwin of IRG for their constructive input and support. Barbara Bever managed production and Pamela S. Cubberly edited and formated the document.

About US-AEP

IMPROVING THE INDUSTRIAL AND URBAN ENVIRONMENTS OF ASIA WITH AMERICAN EXPERIENCE, TECHNOLOGY, AND PRACTICE

Founded in 1992 as a Presidential Initiative, the United States-Asia Environmental Partnership (US-AEP) operates under the leadership of the United States Agency for International Development (USAID) with the cooperation of a broad range of partners: Asian and American individuals, nonprofit organizations, private businesses, and government agencies, including the federal Environmental Protection Agency (EPA) and Department of Commerce, California EPA, and both the National Association of State Development Agencies and the Council of State Governments.

In creating US-AEP, the White House and USAID assumed a growing Asian commitment to sustainable development and an American eagerness to share the world's largest pool of relevant experience, technology, and practice. US-AEP focuses its resources on industry, infrastructure, and the building of a framework of policies, constituencies, and public awareness. Cleaner production in industry coupled with a full-scale attack on the pollution problems of Asia's megacities will improve the quality of life within the region and promote its sustainability.

With Asia approaching an industrial transformation and America earning praise for environmental expertise, US-AEP embodies a new vision of cooperative development, one that maps the way toward more efficient production and a more benign quality of life.

US-AEP has three divisions: Clean Technology and Environmental Management (CTEM); Environmental Infrastructure; and Framework of Policies, Constituencies, and Public Awareness. An Environmental Exchange Program supports the other components.

Executive Summary

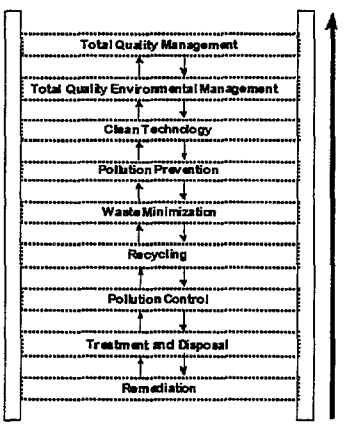
Industrial development in Asia will profoundly affect the future of the global environment. Rates of growth continue to surpass those of other regions by large margins. Nevertheless, the "industrial miracle" has generated, along with its undeniable benefits, a deeply alarming and relentlessly rising tide of pollution.

Threat often travels with opportunity, however. Happily, Asia's industrial development is still in early stages. In Indonesia, for example, only 15 percent of the industrial capacity that will be installed by the year 2010 is in place today—that is to say, the sheer volume of new investments in the next two decades will soon overwhelm the aggregate of all previous investments.

Asian countries, therefore, have a once-in-a-lifetime opportunity to shift forcefully toward a clean foundation and thereby avoid many of the problems that have plagued industrial countries since the postwar dawning of environmental concern. Although most advanced economies have aging industries and infrastructures that require expensive technologies to contain and ameliorate environmental impacts, many Asian countries are capable of making a seamless transition to cleaner production.

In response to this unique opportunity to be clean from the beginning, the United States-Asia Environmental Partnership (US-AEP) promotes the creation of more efficient and less polluting industrial regimes. This means moving away from end-of-pipe controls and away from the cleanup of pollution after it has been generated. It means using nothing less than "clean technology."

FIGURE A. INDUSTRIAL TECHNOLOGY AND ENVIRONMENTAL LADDER



This transition insists on fundamental changes in the practices, processes, and management of industrial facilities. At the heart of its industrial strategy, therefore, US-AEP envisions a conceptual model (figure A) that might be called a "ladder of industrial technology and environmental management."

The higher rungs, which represent more sophisticated and comprehensive concepts, incorporate the more basic and straightforward concepts of the lower rungs; thus, although the overall objective remains moving toward management practices higher on the ladder, many of the concepts represented as lower rungs should still be seen as useful, effective, and legitimate means of achieving specific environmental goals.

This primer brings together current definitions and descriptions for each concept on the ladder and elaborates on the relationships among the various rungs. A thorough grounding in these concepts and relationships should provide a useful framework for evaluating further environmental improvements.

DESCRIPTION OF THE LADDER

The ladder consists of nine interrelated rungs. It is important to note that, as one reads down the ladder, the concepts start with the broadest and most anticipatory and end with the narrowest and most reactive. Here, in descending order, are the basic definitions:

Total quality management (TQM), the top rung, incorporates and affects all aspects of business operations from the highest levels of management to the most perfunctory tasks of employees. Its key components include a dedicated and involved management; focus on satisfying customers; commitment to steady, continuous improvement; trust in employees that leads to investments in training and education and the delegation of authority and power; emphasis on teams, participation, informal interactions, quality circles, and collegial solution of common problems; and, of course, willingness to measure performance with key indicators.[1]

For example, one of the world's leading manufacturers of electronic systems and components discovered in the early 1980s that many of its products and operations were failing to meet expectations of quality. Top management called for a tenfold improvement in quality within five years, reducing defects to 3.4 per million opportunities in all operations. At the end of five years, the company pronounced the experiment to be a resounding success. It had retained its position in global electronics through a companywide renewal of quality improvements, product innovations, and strategic planning. Defects had been cut by 80 percent, and the company had saved some $962 million in inspections, redesigns, and repairs.

Total quality environmental management (TQEM) marries TQM and environmental management. It is, thus, both a subset of TQM and a singular concept that stands alone on its own merits. It assumes such TQM goals as customer satisfaction, constant improvement, and rigorous measurement. It further entails easy access to pivotal information and important communications, especially those that shed light on management's environmental performance. In the end, however, TQEM remains a management-led technique that guides companies with clear environmental goals toward implementing more successful companywide practices. An example of TQEM is Xerox's development of the Environmental Leadership Steering Committee, which has developed initiatives to direct Xerox toward greater environmental accountability.

Cleaner production/clean technology considers the impacts of products from their inception through processing to the end of their life cycle. Cleaner production determines ways to produce products that generate little waste and, when waste is produced, ways to increase its recyclability. An example of cleaner production is the development of new water-based adhesives by the U.K. company Blueminster. The use of water- instead of solvent-based adhesives reduces energy use and the amount of volatile organic compounds released into the environment.

Pollution prevention, a concept that closely resembles waste minimization, focuses on using more efficient manufacturing processes to prevent the production of waste, instead of recycling generated wastes. Pollution prevention includes techniques such as improved process control to use materials more efficiently. For example, the use of a new flux material in printed circuit board manufacturing eliminates the need for highly toxic cleaning materials.[2]

Waste minimization encompasses developing more efficient manufacturing processes and recycling waste to reduce the amount of waste actually generated. Manufacturing processes can be changed to reduce the amount of waste produced or to accommodate more in-process recycling. An example of waste minimization is Polaroid's Toxic Use and Waste Reduction Program. Its goal is to reduce the waste emissions from all plant operations through numerous changes in production techniques, such as using better technology and chemical substitution.[3]

Recycling is the reuse or reclamation of a waste in the same industrial/manufacturing process, in another on-site process, or in a process at an off-site facility producing an unrelated product. This approach prevents the material from becoming a waste that would require treatment and disposal. One example of recycling is Xerox's Asset Recycling Management program, which creates products that are more amenable to recycling and collects these products for reuse once they have reached the end of their productive life.[4]

Pollution control is an end-of-pipe practice that captures contaminants before release into the environment. An example of pollution control is the use of scrubbers in smokestacks to remove contaminants, such as sulfur dioxide, from emissions before they enter the air.

Treatment is the end-of-pipe reduction of contaminants. *Disposal* is the placement of any residuals from this treatment into a protected unit, which minimizes releases into the environment. The electrical equipment manufacturing industry, for example, attempts to deal with its significant generation of polychlorinated biphenyl (PCB)

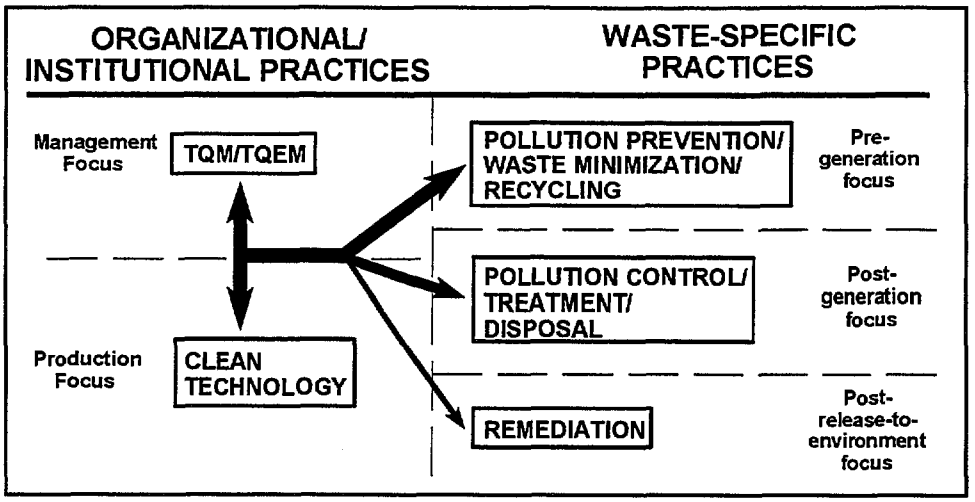


FIGURE B. OVERVIEW OF INTERRELATIONSHIPS AMONG ENVIRONMENTAL MANAGEMENT PRACTICES

wastes through varius treatment and disposal techniques. Handlers of PCBs (such as generators and other waste management facilities) are required to meet stringent treatment requirements to destroy most of the harmful biphenyl contaminants. After treatment, PCB disposal is restricted to permitted and highly regulated disposal units.[5]

Remediation is an environmental practice that solves problems after they have been created. Remediation is the cleanup of contaminants in such media as soil, air, and water after wastes have been discharged. In addition, remediation addresses releases into the environment that create an immediate, emergency situation with possible serious harm to human health and the environment. An example of remediation is the cleanup of Love Canal by capping and containing contaminants in the canal area and removing contaminated soil and debris from surrounding neighborhoods.[6]

SYNTHESIS OF ENVIRONMENTAL MANAGEMENT CONCEPTS

This paper was originally based on the premise that each of these environmental management concepts was linked in a hierarchical order, visualized as the ladder in figure A. As the definition of each concept unfolded, however, the need to view these concepts in two ways emerged. The first was to understand the overlaps and interrelationships among the different environmental management practices. The second way was to see the elements of the ladder as a preferred progression of environmental management practices for industrial development (see discussion beginning on page 89, chapter 11). Figure B above depicts our view of the interrelationships among the defined concepts. The boxes group similar concepts; the arrows indicate the practices that are used to implement each other, and their weight indicates the relative strength of the relationship.

ORGANIZATIONAL/INSTITUTIONAL PRACTICES

The figure breaks the nine individual concepts into two groups. The first, organizational/institutional practices, includes TQM/TQEM and clean technology. These concepts are distinguishable from the other concepts in their focus on activities that promote changes on a large scale and not specifically on a particular waste. These activities span a company's management and decision-making processes based on TQM/TQEM to changes in its operations and production, such as product reengineering and "designs for environment" based on clean technology. In addition, these concepts differ in their emphasis on corporate cultural changes and their effects, not only on waste elimination but energy and resource conservation.

TQM AND TQEM

The first relationship within organizational/institutional practices is the significant overlap between TQM and TQEM. As discussed in chapter 3, TQEM is the application of TQM ideas and techniques to environmental management. TQEM evolved from the realization that corporate environmental management could greatly benefit from quality management and vice versa.

TQEM AND CLEAN TECHNOLOGY

The second important relationship is the interplay between TQEM and clean technology. From an environmental perspective, TQEM and clean technology are mutually reinforcing. TQEM concerns broad management culture and practice issues, whereas clean technology is more directly related to investment, operation, and main-

tenance issues. TQEM practices reinforce the environment-friendly features of clean technology and minimize adverse environmental impact. For example, good environmental management practices can play an important role in key industrial activities in energy use, wastewater discharge, management of industrial chemicals, and management of solid waste.

ORGANIZATIONAL/INSTITUTIONAL AND WASTE-SPECIFIC PRACTICES

The arrows in figure B show another relationship involving TQEM and clean technology: both programs use the concepts of waste-specific activities in the second column. For example, as part of its TQEM system, an existing large manufacturer of chemicals may implement site remediation of its contaminated property. Furthermore, that same industry may implement, as part of its overall cleaner production initiatives, in-process recycling to reduce the amount of a specific waste produced and the virgin materials needed.

As already mentioned, the weight of the arrows indicates the strength of the relationship between TQEM/clean technology and each of the three groupings of waste-specific activities. The thickest arrow to the pregeneration focus grouping indicates that TQEM and clean technology emphasize the use of these practices. As discussed in chapter 3, clean technology shifts the emphasis from end-of-pipe management practices to reduction and prevention of wastes and use of toxic materials. Although both TQEM and clean technology focus on waste before it is generated, pollution controls, treatment, disposal, and remediation options are needed under certain circumstances.

WASTE-SPECIFIC PRACTICES

Waste-specific practices, the second grouping, encompasses pollution prevention, waste minimization, recycling, pollution control, treatment, disposal, and remediation. These six practices clearly differ from the other concepts by concentrating on specific waste streams or production processes, as opposed to focusing more broadly on management or production processes. These practices are divided into three groups based on whether they focus on waste before or after it is generated, or after it has entered the environment.

POLLUTION PREVENTION, WASTE MINIMIZATION, AND RECYCLING

The first group includes pollution prevention, waste minimization, and recycling, all of which focus on activities before a waste is generated. They have much more in common, however. First, pollution prevention and waste minimization are nearly identical. As discussed in chapters 5 and 6, both pollution prevention and waste minimization seek to reduce the amount of waste from a production process. Both can be pursued through product reformulation, process modification, equipment redesign, and resource recovery. Pollution prevention differs from waste minimization chiefly in that it focuses more on the beginning of the process through process engineering changes, whereas waste minimization focuses more on in-process and end-of-process changes through activities such as recycling.

How recycling fits with pollution prevention and waste minimization has been extensively discussed in both government and industry programs. For example, several U.S. Environmental Protection Agency (EPA) memos and its statement of principles have attempted to clarify the role of recycling in pollution prevention. A recent paper by John Cross, deputy director of EPA's Pollution Prevention Division, states that of the three common types of recycling—in-process or closed loop, out-of-process, and off-site recycling—only the first is considered equivalent to pollution prevention. Some in-process recycling, for example, energy recovery through incineration, is excluded from the domain of pollution prevention.[7] Industry has also clarified the role of recycling in pollution prevention and waste minimization programs. For example, Polaroid (see figure 6-1, page 54) has developed a hierarchy of preferred types of recycling, from on-site controlled recycling to off-site vendor recycling.

POLLUTION CONTROL, TREATMENT, AND DISPOSAL

Pollution control, treatment, and disposal have been grouped together as practices that focus on managing wastes after generation. As discussed in chapters 8 and 9, pollution control and treatment perform similar functions and are nearly identical in practice. Both practices perform an end-of-pipe function to prevent harmful contaminants from entering environmental media. In most cases, both of these practices are performed to meet standards set by regulations.

Disposal differs significantly from pollution control and treatment in that a waste is managed after it has come "out of the pipe." Depending on regulatory controls and the characteristics of the waste, it can be disposed of directly into the environment or into units that prevent the waste from entering the environment. Disposal, however, is linked to pollution control and treatment not only because it focuses on waste after its generation but also because the other two practices inevitably produce their own wastes that require disposal.

REMEDIATION

The third group—defined by its focus on waste after it enters the environment—only includes the environmental management activity of remediation. Remediation is unique in that it is only employed once a waste or contaminant enters the environment and poses a threat to human health and the environment. Many argue that, because disposal often places waste directly into environmental media, it should be considered similar to remediation. No matter how dependent remediation is on disposal practices and/or the characteristics of a waste, disposal does not always require the follow-up that characterizes remediation; thus, the goal of remediation is to solve problems posing threats to human health and the environment after they have been created.

TOWARD AN INTEGRATED STRATEGY: A SUGGESTED HIERARCHY OF CHOICES

Chapter 11 describes the industrial environmental management concepts described above from a slightly different perspective, exploring whether, in addition to the linkages among these concepts, any hierarchical relationship exists among them. Our suggested strategy, presented below, is only indicative and not prescribed for environmental management. The suitability of this or any hierarchy for organizations or countries participating in US-AEP programs depends on a number of objective conditions, including the regulatory framework, level of industrialization, as well as role, sphere of influence, and instruments available to the decision maker. This paper does not address these conditions, which relate to industrial policy, in this paper. We expect the questions raised in this chapter will be fully debated in a separate study.

Our suggested strategy for a hierarchical preference for environmental practices, shown in figure C, builds on US-AEP's ladder concept. We have, however, grouped several of the individually discussed environmental management practices together based on this chapter's earlier discussion of the interrelationships among them. Although many may argue that, within each grouping, one activity may protect human health and the environment more than another, we argue that the most effective practice is based more on site- and waste-specific conditions.

A great effort has been made to get away from poor management of wastes requiring the cleanup of contaminated media after the wastes have entered the environment, which, including human health, they might otherwise adversely affect. This effort has gone beyond the reactive practices of end-of-pipe management to more proactive strategies to prevent waste from being generated.

Some hierarchies of environmental practices have ended with pollution prevention, however, a broader attack on environmental management is necessary—one that pushes for corporate culture change, product life-cycle assessment, and design for environment. These concepts move beyond pollution prevention (although this is the best practice among waste-specific activities) to instituting *(a)* organizationwide practices that focus on broader management and operational change in corporate decisions and *(b)* national policy for economywide decisions. At the top of the hierarchy, therefore, are TQEM and clean technology. Both stress efficient use of energy, conservation and long-term sustainability of the ecosystem, and the environmental impact of products during their entire life cycles (i.e., from "cradle to grave"), from mining and manufacturing to use, reuse, and disposal.

How does an organization using this hierarchy make decisions differently from one that uses a hierarchy stop-

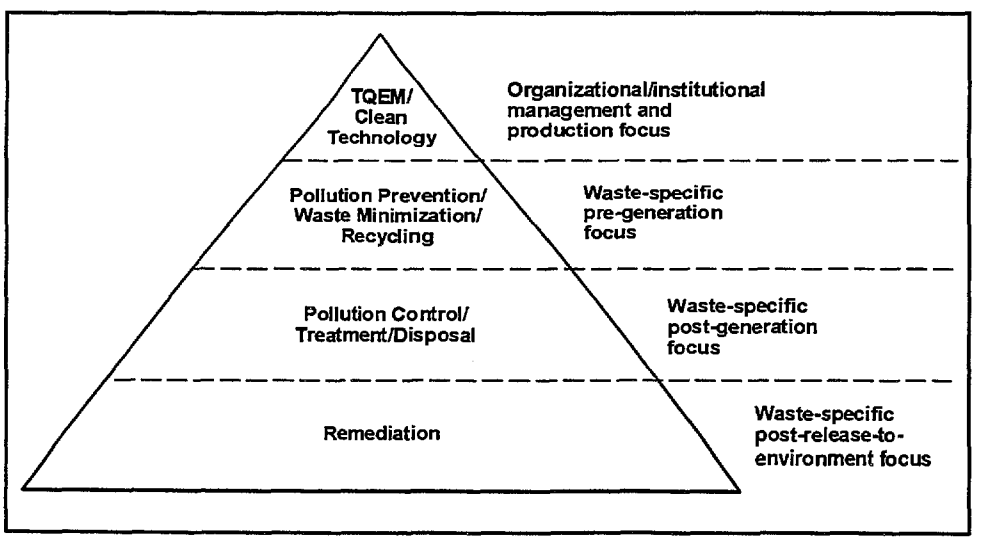


FIGURE C. A SUGGESTED HIERARCHY OF ENVIRONMENTAL MANAGEMENT PRACTICES

ping at pollution prevention? Consider the case of a utility company investing in a new thermal power plant to generate electricity. Suppose that the plant can use high sulfur coal from a nearby mine, low sulfur coal brought in from another region of the country, or imported natural gas. It also has a number of alternatives to reducing emissions of SO_2 in particular, high stacks, a scrubber, and a new cutting-edge abatement technology. Assuming that all the options are financially viable and cost-effective, a clean technology strategy would require the company to incorporate environmental impacts, particularly resource conservation and energy use, in its decision matrix. Relevant cleaner technology concerns are pollution problems at the mine's mouth, pollution during transport of coal, SO_2 and NO_x emissions, storage of coal, and solid waste disposal problems, among other concerns.

CONCLUSION

This paper brings together current and developing environmental management practices to define clearly the scope of each concept, using current literature for background, varied perspectives, and measurement issues for each one; thus, by developing clear definitions, we seek to understand better possible strategies to achieving a "clean revolution." As discussed briefly in chapter 11, each concept is in some way linked to other environmental concepts, and emerging management practices are constantly changing the nature of these relationships. We are not, therefore, suggesting that our presentation of the relationships among the concepts is carved in stone; rather, it is a flexible conceptual structure that simply provides a rule of thumb. We hope it will spark a dialogue among policymakers, industry, academia, and the public on strategies for moving toward the ultimate goal of a sustainable environment through a "clean revolution."

Chapter 11 also briefly discusses the desired movement to the top of the hierarchical pyramid. The hierarchy does not create an either-or test in which a specific clean technology or source reduction plan is the only acceptable strategy for environmental protection. Rather, it is a framework for continuous improvement in strategies to environmental protection.

Chapter 1: Overview

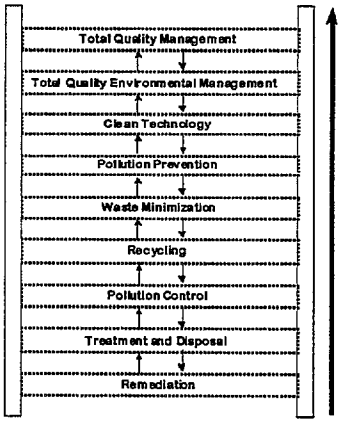
Industrial development in Asia will profoundly affect the future of the global environment. Rates of growth continue to surpass those of other regions by large margins. Nevertheless, the "industrial miracle" has generated, along with its undeniable benefits, a deeply alarming and relentlessly rising tide of pollution.

Threat often travels with opportunity, however. Happily, Asia's industrial development is still in early stages. In Indonesia, for example, only 15 percent of the industrial capacity that will be installed by the year 2010 is in place today—that is to say, the sheer volume of new investments in the next two decades will soon overwhelm the aggregate of all previous investments.

Asian countries, therefore, have a once-in-a-lifetime opportunity to shift forcefully toward a clean foundation and thereby avoid many of the problems that have plagued industrial countries since the postwar dawning of environmental concern. Although most advanced economies have aging industries and infrastructures that require expensive technologies to contain and ameliorate environmental impacts, many Asian countries are capable of making a seamless transition to cleaner production.

In response to this unique opportunity to be clean from the beginning, the United States-Asia Environmental Partnership (US-AEP) promotes the creation of more efficient and less polluting industrial regimes. This means moving away from end-of-pipe controls, away from the cleanup of pollution after it has been generated. It means using nothing less than "clean technology."

FIGURE 1-1. INDUSTRIAL TECHNOLOGY AND ENVIRONMENTAL LADDER



This transition insists on fundamental changes in the practices, processes, and management of industrial facilities. At the heart of its industrial strategy, therefore, US-AEP envisions a conceptual model (figure 1-1) that might be called a "ladder of industrial technology and environmental management."

The higher rungs, which represent more sophisticated and comprehensive concepts, incorporate the more basic and straightforward concepts of the lower rungs; thus, although the overall objective remains moving toward management practices higher on the ladder, many of the concepts represented as lower rungs should still be seen as useful, effective, and legitimate means of achieving specific environmental goals.

This conceptual model, although a logical progression of environmental management practices, has not been fully explored or defined. Even though many of these concepts have existed for years, different perspectives and implementation techniques are used by industry, academia, government, and the public in general. In

addition, some skepticism exists on whether the functional concept of a hierarchical ladder linking the practices is effective in describing the actions needed for sound and sustainable development, not only in rapidly developing but also industrial countries.

The purpose of this concept paper is to bring together the most current definitions and practices for each of these concepts or rungs of the environmental ladder and develop a framework for the interrelationships among the concepts. Clarification of these definitions will assist Asian countries in formulating clear directions and goals for sound and safe industrial development. In addition, this paper provides a framework for industrial countries to formulate goals and objectives for continued environmental improvement. The paper provides definitions that represent potentially opposing opinions on the various concepts on the ladder, developing a consensus from which a clear definition can be derived. In addition, the paper integrates the individual "ladder" concepts into a larger framework for environmental management.

DESCRIPTION OF THE LADDER

It is important to note that, as one reads from the top to the bottom rungs, the concepts start at the broadest and most anticipatory and end at the narrowest and most reactive. Here, in descending order, are the basic definitions:

Total quality management(TQM), the top rung, incorporates and affects all aspects of business operations from the highest levels of management to the most perfunctory tasks of employees. Its key components include a dedicated and involved management; focus on the satisfaction of customers; commitment to steady, continuous improvement; trust in employees that leads to investments in training and education and delegation of authority and power; emphasis on teams, participation, informal interactions, quality circles, and collegial solution of common problems; and, of course, willingness to measure performance with key indicators.[8]

For example, one of the world's leading manufacturers of electronic systems and components discovered in the early 1980s that many of its products and operations were failing to meet expectations of quality. Top management called for a tenfold improvement in quality within five years, reducing defects to 3.4 per million opportunities in all operations. At the end of five years, the company pronounced the experiment a resounding success. It had retained its position in global electronics through a companywide renewal of quality improvements, product innovations, and strategic planning. Defects had been cut by 80 percent, and the company had saved some $962 million in inspections, redesigns, and repairs.

Total quality environmental management(TQEM) marries TQM and environmental management. It is, thus, both a subset of TQM and a singular concept that stands alone on its own merits. It assumes such TQM goals as customer satisfaction, constant improvement, and rigorous measurement. It further entails easy access to pivotal information and important communications, especially those that shed light on management's environmental performance. In the end, however, TQEM remains a management-led technique that guides companies with clear environmental goals toward implementing more successful companywide practices. An example of TQEM is Xerox's development of the Environmental Leadership Steering Committee, which has developed initiatives to direct Xerox toward greater environmental accountability.

Cleaner production/clean technology considers the impacts of products from their inception through processing to the end of their life cycle. Cleaner production determines ways to produce products that generate little waste and, when waste is produced, ways to increase its recyclability. An example of cleaner production is the development of new water-based adhesives by the U.K. company Blueminster. The use of water- instead of solvent-based adhesives reduces energy use and the amount of volatile organic compounds released into the environment.

Pollution prevention, a concept that closely resembles waste minimization, focuses on using more efficient manufacturing processes to prevent the production of waste, instead of recycling generated wastes. Pollution prevention includes techniques such as improved process control to use materials more efficiently. One example of pollution prevention is the use of a new flux material in printed circuit board manufacturing, eliminating the need for highly toxic cleaning materials.[9]

Waste minimization encompasses developing more efficient manufacturing processes and recycling waste to reduce the amount of waste actually generated. Manufacturing processes can be changed to reduce the amount of waste produced or to accommodate more in-process recycling. An example of waste minimization is Polaroid's Toxic Use and Waste Reduction Program. The program's goal is to reduce the waste emissions from all plant operations through numerous changes in production techniques, such as using better technology and chemical substitution.[10]

Recycling is the reuse or reclamation of a waste in the same industrial/manufacturing process, in another on-site process, or in a process at an off-site facility for production of an unrelated product. This approach prevents the material from becoming a waste that would require treatment and disposal. One example of recycling is Xerox's Asset Recycling Management program, which creates products that are more amenable to recycling and collects these products for reuse once they have reached the end of their productive life.[11]

Pollution control is an end-of-pipe practice that captures contaminants before they are released into the environment. An example of pollution control is the application of scrubbers, used in smokestacks to remove contaminants such as sulfur dioxide from emissions before entering the air.

Treatment is the end-of-pipe reduction of contaminants. *Disposal* is the placement of any residuals from this treatment into a protected unit, which minimizes releases into the environment. The electrical equipment manufacturing industry, for example, attempts to deal with their significant generation of polychlorinated biphenyl (PCB) wastes by using various treatment and disposal techniques. Handlers of PCBs (such as generators and other waste management facilities) are required to meet stringent treatment requirements to destroy most of the harmful biphenyl contaminants. After treatment, PCB disposal is restricted to permitted and highly regulated disposal units.[12]

Remediation is an environmental practice that solves problems after they have been created. Remediation is the cleanup of contaminants in such media as soil, air, and water after wastes have been discharged. In addition, remediation addresses releases into the environment that create an immediate, emergency situation with possible serious harm to human health and the environment. An example of remediation is the cleanup of Love Canal by capping and containing contaminants in the canal area and removing contaminated soil and debris from surrounding neighborhoods.[13]

ORGANIZATION OF THE PAPER

The following chapters elaborate on each environmental management concept described above. Each chapter briefly introduces a ladder concept, provides brief background on its development and use, presents a consensus definition of the concept, describes its measurement and obstacles to implementation, and provides a brief example of how the concept has been put into effect in manufacturing industries. The final chapter sets forth a framework for integrating these concepts into a coherent structure, highlighting overlaps and interdependencies among the concepts.

Chapter 2: Total Quality Management

Total Quality Management (TQM) is being called the most significant shift in American management thought and practice since the Industrial Revolution. Some of the larger U.S. companies that have adopted TQM are Motorola, Xerox, Ford, Westinghouse, Corning, Cadillac, and Federal Express. Seminars, books, and dedicated journals are available that promote the message and components of TQM. TQM has both enthusiastic proponents and highly vocal critics. It is regarded by some as essential to the survival of an organization and by others as simply the latest fad in industrial management.[14]

TQM practices have received considerable attention from industry after environmental management initiatives adopted and embraced its basic principles. Some have advocated linking the TQM system to pollution prevention plans to facilitate their implementation.[15]

This chapter offers different perspectives on TQM from leaders in the TQM movement and the U.S. manufacturing industry, highlighting the evolution of TQM and its role in today's industrial management landscape. The chapter presents the principal features of TQM, its relationship with International Organization for Standardization (ISO) 9000 standards, conditions for its success, and some lessons learned by U.S. corporations. The chapter also includes a case study on implementation of TQM principles by Motorola

BACKGROUND

In the 1950s and 1960s, quality replaced productivity as the key to commercial success in an increasingly competitive world economy led by the rapidly growing influence of the Japanese market. W. Edward Deming, who had a significant influence in stimulating Japanese quality efforts, articulated his view that 85 percent of all quality problems in American industry result from ineffective management structures.[16]

As industrial managers in the United States encountered the philosophies of Deming and other TQM leaders, such as Philip B. Crosby and Joseph M. Juran, they began to reexamine management's assumptions and practices. These experts had been working for forty years with Japanese managers to develop and refine systems for continuous quality improvement. As a result, government agencies and private and public sector institutions have begun to change their management thinking and practices.[17] Although many U.S. companies have been motivated by the success of Japanese industries to improve quality, one significant factor in the national quality revolution in the United States has been the Malcolm Baldrige National Quality Award, created in 1987 by an Act of Congress to increase the quality and productivity of U.S. companies.

Companies that implement TQM enjoy a variety of benefits. In May 1991 the U.S. General Accounting Office (GAO) undertook a study of companies using the approach. The GAO concluded that "companies . . . adopt[ing] quality management practices experienced an overall improvement in corporate performance. In nearly all cases . . .[they] achieved better employee relations, higher productivity, greater customer satisfaction, increased market share, and improved profitability."[18]

MULTIPLE PERSPECTIVES ON TQM

TQM has been defined by the U. S. Federal Office of Management and Budget as "a total organizational approach for meeting and exceeding customers' expectations, involving all employees of an organization and using quantitative methods to continuously improve the organization's processes, products, and services."[19]

According to *Quality Progress,* a publication of the American Society for Quality Control, TQM "is a management strategy for long-term success through customer satisfaction. TQM is based on the participation of all members of an organization in improving processes, products, services, and the culture they work in."[20]

This definition reveals four elements of TQM, namely, that it:

- Is a management approach
- Is a long-term approach
- Involves everyone in the organization
- Is based on continuous improvement.

The Federal Quality Institute compared TQM principles and traditional management styles.[21] Figure 2-1 highlights the characteristics of TQM that differ from traditional management.

Because the Baldrige award recognizes U.S. companies for business excellence and quality achievement, the criteria used in assessing applicants' efforts provide another perspective on business practices valued by TQM leaders. Applications for the Baldrige award are evaluated and scored in seven principal categories, including leadership, information and analysis, strategic planning, human resource development and management, process management, business results, and customer focus and satisfaction. Baldrige award recipients are expected to show strong achievements in business results and customer satisfaction because these factors are weighted more heavily in the scoring process (see figure 2-2).

CONSENSUS

From the perspectives presented above, the principal components of TQM are elaborated below with examples:

COMMITTED AND INVOLVED MANAGEMENT

A committed and involved management is an essential condition for the success of TQM. TQM is an important strategic process; top management should take the lead in formulating policy, communicating it throughout the company, and implementing the policy.

John A. Betti, former Ford Motor Company executive, said that "commitment to quality must start at the top. But as we at Ford learned, commitment in itself is not enough. Along with commitment must be dedication and involvement. Actions, not words, produce results."[22]

Traditional	TQM
The organizational structure is hierarchical and has rigid lines of authority and responsibility.	The organizational structure becomes flatter, more flexible, and less hierarchical.
The focus is on maintaining the status quo. ("If it ain't broke, don't fix it.")	Focus shifts to continuous improvement in systems and processes. ("Continue to improve it even if it isn't broken.")
Workers perceive supervisors as bosses or cops.	Workers perceive supervisors as coaches and facilitators. The manager is seen as a leader.
Supervisor-subordinate relationships are characterized by dependency, fear, and control.	Supervisor-subordinate relationships shift to interdependency, trust, and mutual commitment.
The focus of employee efforts is on individual effort; workers view themselves as competitors.	The focus of employee efforts shifts to team effort; workers see themselves as teammates.
Management perceives labor and training as costs.	Management perceives labor as an asset and training as an investment.
Management defines quality and determines whether it is being provided.	The organization asks customers to define quality and develops measures to determine if customers' requirements are met.
The primary basis for decisions is "gut feeling" or instinct.	The primary basis for decisions shifts to facts and systems.

Source: Federal Quality Institute. 1991. *Introduction to Total Quality Management in the Federal Government.* Washington, D.C.: U.S. Office of Personnel Management. pp. 16–17.

FIGURE 2-1. COMPARISON OF TRADITIONAL AND TQM ORGANIZATIONS

FOCUS ON CUSTOMER SATISFACTION

Most TQM leaders define customers not only as the people who actually purchase their products and services, but also any recipient of a product or service within or outside the company, including shareholders, employees, suppliers, and members of surrounding communities. TQM leaders consider meeting customers' requirements and ensuring customer satisfaction the top priority and presume it to be the key to the survival and growth of an organization. Customers—not engineers, designers, or accountants—set the ultimate criteria for quality. In contrast, traditional organizations view the customer "... as simply the end target—someone to be persuaded, influenced, and even manipulated, if necessary, to buy what you have produced."[23]

At Xerox, customer satisfaction is the number one priority. The corporation's strategy for achieving that priority is termed "Leadership Through Quality," the Xerox total quality initiative that permeates the management policies of the entire organi-

Customer Focus	Business Results
Customer satisfaction	Product and service quality
Customer satisfaction relative to competitors	Productivity improvement
Customer retention	Waste reduction/elimination
Market share gain	Supplier performance
Financial results	

FIGURE 2-2. BALDRIGE AWARDS: CRITERIA USED

zation. Xerox Quality Policy states, "Quality means providing our external and internal customers with innovative products and services that fully satisfy their requirements."[24]

CONTINUOUS IMPROVEMENT

In a TQM organization, managers continually work to improve quality; they do not view it as a one-time effort. As long as situations are not perfect, room always exists for improvement: new products can get to market faster, new adjustments in processes can cut down on production time and costs, and the work environment can be more satisfying. In the words of David Kearns, CEO of Xerox Corporation, "Quality is a race without a finish line. . . . we are on a mission of continuous quality improvement."

The goal of continuous improvement is rooted in the Japanese concept and practice of *kaizen*. *Kaizen* translates as the commitment to work for steady, continual improvement. The Japanese have clearly demonstrated the power of *kaizen*—the day-by-day, week-by-week discovery of small steps that make industrial processes more efficient, economical, and dependable.

PEOPLE INVOLVEMENT/ TEAMING/EMPOWERMENT

Participation of employees at all levels of the organization, teamwork, and employee empowerment ensure successful implementation of TQM. Employees are considered natural sources of ideas for ways to improve quality and customer service. Every person from the CEO to hourly employee is involved through informal interactions, suggestion systems, quality circles, problem-solving teams, joint labor-management committees, and similar arrangements.

At Xerox, 75 percent of all employees are actively involved with quality-improvement or problem-solving projects. Ninety-four percent of Xerox employees acknowledge that customer satisfaction is their top priority.[25]

MEASUREMENT IN ALL AREAS

Measurement is essential to ensuring implementation of planned quality improvements. By measuring important indicators, teams are able to identify the likely outcomes and to act when work processes do not meet customers' requirements. Measurement provides management and all stakeholders with process control and the opportunity to prevent defects.

MEASUREMENT AND OBSTACLES TO IMPLEMENTATION

MEASUREMENT

Continuous quality improvement requires identifying benchmarks and measuring and monitoring progress toward goals. TQM organizations heavily emphasize gathering and using reliable and objective information to guide decision making. Goals are stated in measurable terms; problems are described as objectively as possible; and charts and graphs are used to illustrate progress in TQM implementation.

For example, customer satisfaction can be measured by formal customer surveys, focus groups, informal customer complaints, quality audits, testing panels, statistical quality controls, interaction with customers, and other methods. A combination of several of these is often used.[26]

National and state quality awards are based on criteria that emphasize establishing the means to monitor progress toward goals. As illustrated in figure 2-2 above, the Baldrige award weights the following measurement-based criteria: customer satisfaction, customer satisfaction relative to competitors, customer retention, market share

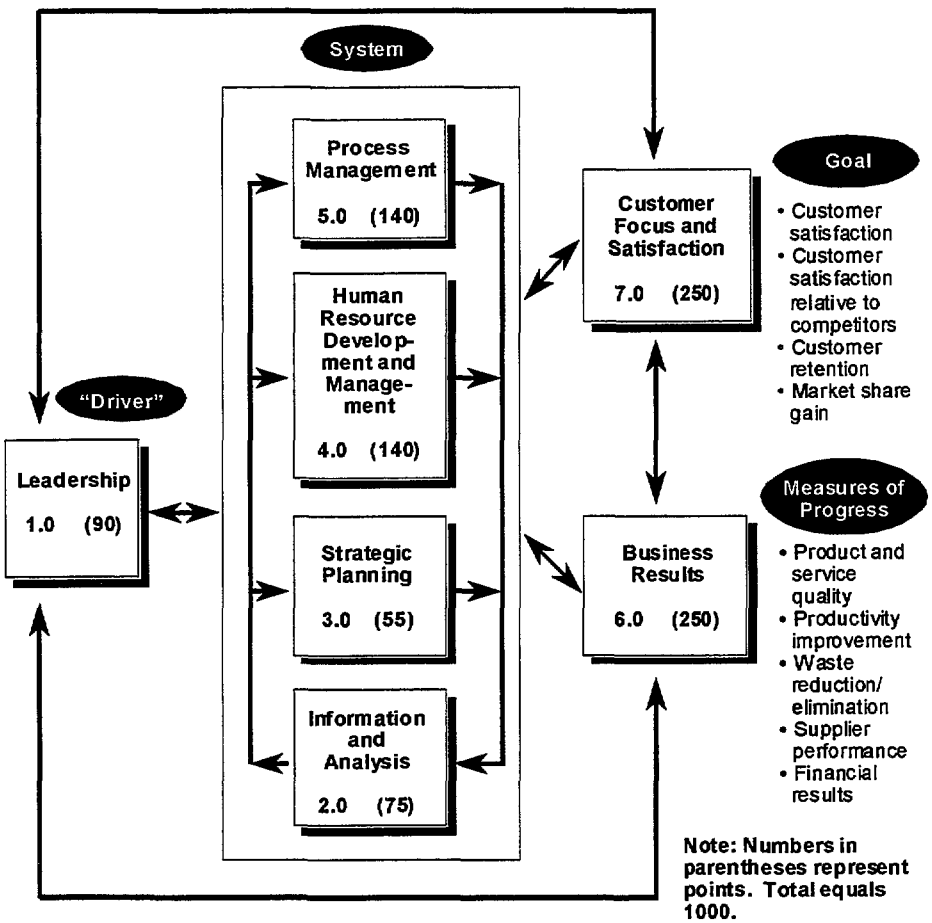


FIGURE 2-3. BALDRIGE AWARD CRITERIA FRAMEWORK

gain, product and service quality, productivity improvement, waste reduction/elimination, supplier performance, and financial results. In addition, the Baldrige award looks at the dynamic relationship among TQM processes in considering the goals and measurement of success (see figure 2-3).

OBSTACLES

Like any management approach, TQM works better in certain situations than others and has failed in many organizations. On the basis of interviews and readings, Schmidt and Finnigan have identified the following principal areas of concern with the concept of TQM[27]:

- Overselling TQM
- Setting mediocre expectations
- Diagnosing the situation poorly or inadequately
- Failing to train employees
- Making continuous improvement too complex and unnatural.

IMPLEMENTATION EXAMPLE

Motorola is one of the world's leading manufacturers of electronic equipment, systems, and components.[28] Its products include two-way radios, pagers, cellular phones, defense and aerospace electronics, and data communications equipment. In the early 1980s the company ascertained that many of its products and operations were simply not meeting quality expectations. To meet this challenge, Motorola's

top management formally restated company objectives, calling for a tenfold improvement in quality within five years. In addition, Motorola intended to implement stringent quality standards—3.4 defects per million opportunities—not just in manufacturing operations, but all operations by 1992.

In an era of intense international competition, Motorola has been able to maintain a position of leadership in the electronics industry through a combination of improvement in quality, product innovation, and strategic long-range planning. Its attention to quality has improved the bottom line, according to Richard Buetow, vice president and director of quality. Buetow asserts that from 1987 to 1992 defects have been cut by 80 percent and the company has saved approximately $962 million in inspection and rework costs.

Appendix: ISO 9000 and TQM

ISO 9000 is an international standard that outlines the elements of an effective quality management system. It was written by Technical Committee 176 of the International Organization for Standardization (ISO). ISO 9000 can be applied to any business in the world, so its requirements are generic. The standard specifies the minimum requirements of a system to manage quality effectively but does not specify how these elements are implemented.

ISO 9000 is a series of five standards—ISO 9000 through ISO 9004. The first and the last of these standards (9000 and 9004) are advisory; their purpose is to provide guidance to the user. The remaining three standards, ISO 9001, 9002, and 9003, are contractual, standards that a business may choose to adopt through registration. A business chooses one of the three standards, depending on the type of operations.

ISO 9003 is the most limited of the contractual standards and applies only to businesses that inspect and test products. ISO 9002, which contains eighteen separate elements including all elements of 9003, applies to manufacturing companies that do not design products. ISO 9001 is the most comprehensive of these standards and contains all ISO 9002 elements plus two others—one on design and one on after-sales servicing. It is applicable to manufacturing companies that design products and offer after-sales servicing.

TQM is a management system that companies adopt to improve quality and customer satisfaction, whereas ISO 9000 is a formal certification process for international competitive advantage. Both systems are voluntary; often companies that pursue TQM also adopt ISO 9000 if competing in the international market. DuPont, which is leading the United States in ISO 9000 registration, has seventy national registrations and 160 worldwide.

TQM and ISO 9000 standards do differ in some respects. The goal of TQM is excellence and continuous improvement, whereas ISO sets forth "minimum quality system requirements." ISO fails to address many attributes of world-class companies—customer focus and satisfaction, continuous improvement, teaming and empowerment, and quality results.

Chapter 3: Total Quality Environmental Management

Total Quality Environmental Management (TQEM) is a recent but increasingly predominant practice in industrial management.[29] TQEM results from applying TQM ideas and techniques to environmental management, an effort spearheaded by the Global Environmental Management Initiative (GEMI), an organization formed by leading U.S. corporations.[30] TQEM evolved from the realization that a close interrelation exists between corporate environmental management and quality management. The success of TQM has motivated many of the large corporations, including 3M, General Motors, Kodak, DuPont, Xerox, and Proctor & Gamble, to embrace TQEM to overhaul corporate culture as well as achieve increased profitability and strategic advantages in today's global marketplace.

TQEM has fostered a number of offshoot initiatives to integrate environmental concerns at all stages of the corporate decision-making process. These initiatives include product stewardship, environmental safety and health initiatives, environmental management systems (EMS), and ISO 14000 standards. These and other innovative initiatives are evolving along with the concept of TQEM.[31]

This chapter offers some perspectives on Total Quality Environmental Management and highlights the principal developments in the TQEM movement and examples of corporations that are leading the way. TQEM's relationship with the proposed ISO 14000 standards, conditions for its success, and some lessons learned by U.S. corporations are presented. This chapter also includes an example of the implementation of TQEM principles.

BACKGROUND

The role of environmental programs within business organizations has been evolving during the past twenty years.[32] Corporate environmental management was begun in the early 1970s as Congress required technology- and environmental quality–based standards under the Clean Water Act, Clean Air Act, and the Resource Conservation and Recovery Act.[33] The corporate response to these statutes was "a technically based management approach that was tactical and defensive" and designed to achieve simple compliance with a relative handful of regulations—usually through implementation of post-treatment or end-of-pipe treatment for existing processes.[34] Initiation of these programs typically amounted to a relatively small portion of the total business budget and available management staff.

During the 1980s the number of environmental requirements increased dramatically, requiring dedication of additional financial and administrative resources to meet them. By the mid-1980s, the high cost of compliance led firms to focus on

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waste reduction in addition to pollution control. The financial implications of compliance, damages resulting from poor environmental management (e.g., Bhopal and Exxon Valdez), and the strategic advantages of sound environmental practices (ISO certification and "green movements" worldwide) have all led to growing interest in applying quality management concepts and techniques to environmental management.

The benefits of adopting TQEM are reported by advocates, including corporate leaders. Businesses that achieve greater integration of environmental management into business operations are realizing the power and potential inherent in the synergy of such integration.[35] Truly proactive environmental programs can cease a drain on the business's bottom line and improve the health, robustness, and competitive edge of the venture.[36] Other benefits of implementing TQEM concepts include a cleaner environment; fewer violations of EPA, Occupational Safety and Health Administration (OSHA), and Food and Drug Administration regulations governing workplace and industrial practices; reduction of future liabilities; consumer loyalty; and a dynamic work force.[37]

MULTIPLE PERSPECTIVES ON TQEM

Bennett, Freierman, and George state that "TQEM is a specific application of the proven principles of total quality management."[38] The authors adopt the definition of TQM offered by *Quality Progress*, a publication of the American Society for Quality Control (see chapter 2, page 12) and identify the key elements of TQEM, namely, that it:

- Is a management approach
- Is a long-term process
- Involves everyone in the organization
- Is based on continuous improvement.[39]

A similar view is offered by Willig, who states that "TQEM is the practice of applying TQM practices to an organization's environmental efforts." Willig identifies three areas as principal corporate goals for a TQEM program: pollution prevention, sustainable development, and environmental responsibility.[40]

Nash and others highlight the outcome and the process of TQEM in their characterization of this initiative. "TQEM can be defined as an approach for continuously improving the environmental quality of processes and products through the participation of all levels and functions in an organization."[41] Wells and others emphasize the philosophy behind TQEM: "It is not enough [for TQEM systems] to ensure regulatory compliance and prevent industrial accidents and Superfund liabilities, [they] must also create incentives to move beyond compliance."[42]

A similar perspective on corporate responsibilities is expressed by Richard Monty, general manager of environmental health and safety at GE Plastics, who envisions an important role for business leaders,[43] who must go beyond compliance with environmental regulations to protect human health and the environment. Environmental awareness must pervade an organization and be integrated into such traditional business concerns as financial soundness, legal compliance, and marketing strategies.

Porter and van der Linde equate pollution with inefficient resource utilization and urge quality-conscious companies to accomplish more than simple pollution prevention:

> When scrap, harmful substances, or energy forms are discharged into the environment as pollution, they are a sign that resources have been used incompletely, inefficiently, or ineffectively. . . . But, although pollution prevention is an important step in the right direction, ultimately companies must learn to frame environmental improvement in terms of resource productivity.

They recommend that companies follow the same basic principles used in quality management programs: use inputs more efficiently, eliminate the need for hazardous hard-to-handle materials, and eliminate unneeded activities.[44]

CONSENSUS

The principal concepts emerging from these and other perspectives on TQEM are elaborated below with examples.

MANAGEMENT-LED APPROACH

TQEM is a management-led process. According to the Baldrige criteria, "A company's senior leaders must create clear and visible quality values and high expectations. Reinforcement of the values and expectations requires [the senior leaders'] substantial personal commitment and involvement." Leading companies in environmental management post clear, visible statements of environmental values, usually in the form of mission statements, prominently throughout their facilities.

For example, to implement its environmental vision successfully, Eastman Kodak Company has deployed a network of interlocking teams and working groups at all levels of the corporation to develop and implement operational policies. The company's Management Committee on Environmental Responsibility chaired by the CEO oversees these working groups. The management committee's chief responsibility is to articulate Kodak's environmental policies, principles, and performance standards. The Public Policy Committee, which consists of members of the board of directors, reviews the company's policies and procedures and makes recommendations to the management committee.

3M Corporation elevated its environmental decision-making process to the senior boardroom by changing its corporate structure and considering environmental engineering as an operating unit at the senior level. 3M's senior managers are required to incorporate the company's environmental policies, objectives, and standards into their operations.[45]

CUSTOMER SATISFACTION

One of the central themes of TQM is an expansion of the definition of "customer" from an external purchaser to any recipient of a product or service within or outside the company. An environmental quality approach extends this definition further by also considering other stakeholders, including regulators, employees, suppliers, community members, conservation groups, and society.

Proctor & Gamble credits its success to its ability to listen to consumers and recognize and meet their needs. Consumers indicate that they want products that are compatible with their environmental concerns, which Proctor & Gamble interprets as an opportunity for competitive advantage. "If we meet this new need first and best in an ethically sound way, consumers will buy our products in preference over our competitors," said Deborah Anderson, Proctor & Gamble's vice president of environmental quality. All plastic bottles used by Proctor & Gamble are now coded for recycling and certain product line bottles are made entirely of recycled soft-drink bottles. New packaging technology has eliminated the need for excess cartons for Proctor & Gamble's deodorants, saving 3.4 million pounds of solid waste each year.

In response to ongoing concerns over the contribution of disposable diapers to solid waste problems, Proctor & Gamble has committed $20 million to support pilot solid waste–composting programs nationwide.[46]

POLLUTION AS DEFECT

The TQM manufacturing operating strategy relies on close observation and measurement of performance deviation. In translating this concept to environmental management, environmental performance is included as a component of production performance. Emissions to the environment are regarded as quality defects, similar to a deviation in product specifications.

"Pollution is a defect," according to Tom Zosel, 3M's Manager of Pollution Prevention programs. "Our goal is zero defects, in the same way that the goal in our quality process is zero defects."[47] At Xerox, the goals of TQEM are "Zero Defects, Zero Disposal, and Zero Pollution."[48]

BEYOND COMPLIANCE

Companies that practice TQEM often establish goals that progress beyond complying with government regulations. In the environmental arena, new issues are always emerging and new demands are being made by environmental groups and regulatory "customers." Many companies have found that merely complying with regulations makes them ill-equipped to address new situations. For example, strict liability legislation, such as Superfund, stipulates that, if past environmental actions (or inactions) cause subsequent problems, the legality of those actions is not a defense. The polluter must still pay; hence, the least risky option is to adopt more stringent internal standards than compliance standards. "By raising the high bar above mere compliance, you prepare your company for ongoing improvement and change for the better."[49]

Kodak has a structured worldwide site assessment program designed to keep the company in compliance with regulations and, at the same time, identify opportunities to surpass government standards. The company also incorporated environmental objectives in facility operations. As such, these objectives are a factor in evaluating the performance of middle and upper management and are important criteria on which salary review is based.[50]

Another example of progressing beyond compliance is the accelerated phaseout of chlorofluorocarbons (CFCs) by many businesses. Raytheon announced that by the end of 1992 it would eliminate its use of virtually all ozone-depleting substances.[51] This goal was considerably more aggressive than the terms set forth in the Montreal Protocol, which call for a 50 percent reduction in CFC production by the end of 1998.

CONTINUOUS IMPROVEMENT

TQEM (as in TQM) aspires to meet or exceed the ever-changing actual or latent customer expectations of a product or service. This requires a constant search for improvement opportunities. No company can achieve environmental excellence with a reactionary strategy. According to George Carpenter, GEMI chairman and director of environment, energy, and safety systems at Proctor & Gamble, "Total quality begins with accepting that we are never as good as we can be. Continuous improvement based on data and measurement is the fundamental bedrock of total quality."[52]

At Xerox, the "TQEM goal is continuous improvement, until we can virtually eliminate pollution and waste. We will continue to benchmark the world's leading companies for each of our environmental initiatives and learn from these companies

to equal or exceed their environmental performance and to be the 'best of the best'." As with TQM, advocates of TQEM have embraced the Japanese concept of *kaizen* (see chapter 2, page 14).

Another example of continuous improvement is the original recycling goals of Xerox, set in early 1990 at 50 percent waste reduction and recycling to be met by the end of 1992. By early 1991, many of the larger manufacturing sites were already exceeding the 50 percent goal. The recycling target was then revised for continuous improvement, quarter over quarter and year over year. By the end of 1991, a number of sites had reached 60 percent waste reduction and the manufacturing site in Oklahoma City achieved 78 percent reduction; whereas the site in Venray, Netherlands, exceeded 82 percent. The initial Xerox goal of 50 percent by 1992 was based on industry benchmarks. Internal industry benchmarks demonstrated that this goal was not high enough for individual sites that could aspire to 90 percent waste reduction.[53]

ENVIRONMENTALLY RESPONSIBLE WORKPLACE

An important force behind corporate environmental management stems from pressure exerted by employees who demand more environmentally responsible workplaces. Workers expect employers to reduce waste and pollution and minimize their exposure to environmental hazards.[54] In turn, the workers often play a leading role in promoting environmentally responsible behavior.

One tenet of TQM is "getting it right the first time," that is, eradicating defects at the source. This requires all employees to adopt environmental quality as their responsibility. Deming, the "father of TQM," strongly advocated for worker participation in decision making. It is not enough to develop a corporate environmental policy within the upper echelons of management and disseminate that message via memo and meeting. Employee involvement is critical to successful, long-term environmental management.

Edward Wooland, chairman and CEO of E. I. du Pont de Nemours states in *Managing the Global Environmental Challenge*, a report published by Business International Corporation, that "as long as environmental protection remains in a special category assigned to certain people—instead of part of the mental checklist with which each person approaches every task—then our environmental accomplishments will remain reactive and corrective rather than proactive and innovative."[55]

For example, a nine-person Problem Stoppers team at the Sylvania Lighting facility in York, Pennsylvania, provided an innovative solution to eliminating glass waste, saving the company $142,000. The facility formerly shipped more than 800,000 pounds of excess glass annually to a hazardous waste landfill. The Problem Stoppers, a multilevel, multifunction team, changed the process to eliminate the generation of unusable glass waste. Now, the molten glass is cooled into pellets and recycled in the plant.[56]

ENVIRONMENTAL COMMUNICATION

Environmental communication and outreach is also a necessary part of the TQEM approach.[57] At Xerox, communication efforts include customer and employee education and provide information to the shareholders, surrounding communities, and the general public. Several other TQEM leaders, including Proctor & Gamble, McDonald's, and 3M, have built their systems on clearly stated environmental policies and objectives.[58] These policies are communicated frequently and consistently through internal newsletters, correspondence, and paid announcements.

MEASUREMENT

Continuous quality improvement requires identifying benchmarks and measuring and monitoring progress toward goals. An effective TQEM system makes substantial demands on the company to provide considerable quantities of information across a wide range of subject areas. Because TQEM is based closely on TQM principles, progress toward environmental excellence follows the same guidelines as progress toward excellence in quality. A survey of existing TQEM structures, however, concludes that development of effective measurement systems is still in its early stages.[59] As the systems evolve, both quantitative and qualitative indicators are expected to be incorporated in measures of environmental progress.

According to Wells and others, effective environmental management systems look at measurement from three perspectives: *(a)* process improvements, *(b)* environmental results, and *(c)* customer satisfaction.[60] TQEM measurement systems typically include the following strategies:

- Absolute values
- Reductions over time
- Percentage of inputs.

IMPLEMENTATION OBSTACLES

Some of the most often cited difficulties encountered in implementing TQEM are the lack of management support, clear objectives, and adequate resources. Although in the long term, TQEM improves the bottom line and customer satisfaction, it has start-up and capital costs that often cause companies to resist change. In 1982 a representative of a major utility said, "we [utility companies] understand we are going to have to clean up these emissions. We recognize that sooner or later the American people are going to demand it, but from our point of view, we want to delay that because it frees up capital for however long we can delay."[61]

FIGURE 3-1. SELECTED TQEM MEASUREMENT SYSTEMS

Company	Parameters
Sandoz Corporation	Key indexes reported at all facilities: Lost time and workday accident rates Total: energy, water, waste S&E investments, expenses, personnel Total production, personnel
Xerox Corporation	Economic incentives: Gain market share via positioning Cost savings reporting Reduce risks, future costs
3M Company	Waste quantities reflect 3P, efficiency

Source: FitzGerald (1994), p. 169.

Other problems encountered in implementing TQEM include the following:

- Successful implementation of an environmental management program requires an efficient information system. "There is an overwhelming demand placed on companies to provide considerable quantities of information across the widest range of subject areas."[62]
- Management does not have adequate information to assess the costs of wasted resources and the benefits of environmental innovation.[63] Porter and van der Linde even argue that "many companies do not even track environmental spending carefully or subject it to evaluation techniques typical for 'normal' investments."[64]

IMPLEMENTATION EXAMPLE: XEROX

Early in the 1980s Xerox adopted its basic environmental policy. In January 1985 the Xerox environmental health and safety group was directed to identify and eliminate all potential environmental hazards in the company. The company formed a senior management Environmental Leadership Steering Committee in late 1990 to guide the environmental programs. Principal features of Xerox's environmental initiatives are:

- Teamwork, communication, recognition, and information sharing
- Setting benchmarks for the progress of other companies to provide a yardstick for Xerox's efforts
- Adopting a "cradle-to-grave" requirement for design architectures and the design for environment philosophy
- Reuse and recycling of packaging, production of "environmental paper," and recycling of toner cartridges
- Cooperating with other organizations and supporting EPA's Green Lights and 33/50 programs and the International Chamber of Commerce's Charter for Sustainable Development
- Setting goals and monitoring improvements.

Appendix: ISO 14000 and TQEM

ISO 14000 is a set of voluntary standards that integrates environmental responsibility into everyday corporate management. These standards, in the form of specifications and guidelines to be implemented in 1996, will assure a uniform strategy for environmental management by many organizations, including those in the manufacturing and service industries of all sizes, located anywhere in the world. It is expected that firms eventually must adopt such management standards to earn a critical ISO certification to conduct business internationally. Supporters say this "green passport" will also improve corporate performance—ultimately cutting pollution and saving resources.

ISO 14000 is a series of standards, numbering 14001 to 14044, under development in the following general areas:

- Environmental management systems (EMS)
- Environmental auditing (EA)
- Environmental labeling
- Environmental performance evaluations life cycle assessment
- Environmental aspects of product standards.

TQEM principles and ISO 14000 standards are similar in scope. TQEM principles are voluntary; companies that declare their commitment to TQEM regulate their adherence to these principles. In the near future, however, once ISO 14000 standards are in place, independent third-party "registrar" companies are expected to perform EMS certification audits. Many expect that companies will register for ISO 14000 certification to gain global competitive advantage.

The TQEM system adopted and the extent to which it is implemented vary from company to company. Industry leaders, including Xerox, Kodak, and Motorola, have EMS that are among the best in the world. Other organizations that have declared compliance with TQEM may have only implemented basic environmental systems that are considered primitive when compared with industry leaders. The goal of ISO 14000 certification, however, is standardization of environmental systems. All certified environmental management systems are expected to meet the minimum standards in the respective category. The standards will be considered a "floor" rather than a "ceiling." ISO 14000 certification, therefore, only assures that a company has met the minimum standards, whereas TQEM leaders strive to go well beyond the minimum requirements (see figure 3-2 on next page).

An effective system for compliance with applicable laws and regulations is one component of an ISO 14000 EMS. An ISO 14001 audit is not a regulatory compliance audit but rather an audit of the organization's environmental management system. All TQEM organizations, whether they achieve ISO certification or not, endeavor to go beyond compliance with environmental laws and rules and environmental, health, and safety codes.

The ISO standards address systems and continuous improvement tools. Performance levels, such as emission limits, are specifically excluded. The standards do not address occupational health and safety issues.[65]

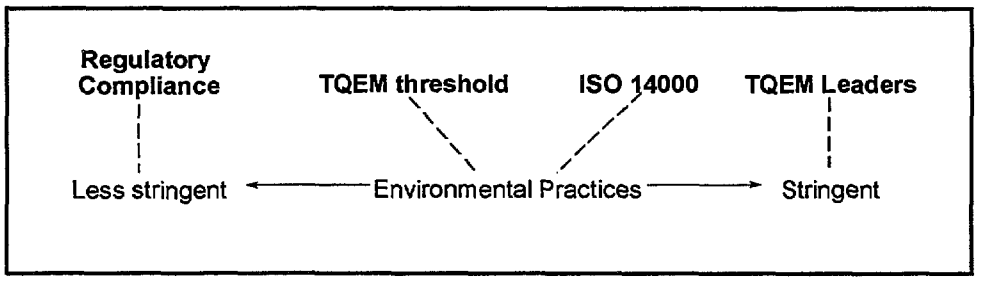

FIGURE 3-2. COMPARISON OF TQEM AND ISO14000 PRACTICES

Chapter 4: Clean Technology for Process, Products, and Packaging

The awareness that industrial expansion in all countries—industrial and developing—has occurred at some cost to public health and the environment has given a new focus to the concept of cleaner production, which includes clean technology, clean processes, and clean products. Cleaner production is a comprehensive, preventive strategy for environmental protection that encompasses conservation of energy and materials, elimination of toxic substances, and reduction of the amount of wastes and pollutants created by processes and products. This approach relates to all phases of manufacturing processes and product life cycles, including product use.[66] Clean technology is a general concept that has arisen in recent years as part of the search for more sustainable production processes to satisfy human needs.[67] Clean technology focuses on developing, demonstrating, and evaluating innovative processes for reducing pollution through source reduction. Clean products focus on the design and development of products whose manufacture, use, recycling, and disposal reduce impacts on the environment.

This chapter addresses the critical issue of how consumer and industrial products and services should be designed, manufactured, and used for minimal effect on the environment. It defines clean technologies used in production processes, products, and package design. The chapter also discusses the meaning of the concept "clean" as applied in the context of industrial production and presents some perspectives on clean technologies used in processes, products, and packaging. This chapter also presents specific examples of cleaner production, that is, clean processes, clean technologies, and clean products.

BACKGROUND

The increase in number and scope of pollution problems, caused by the accumulation of the "externalities" of industrial growth, has spurred a movement toward use of cleaner technologies—environmentally sound consumer products, low-emission processes, pollution control devices, recycling systems, and environmentally friendly materials.[68] Now, toward the end of the 20th century, a subtle change has occurred in the way many industries are confronting environmental concerns. It is a shift away from treatment or disposal of industrial waste to preventing its creation.[69] In Western industrial countries, many industries are becoming increasingly aware that waste minimization and cleaner production reflect a basic change in perspective from the traditional end-of-pipe regulatory strategy for environmental pollution. Industry has begun to understand that a comprehensive environmental management plan, based on the concepts of waste minimization, pollution prevention, and clean production can benefit the environment and industry, economically, in savings in energy, water, and raw materials.[70]

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Because of the globalization of economies, developing countries are experiencing both rapid industrial growth and increasing environmental problems. These countries face a critical choice: to pursue rapid industrial growth with little consideration for resulting environmental damage or opt for a slower rate of economic growth through ecologically sustainable industrial development.[71] They could pursue the latter by *(a)* investing initially in clean industry-specific "process" technology, *(b)* sizing investments in "add-on" recycling technology appropriately, and *(c)* minimizing expenditures on pollution treatment and disposal.

In addition, government and institutional support has been increasing for clean industry technology. These include *(a)* the United Nations Environment Programme's (UNEP's) Cleaner Production Program and Environmental Assessment of Technology program, *(b)* EPA's Design for the Future program, *(c)* national research laboratories technology centers, *(d)* various country-specific productivity councils, *(e)* university "green manufacturing and industrial ecology" programs, and *(f)* market-based incentives—for example, import and income tax incentives—supporting investment in pollution prevention. These initiatives have helped increase understanding of the two chief advantages of clean technologies: they make it possible to reduce or eliminate pollution and they create savings in energy and raw materials, which lead to an increased return on investment for the firm.[72]

Various forces are pushing the top management to consider the environmental impacts of their products early in the design stage and to achieve the goal of adopting clean technology. These forces include introduction of regulations, economic and financial incentives to encourage technological innovation, increasing importance of clean production and consumer demand, community pressures, multimillion-dollar liability suits, stricter civil and criminal enforcement of environmental regulations involving mandatory recycled content, requirement for reduced hazardous chemical content, the ISO 14000 initiative, and environmental labeling.[73]

MULTIPLE PERSPECTIVES ON CLEAN TECHNOLOGY AND CLEANER PRODUCTION

Clean technology is also referred to as "environmental technology" or low and nonwaste technology. Clean technology covers the whole range of technological procedures that contribute to reducing or suppressing polluting wastes from industrial production activities.[74] Clean technology essentially includes process and product technologies used to manufacture goods—such as shoes, paper, and consumer electronics—that incorporate performance specifications into their design, minimizing the negative effect of production on the environment.[75]

An environmental technology has been defined "as a technology that advances sustainable development by reducing risk, enhancing cost effectiveness, improving process efficiency, and creating products and processes that are environmentally beneficial or benign."[76] Technology, in this context, includes hardware, software, systems, and services.

The Industry and Environment office of UNEP coined the term "cleaner production," which they point out "is similar to other terms [such] as clean technology, pollution prevention, waste reduction, waste prevention, ecoefficiency, and waste minimization."[77] Clearly, no universal consensus exists on what these terms mean exactly and how they differ from each other. Understanding them requires looking beyond the words and analyzing the actions taken for each one.

The actions encompassed by cleaner production include:

- Conserving energy and raw materials used
- Eliminating toxic substances (as raw materials and as product constituents)
- Reducing the amount of wastes and pollutants created by processes and products.

In essence, cleaner production includes "any attempt to design environmentally friendly and recyclable products for the market, right from the beginning, with an aim to sustaining resources and reduce pollution."[78]

The concept of cleaner technology, as used by Kemp (1993), encompasses clean production, clean processes, and clean products. Cleaner technology is also defined as "environmentally sound consumer products, low-emission processes, pollution-control devices, recycling systems, or environmentally friendlier materials."[79]

Clean technology has also been defined as "a relative term for a process that raises standards above those that would formerly have been accepted as the norm."[80] This does not mean zero emission, but it does mean a shift of emphasis from end-of-pipe treatment toward preventing formation of any environmental problems. A prime example of clean technology is ICI's life cycle assessment (LCA) ammonia process, which apparently cut the size of the plant to half, reduced energy use, and eliminated sulfur emissions while cutting NO_x emissions by a factor of seven.

The Clean Technology Research Programme of the Engineering and Physical Science Research Council in the United Kingdom defines the concept of clean technology as "a means of providing a human benefit that overall uses less resources and causes less environmental damage than alternative means with which it is economically competitive." As quoted by Clift, the implications of this definition are as follows:

- The concept of clean technology cannot be developed without reference to economic performance.
- Overall resource use and environmental damage can only be assessed by using cradle-to-grave analysis; that is, life cycle assessment is an integral part of clean technology thinking.
- Clean technology concentrates on delivering a benefit or service, not just manufacturing or processing to make a particular product.
- Waste minimization and pollution prevention are components of clean technology.[81]

Most of these are similar to other perspectives on clean technology except the shift of focus from product to service. This adds a new dimension of "dematerialized economy" according to Roland Clift to the concept of clean technology, who says that the goal of clean technology is to create a future economy in which "benefits are provided without trading material products or artifacts." For example, instead of selling pesticides, the agrochemical industry would shift to providing a crop management service; similarly, instead of selling detergents and washing machines, companies would provide the service of cleaning clothes. This shift would make the industry adopt cleaner processes to reduce their liability and move rapidly to reuse and recycling. In addition, making the supplier of products responsible for managing the postconsumer waste would provide a clear incentive for designing products for the environment.

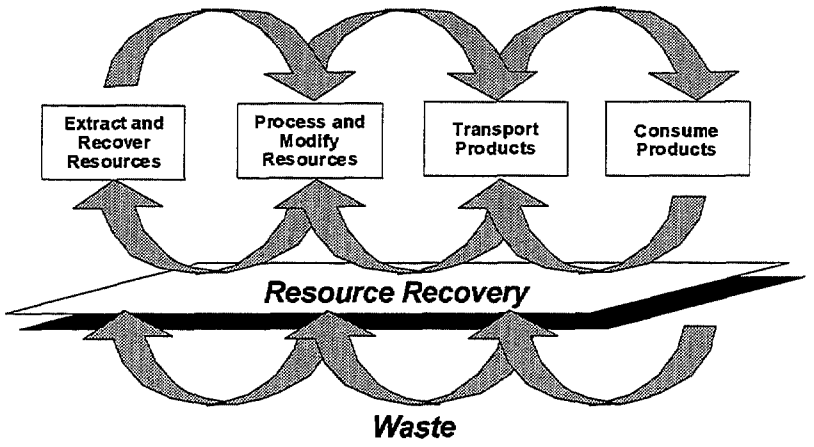
According to Yhdego, industries that have introduced cleaner production (or are using cleaner technologies) have benefited from savings in raw materials and energy, decreased waste management costs, improved product quality, increased productivity, decreased downtime, reduced worker health risk and environmental hazards, and decreased long-term liability for the cleanup of waste materials that might otherwise have been buried.[82] A good example of profitable clean technology is the production of terephthalic acid by the catalytic oxidation of paraxylene. In early plant designs, the effluent stream needed careful treatment, whereas in the new design virtually everything is recycled back through the process, resulting in considerable savings in capital equipment and energy costs.[83]

A number of new concepts in the literature are related to cleaner production, all of which involve paying attention to or closely examining the potential effects of excess waste and pollution in manufacturing. Each of them are explained in the following discussion:

Industrial ecology. The concept of industrial ecology is closely related to clean technology. Industrial ecology is a relatively new strategy for the industrial design of products and processes and the implementation of sustainable manufacturing strategies (see figure 4-1below). In this approach, not only are environmental considerations incorporated into all aspects of product and process design, but technology also plays a more active and positive role in achieving sustainable development.[84] Industrial ecology is a systems approach in which the industrial system is viewed not in isolation from its surrounding systems but in concert with them. Industrial ecology "seeks to optimize the total materials cycle from raw materials to finished materials, to product, to waste product, and to ultimate disposal."[85]

In essence, industrial systems are comparable to natural ecosystems in which plants consume minerals, water, and sunlight and in turn are consumed by other organisms in interdependent processes that include production of wastes. The industrial ecosystem operates much the same way, consuming resources and producing waste. Industrial ecology adopts a no-waste or low-waste strategy for industrial processes, emphasizing the need for in-stream recovery and reuse of materials.[86]

FIGURE 4-1. INDUSTRIAL ECOLOGY FOR SUSTAINABILITY



Industrial ecology is the study of a closed loop in which resources and energy flow into production processes and excess materials are put back into the loop so that little or no waste is generated. Products used by consumers flow back into production loops through recycling to recover resources. Ideally, the loops are closed within a factory, among industries in a region, and within national and global economies.

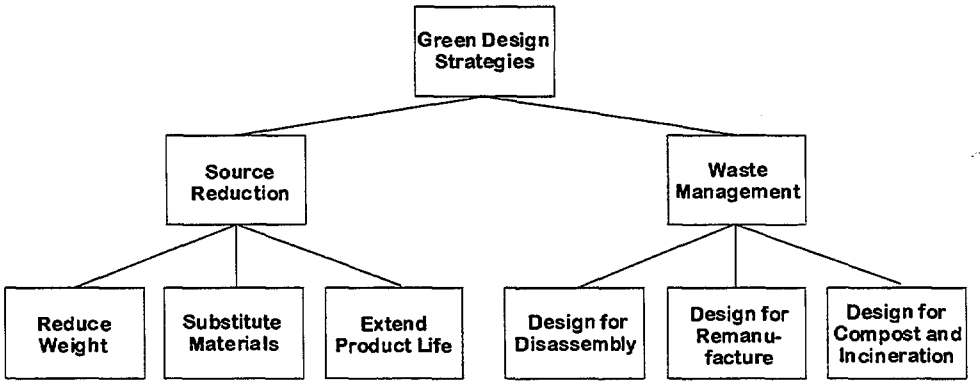


FIGURE 4-2. GREEN DESIGN STRATEGIES

Source: Bhat (1993).

According to Frosch, industrial ecology reduces inefficiency in manufacturing by making designs and producing products in a way that makes "the control of waste and pollution part of their enterprise, not just an afterthought."[87] Although other approaches generally seek incremental improvements in various subsystems, industrial ecology's greatest value is in adding depth to the whole-system perspective and emphasizing systemwide change to reach the goal of industrial transformation. It offers analytical and modeling tools to support such a transformation.[88] Tibbs offers an integrated managerial and technological interpretation of industrial ecology.[89]

Design for environment. Based on the principles of industrial ecology, the concept of design for environment (DFE) is a means to achieving environmentally conscious designs.[90] Pfahl analyzes three experiences with environmental issues that are being addressed by DFE and the feasibility and benefits of implementing DFE. From a cost-reduction experience in a manufacturing industry, he concludes that if a firm fails to integrate environmental costs and considerations into its technology decisions, it can create higher economic costs for itself, even in the short term.

Green design/green products. Clean or green products require green design, because product design determines input materials, manufacturing processes, packaging, distribution, and disposal methods.[91] Product design decisions have significant effects on the quantity of wastes generated at different stages of a product life cycle. To promote green design, Bhat suggests two broad types of green design strategies (see figure 4-2 above): source reduction and better waste management. Source reduction design strategies include weight reduction, material substitution, and product life extension. Better waste management techniques promote recycling and reclamation of materials. Waste management techniques include design for disassembly, design for recyclability, design for remanufacturing, and design for composting and incineration.

A source reduction strategy for producing green products includes designing packaging for products to minimize waste generated after consumer use. Strategies for redesign of packaging include eliminating or reducing product packaging or producing recyclable packaging. In addition, concentration of products in a package, for example, concentrated detergent, is another way to reduce packaging waste. Substituting nonpolluting for polluting materials is a way to ensure that a product is nonpolluting and, therefore, more acceptable by consumers, helping a company remain competitive. Source reduction also includes producing products that have a long service life by using more durable goods or designing modular products so the components have definable functionality. Modular products can be easily serviced, and components can be replaced without affecting other components.

According to Bhat, designing for clean products is intended to make products that are easy to remanufacture, recycle, compost, and incinerate. The concept of designing for disassembly is to develop products, for example, an automobile or a refrigerator, that are multifunctional and should be easy to disassemble into component parts. This will enable remanufacturers to renovate old products by using subcomponents that otherwise would have been scrapped. Currently, kitchen appliances, machine tools, and copiers are being remanufactured.

Life cycle analysis. Life cycle analysis (LCA) is an analytic methodology developed for evaluating the cost and benefit of various green designs for cleaner production. The objective of LCA is to estimate the total environmental risk from input and output wastes generated during extraction, manufacturing, product distribution, product use, and product disposal.[92] LCA is also known by other names, including product life cycle analysis, ecobalance, cradle-to-grave analysis, and resource and environmental profile analysis. LCA is being practiced in a few U.S. firms, such as Coca-Cola, Proctor & Gamble, and 3M. The 3M Corporation defines its LCA approach as looking at how waste can be reduced or eliminated starting at the point of generation in the manufacturing operation to its processing, treatment, or ultimate disposal as a residual hazardous waste. Proctor & Gamble, in contrast, defines LCA as an attitude that displays an acceptance by manufacturers of consumer products that they are taking fair responsibility for the environmental burden caused by their products from design to disposal.

Design for recycling. The concept of design for recycling, a program adopted by the Institute of Scrap Recycling Industries has the explicit goal of "encouraging preproduction planning for safe recycling by the elimination of hazardous materials from the production process."[93] The institute's guidelines focus on promoting the design and manufacture of durable consumer goods that, at the end of their useful life, can be recycled safely and efficiently without creating risks to human health or the environment from hazardous constituents.

Sustainable manufacturing. Sustainable manufacturing is another term in the literature for cleaner production/clean technology. Some define sustainable manufacturing as "a comprehensive business strategy that aims to incorporate environmentally proactive thinking into every step of the manufacturing process."[94] Sustainable manufacturing is a larger concept that includes pollution prevention, DFE, toxic use reduction (TUR), and product LCA. The National Wildlife Federation Corporate Conservation Council (NWFCCC) clearly differentiates among these concepts. According to them, DFE revolves only around the product and does not include work environment, factory and machinery design, or overall corporate environmental policy. TUR focuses on internal and external chemical risks at the process and worker levels but does not take into account packaging, energy use, or end product disposal. Product LCA defines environmental life of the product but does not address management strategies or worker health and safety issues. Sustainable manufacturing, in contrast, includes[95]:

- Materials selection
- Design for environment
- Optimizing production using pollution prevention and TUR strategies
- Energy conservation
- Eliminating worker health and safety risks
- Reducing packaging and using reusable packaging

- Design for disassembly, that is, design of products for repair and replacement of components, rather than disposal
- Design for recycling and reuse, that is, reducing product persistence in the environment.

Because clean technology includes environmental considerations in the numerous steps from cradle to grave for manufacturing a product, interpretations vary when it comes to practicing cleaner production. For instance, EPA and UNEP consider clean technology applicable to raw materials that go into producing the product, whereas most practitioners view the concept as starting at the process, that is, manufacturing stage. For instance, Dow Chemical considers concern for making, distributing, and using the product part of "product stewardship," another term for green products.[96]

The concept that "cleaner production is the way to achieve both environmental protection and economic benefits" is under debate.[97] The argument centers on the "win-win" notion that making environmental improvements is often the best way to increase a company's efficiency and, therefore, profitability. Those who agree with this concept also claim that green product design is a strategy that will allow companies to remain competitive in the international market.[98] The claim is supported by the estimate that U.S. companies produce five times more pollution per dollar of revenue as the more competitive Japanese companies and twice as much as German companies.[99]

The opposite perspective is that "it is not easy being green."[100] Walley and Whitehead, who are at the center of the controversy, argue against various solutions suggested for integrating environmental issues in business decision making, claiming that "most of [these solutions] fail to provide a clear framework that will allow the senior managers to set priorities and turn their good intentions into reality."[101] A number of experts have participated in the debate on whether win-win solutions should be part of a company's environmental strategy. This discussion, however, goes beyond the scope of this paper; for a summary of their arguments, see the Harvard Business Review article by Richard Clarke.[102]

CONSENSUS

Although various concepts are relevant to clean technology, our literature review clearly shows the term to be synonymous with cleaner production, clean production, cleaner technologies, and environmental technologies. Agreement appears to exist that clean technology is "a means of providing a human benefit which, overall, uses less resources and causes less environmental damage than alternative means with which it is economically competitive."[103] Although consensus on the definition of clean technology has yet to emerge, the following briefly describe a number of common themes:

Shifts emphasis from end-of-pipe treatment. Clean technology stems from the realization that regulatory approaches that encouraged end-of-pipe treatment of waste create excess economic burdens. Clean technology clearly departs from efforts to manage waste created by either the manufacturing process or product disposal. The basic tenet of clean technology is to develop processes and products that do not create waste.

Conserves use of energy and raw materials. An essential feature of clean technology is that product design considers raw material use and energy input during the entire process, from production to disposal. Clean technology minimizes the use of virgin

materials and maximizes the use of recycled materials in production processes and product design. It also maximizes the use of environmentally nondemanding materials to decrease waste and the energy required for processing.

Eliminates toxic substances as raw materials and product constituents. An important consideration in clean technology is finding substitutes for toxic substances used as raw materials in both products and processes. For example, changing to the more benign process of wet dry cleaning eliminates the use of toxic perchloroethylene (PCE) in the dry cleaning process.

Reduces the amount of waste and pollutants from processes and products. Clean technology favors efficient management of chemicals and their related processes. Source reduction or preventing waste at the source within the production process is an important component of clean technology. For processes, the general approach includes reducing the quantity and extent of pollution of all emissions and wastes before they leave the production process. For products, the designs should be such that the product will create less waste from material extraction to the ultimate disposal of the product.[104] UNEP publications (1993; 1994) provide many examples worldwide of various applications of clean technology used in products and processes that have resulted in reducing the amount of waste and pollutants.

Increases competitiveness and is economically beneficial in long run. Use of cleaner technology brings economic advantages as well as reduced environmental costs. Industries that have introduced cleaner production have benefited from savings in raw materials and energy, decreased waste management costs, improved product quality, improved productivity, decreased downtime, reduced worker health risk and environmental hazards, and decreased long-term liability for the cleanup of waste materials that might otherwise have been buried.[105] In addition, adopting clean technology and green designs makes a company more competitive, because increasingly, consumers, if given a choice, prefer a product that is "green" to one that is not. For example, a metal-processing industry in Singapore adopted a new process of gas phase heat treatment for metals that has resulted not only in savings in energy and resource costs in annual operations but also in reduction of effluents and improvement in the working environment, worker safety, and product quality.[106]

Measures product designs using cradle-to-grave analysis, that is, life cycle assessment (LCA). Clean technology combines overall resource use and environmental damage into a single measure of environmental cost. This implies that the cleanliness of a technology must be assessed by including the environmental cost of "upstream" suppliers and "downstream" users or waste disposers. Life cycle assessment is the analytic process to evaluate the environmental burdens associated with a product, process, or activity from extraction and processing of raw materials, manufacturing, transportation and distribution, use, reuse, maintenance, recycling, and final disposal. LCA studies have been performed to compare different products, for example, plastic with glass bottles and cloth with disposable diapers. Many U.S. firms, such as Proctor & Gamble and 3M, have applied LCA to evaluate various process designs.[107]

Pursues goals through technological changes. General consensus exists that technological change is essential to achieving pollution prevention and requires a fundamental shift in the design of products and processes. Necessary technological changes must include:

- Substitution of input materials

- Process design
- Final product reformulation.[108]

Requires basic attitudinal changes at all levels of the firm. Implementation of clean technology requires attitudinal changes at all levels within a firm. Because the concept of clean technology spans the entire process—from conceptualizing a product design to its ultimate disposal—its successful implementation requires acceptance and an environmentally responsible attitude at all levels of the industry—from top management to shop floor operators.

MEASUREMENT AND OBSTACLES TO IMPLEMENTATION

MEASUREMENT

An analytical methodology to evaluate the cost and benefit of various green designs for cleaner production is the product life-cycle analysis (LCA). An LCA provides a snapshot of inputs and outputs to identify environmental impacts associated with a specific product or process that helps in evaluating opportunities to reduce these effects. Curran calls it a "holistic approach that analyzes the entire system around a particular product from extracting raw materials; manufacturing; transportation and distribution; use, reuse, and maintenance; and recycling and waste management." LCA also includes the downstream and upstream effects of product use. The Society of Environmental Chemistry and Toxicology has rightly termed LCA a holistic analysis of environmental consequences associated with the cradle-to-grave life cycle of a product or process.[109]

LCA can improve our ability to measure the full cost and potential effects of new products and their associated technologies. Conducting a life cycle analysis is complex and requires an intricate understanding of material flows, resource reuse, and product substitution. It also requires a shift to a systems approach that considers all resources, products, and waste as an interdependent system.[110] Because of the complexity of measures involved, a consistent methodology with which to conduct an LCA is still being refined, because variations in accounting methods can greatly affect the results of analysis. The complexity lies in comparing, for instance, one pound of heavy metal sludge to one gallon of water use to consumption of one Btu of energy. For example, a study sponsored by Proctor & Gamble found that cloth diapers consume more than three times as much energy from cradle to grave as disposable diapers do, whereas another study conducted by the Association of Diaper Services reported that production, use, and disposal of disposable diapers consume 70 percent more energy than cloth diapers. This discrepancy is largely caused by variations in measurement and accounting for various processes, which in the diaper case was related to the process of cogeneration that produces air pollution. This exemplifies the subjectivity and uncertainty involved in evaluating the results of an LCA, which, according to EPA and environmental groups, are not ready to be used as a marketing tool for product comparisons.[111]

The debate whether clean technology is cost-competitive for firms in the long run centers around the accounting of costs. Clean technology or sustainable manufacturing views wastes as materials that could be recovered from recycling or reuse and account for them as lost raw materials. These concepts also consider costs associated with treatment and disposal of process wastes, permit fees, and materials taxes as potential revenue sources, whereas costs associated with not recycling and not conserving energy or materials are considered lost revenue. Cost accounting also includes the costs of training workers to handle toxic chemicals and spills safely.[112]

FIGURE 4-3. POLICY INITIATIVES TO PROMOTE CLEAN TECHNOLOGY

Regulatory Initiatives:

- Shift attention from risk to risk reduction
- Focus on the appropriate target
- Individual hazards:
  - Industry sector
  - Industrial processes
- Source reduction
  - Input substitution
  - Product reformulation
  - Process redesign
- Multimedia focus, including worker health
- Coordination of environmental, energy, and industrial policies
- Design regulation to get the technology desired
- Strict standards with flexible provisions

Technical Assistance Initiatives:

- Technical assistance to firms

Economic Instrument Initiatives:

- Tax policy
- Taxes on inputs and production
- Liability and financial responsibility

Stakeholder Participation Initiatives:

- Involve citizens and workers

International Policy Initiatives:

- Devise international policies

Source: Ashford (1995).

IMPLEMENTATION OBSTACLES

Because the development of clean technologies is a new concept for industry, the principal hindrance to their development is lack of managerial knowledge and the attitudinal change required. Ashford suggests that significant government intervention is necessary to stimulate change in industrial sectors to overcome these obstacles. To facilitate implementation of a technology-focused, environmental risk management strategy, Ashford suggests five principal groups of policy initiatives: regulatory, technical assistance, economic instruments, stakeholder participation, and international policies (see figure 4-3 above).[113]

A change of attitudes within industry has also been emphasized as necessary to expanding the concept of design for environment. Pfahl examined various case studies to identify factors influential in facilitating DFE. He concludes from an experience with CFC elimination that DFE can be employed successfully in a manufacturing organization in which the regulatory structure permits its implementation. He argues that the existing command and control strategy for environmental regulation and the adversarial attitude it engenders hinders implementation of DFE.[114]

In addition to government initiatives to increase market demand for cleaner technology, several other factors that influence the decision to adopt cleaner technologies have been identified by Kemp.[115] These factors include *(a)* price and quality of the

innovation, *(b)* the transfer of knowledge and information that is required to realize a transaction, and *(c)* risk and uncertainty on the economic consequences of installing a new technology.

The following describe examples of the implementation of clean technology, clean products, and clean processes:

Clean technology for recycling water and waste in the photographic industry.[116] The photofinishing industry traditionally uses large volumes of water in photographic processing. In the past, this has led to waste in processing chemicals and pollution problems associated with the discharge of wastewater. A cleaner technology, termed "System Crystal" has been designed to solve these problems by Altech Technology Systems Inc. The System Crystal is a closed-loop system that cleans and recycles water and regenerates and reuses some of the photographic wastes for Canada's largest photofinisher, Black Photo Corporation. The application of this new technology in the photofinishing plant, which used to discharge 265,000 liters of wastewater daily, has resulted in a final closed-loop system by-product of only 750 liters of mixed photochemistry concentrate daily.

The System Crystal consists of three interrelated processes: *(a)* Aqua-Flo is the closed-loop water treatment system that uses water sterilization and membrane separation technologies to achieve a 97 percent reduction of process water use, *(b)* Chemcharge is the process chemical analysis and treatment step that allows more than 90 percent of the chemicals used in photofinishing to be regenerated and reused, and *(c)* Chemnet uses a vacuum distillation unit to recover the water from the mixed photochemistry concentrate, leaving a small residual, which is disposed of as a hazardous waste.

The advantages of this cleaner technology application is not only environmental, but also economic. These include:

- Eliminating sewer discharge
- Reducing water consumption (from 77 million liters in 1990 to 24 million liters in 1993)
- Reducing chemical use through regeneration and reuse
- Setting new standards for waste management in the photofinishing industry
- Reducing cost of raw materials
- Resolving the challenge of regulatory compliance
- Increasing competitive advantage of the firm.

Water-based adhesives: a clean product. An example of a clean product from the United Kingdom, where Blueminster has developed the technology of water-based adhesives by producing a wide range of resin dispersions.[117] This enabled solvent-free adhesive systems to improve on and replace solvent-based adhesives. In most existing adhesives, either the solvent is a volatile organic compound, which evaporates to the atmosphere, contributing to atmospheric pollution, or the solvent is removed by high energy drying. Hot-melt adhesives that do not use solvents, are also high-energy consumers. In contrast, water-based adhesives have a much higher solids content than solvent-based adhesives and requires less energy to remove the water from the adhesive film. The advantage, thus, is that the water-based adhesives are non-toxic, they do not pollute the atmosphere or water systems, do not require special handling, and are not a fire hazard. These new adhesives are now finding application in flooring, pressure sensitive tapes, food packaging, and labeling.

A clean process: reducing toxic waste in electronic manufacturing. The manufacture of printed circuit boards traditionally involved the electrodeposition of a tin/lead alloy onto a copper circuit.[118] This alloy coating protected the copper circuit during the etching process. The tin/lead electroplating bath contained 30 percent toxic lead metal and fluoroborate-based waste, which were difficult to treat. A new process was introduced in Hong Kong, in which pure tin was used as the coating with sulfate-based plating. This eliminated lead and fluoroborate from the wastewater, which was therefore easier to treat. The new technology was developed by the manufacturers of electroplating chemicals. The new process has no adverse effects on product quality. The advantages of this clean process include:

- Elimination of lead and fluoroborate from wastewater
- Simplification of wastewater treatment
- Reduction of wastewater treatment costs
- Low initial investment
- No adverse affect on other manufacturing processes.

Chapter 5: Pollution Prevention and Source Reduction

Pollution prevention is one of the most frequently discussed and debated concepts in environmental policy because of its central role in environmental management. Academia, government, and corporate leaders have published a considerable amount of literature on the meaning of pollution prevention. Issues raised include its scope, purpose, and relationship to pollution control, source reduction, recycling, and other initiatives undertaken by the public and private sectors. Various efforts have widened and narrowed the definition of pollution prevention, depending on their purpose and goals.

This chapter outlines the various definitions of pollution prevention, highlighting the statutory definition of pollution prevention as provided in the Pollution Prevention Act of 1990 (PPA). The chapter also discusses the differences between pollution prevention and pollution control and provides several examples illustrating the main concepts and implementation of pollution prevention. An appendix to this chapter summarizes selected public and private initiatives to accelerate pollution prevention efforts.

BACKGROUND

The primary tenet of pollution prevention is well summed up by the maxim "an ounce of prevention is worth a pound of cure." Preventing the generation of pollution rather than controlling it at the end of the pipe or cleaning up media once pollution enters the environment is a more logical and environmentally benign strategy for environmental management. Although the concept of pollution prevention has existed for several years, it only gained popularity in practice during the 1980s.

During the past twenty-five years, U.S. response to its pollution problems has evolved "from pollution control to waste management to waste minimization to pollution prevention," according to Joseph Breen, a chemist with the EPA Office of Toxic Substances.[119] The factors contributing to this transition include the enormous cost of end-of-pipe pollution control, inefficiency in resource utilization, and societal and economic pressures. EPA Administrator Carol Browner summarized the importance of pollution prevention as follows:

> Today, we must move upstream in the manufacturing process to prevent the waste from being generated in the first place. Improvements in treatment and disposal techniques have led to dramatic reductions in pollutant loadings, but they have proved costly, and they have barely kept pace with traditional problems, let alone managing new ones. Perhaps most disturbing, some of the investments driven by our single-medium decision-making process have simply shifted waste from one part of the environment to another.[120]

According to EPA, the total cost associated with federal environmental regulation in 1992 was $135 billion.[121] Both government and private industry attribute this enormous price tag to the prevailing end-of-pipe pollution control strategy. In response, EPA established the Office of Pollution Prevention in 1988 to promote appropriate multimedia strategies for pollution prevention programs.[122] In 1990 Congress passed the PPA, which established an environmental protection hierarchy, listed in order of decreasing desirability as *(a)* prevention and reduction at the source, *(b)* recycling, *(c)* treatment, and *(d)* disposal or release.[123]

Chapter 313 of the 1986 Emergency Planning and Community Right to Know Act (EPCRA) requires industrial facilities to estimate and publicly release information pertaining to toxic emissions through the Toxics Release Inventory (TRI), Form R.[124] When the first inventory was released in 1987, U.S. facilities were discharging billions of pounds of toxic pollutants and losing billions of dollars in waste.

Some U.S. business leaders recognized the benefits of pollution prevention before regulatory changes became established. For example, 3M started its Pollution Prevention Pays program in 1975, expecting four measurable benefits—a better environment, conserved resources, improved technologies, and reduced costs.[125] Corporations, including Xerox, Kodak, and Proctor & Gamble, have embraced the principle of pollution prevention as a core component of their TQEM system.[126]

The benefits of pollution prevention include avoiding the generation of pollution and cutting costs associated with treatment and disposal.[127] Pollution prevention also promotes a comprehensive, multimedia strategy for reducing pollution rather than a media-by-media approach and encourages environmental management to function similarly to any other market-driven initiative.[128] New EPA policies encourage consideration of pollution prevention in regulatory enforcement settlements, whose advantages include improved prospects for future compliance and the potential for a reduced penalty.[129]

MULTIPLE PERSPECTIVES ON POLLUTION PREVENTION

The PPA "declares it to be the national policy of the United States that pollution should be prevented or reduced at the source whenever feasible." According to the PPA, the term "source reduction" means any practice that:

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

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

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

Some controversy regarding the scope of the definition of pollution prevention arose both within and outside of EPA as the agency established a source reduction pro-

gram and began various incentive programs. EPA sought to clarify the meaning of pollution prevention through memos and other public announcements.

Henry Habicht, EPA deputy administrator, stated in a memorandum that pollution prevention means source reduction as defined under PPA and other practices that reduce or eliminate the creation of pollutants through:

- Increased efficiency in the use of raw materials, energy, water, or other resources or
- Protection of natural resources through conservation.[130]

Habicht also discusses the relationship of pollution prevention to other environmental initiatives. In this interpretation of PPA, the following practices are not included within the definition of pollution prevention: recycling, energy recovery, treatment, and disposal. Some practices described as "in-process recycling" may qualify as pollution prevention.

Habicht's memo also addresses the relevance of pollution prevention in other industry and energy sectors. Pollution prevention can reduce environmental damages from the extraction, processing, transportation, and combustion of fuels. Pollution prevention approaches include:

- Increasing efficiency in energy use
- Substituting environmentally benign fuel sources
- Implementing design changes that reduce the demand for energy.

Hirschhorn and Oldenburg define two forms of pollution prevention, primary and secondary.[131] Primary pollution prevention consists of avoiding and eliminating the production of wastes and pollutants. Secondary pollution prevention is avoiding or eliminating waste management and pollution control actions, even though a waste or potential waste is produced (see figure 5-1).

Included in the primary pollution prevention category for industries, commercial establishments, farms, military installations, and consumers are actions that eliminate or avoid all or part of the wastes and pollutants at the point in the production process at which they are first generated. These actions may reduce the volume and/or toxicity of wastes and pollutants. Pollution prevention addresses the character of the original waste-producing situation—the source—by substantially changing or improving it or making it more efficient.

Hirschhorn and Oldenburg consider internal recycling and reuse of products and wastes as secondary pollution prevention. Internal recycling in industrial facilities is often called "closed-loop" or "in-process" recycling. For example, in chemical processing plants, by-products or wastes from one process may be used directly in another on-site process. The authors consider secondary pollution prevention less desirable because a waste material is still produced, even if it is recycled. Although some closed-loop processes do prevent pollution, other kinds do not prevent pollution even though wastes are reduced. For example, although steel mills typically recycle in-process scrap, its production, nonetheless, generates pollution.

According to Becker and Ashford, pollution prevention technological changes may be achieved either through innovation, the first commercial application of a new invention, or adoption of existing technology. Major innovation represents a significant improvement in technology; incremental innovation involves smaller changes

FIGURE 5-1. POLLUTION PREVENTION: HIERARCHY OF OPTIONS

For Primary Pollution Prevention

In industry and other institutions:

- Change processes or equipment
- Change composition, packaging, or durability of products
- Change or reduce raw material inputs
- Improve controls of processes
- Improve inventory controls
- Improve materials handling and cleaning operations
- Improve maintenance and repair of equipment

By consumers:

- Purchase different products
- Use less of a product

For Secondary Pollution Prevention

In industry and other institutions:

- Internally recycle waste in process
- Reuse waste on site
- Provide waste for reuse off site

By consumers:

- Repair products
- Reuse products
- Provide products for reuse by others
- Reuse waste and compost food and yard wastes
- Provide waste for reuse off site

Source: Hirschhorn and Oldenburg (1991), p. 40.

to or significant adaptation of existing technology. Diffusion denotes the widespread adoption of existing technology, involving minor adaptation with little or no innovation.[132]

CONSENSUS

In reviewing the different perspectives on pollution prevention, although disagreement exists on some issues, the following categories are generally thought to be features of pollution prevention:

MULTIPLE PATHS TO POLLUTION PREVENTION EXIST

Pollution prevention can be accomplished in a number of ways and may be achieved by innovations in process design, input use, and/or product design (see figure 5-2). For example, 3M's Pollution Prevention Pays program encourages technical innovation to prevent pollution at the source through the following:

- *Product reformulation.* Developing nonpolluting or less polluting products and processes.
- *Process modification.* Changing manufacturing processes to minimize waste or incorporate nonpolluting or less polluting materials.
- *Equipment redesign.* Modifying equipment to use available resources better.
- *Resource recovery.* Recycling by-products for sale or use in other products and processes.

FIGURE 5-2. CONTROL AND PREVENTION TECHNOLOGIES: SOME EXAMPLES

Prevention

- Improved process control to use energy and materials more efficiently
- Improved catalysis or reactor design to reduce by-products, increase yield, and save energy in chemical processes
- Alternative processes (e.g., low or no chlorine pulping)
- In-process material recovery (e.g., vapor recovery, water reuse, and heavy metals recovery)
- Alternatives to chlorofluorocarbons and other organic solvents
- High-efficiency paint and coating application
- Substitutes for heavy metals and other toxic substances
- Cleaner or alternative fuels and renewable energy
- Energy-efficient motors, lighting, heat exchangers, and so on
- Water conservation
- Improved "housekeeping" and maintenance in industry

Control/Treatment/Disposal

- Sewage treatment
- Industrial wastewater treatment
- Refuse collection
- Incineration
- Off-site recovery and recycling of wastes
- Landfilling
- Catalytic conversion and oxidation
- Particulates control
- Flue-gas desulfurization
- Nitrogen oxides control technology
- Volatile organic compound control and destruction

Source: Fletcher and Sobin (1994).

POLLUTION PREVENTION IS AN UPSTREAM EFFORT

Pollution prevention requires that efforts be directed upstream in the production process, rather than at the end of the pipe. For instance, to control SO_2 emissions from coal-burning power plants, most utilities install end-of-pipe, flue-gas desulfurization equipment; however, use of low-sulfur coal, which would also reduce the generation of SO_2, is considered source reduction. Another example of upstream pollution prevention is the effort by Pacific Gas & Electric of California to obtain approximately half of its energy from renewable technologies such as hydropower, geothermal, biomass, wind, and solar.[133]

POLLUTION PREVENTION IS A MULTIMEDIA EFFORT

Pollution prevention discourages intermedia transfers of pollutants. Often pollution control or waste minimization efforts may curb pollution in one medium but cause pollution in another. For example, wastewater treatment plants in compliance with federal water quality regulations are now among the largest sources of toxic air emissions, exceeding some industrial facilities. To address this problem, a large manufacturer of casted metal products redesigned the rinse systems used in coating and cleaning process lines and substituted aqueous and semiaqueous cleaners for organic solvents and Freon. This conversion reduced wastewater by 100,000 gallons per day as well as the energy requirements of the facility.[134]

POLLUTION PREVENTION IS A COMPREHENSIVE APPROACH

Pollution prevention does not entail eliminating all wastes from all production processes. A comprehensive pollution prevention approach, however, provides a more systemic outlook in abatement decisions. For example, conventional scrubbers used in coal-burning power plants were designed to remove sulfur dioxide at the end of the pipe and reduce the industry's emissions contributing to acid precipitation. Conventional scrubbers, however, increase carbon dioxide emissions into the atmosphere, contributing to global warming.[135] One form of pollution is prevented, therefore, at the cost of another. An alternative pollution prevention approach adopted by many utilities includes materials substitution using less polluting fuels and alternative sources of energy.

POLLUTION PREVENTION IS A PROACTIVE APPROACH

The idea of preventing and minimizing the need to control pollution is considered a proactive and, in some cases, preemptive strategy. 3M's Pollution Prevention Pays program exemplifies the benefits of adopting pollution prevention strategies to achieve environmental compliance.[136]

MEASUREMENT AND OBSTACLES TO IMPLEMENTATION

MEASUREMENT

Different companies and regulatory agencies have adopted different measures to monitor pollution prevention initiatives, including quantitative measurements of pollutants released into the air, water, and soil. For example, EPA's 33/50 Program measures the reduction in use and/or release of seventeen of the chemicals listed in the Toxics Reduction Inventory chemicals. EPA also measures reduction in 189 chemicals listed in the Clean Air Act as "air toxics."

Polaroid Corporation established a risk-weighted program for measuring the use of toxic chemicals. Under this program, the company assigns all materials to five categories that range from categories I and II (carcinogens and other high-priority toxics) to category V (nontoxic solid waste). The program sets a goal of 10 percent annual reduction in the use of categories I and II materials or the waste generation of categories III, IV, and V materials.[137]

IMPLEMENTATION OBSTACLES

Obstacles to adopting pollution prevention management approaches include financial, regulatory, institutional, and technological.[138] Hunt and Auster consider it often difficult to persuade corporate management to invest in preventive measures, particularly as many shareholders are increasingly interested in short-term profitability at the expense of long-term sustainability.[139] Others are critical of EPA's operational definition of pollution prevention. Karen Rasmussen of General Electric Company disagrees with EPA's definition of pollution prevention and advocates a definition that is broad, flexible, and multimedia in scope. John Cross, EPA's deputy director of the Pollution Prevention Division, states that:

> Rasmussen argues that the [EPA's] definition [of pollution prevention] could frustrate the efforts of well-intentioned companies by putting "an enormous number of excellent and legitimate environmental projects in 'scorecard limbo'" because "[t]hey are good to do but not good enough to count."[140]

Byers and Pfahl cite several government policies and regulations that hinder pollution prevention efforts.[141]

IMPLEMENTATION EXAMPLES

Approaches that different companies have adopted to phase out ozone-depleting substances (ODSs), such as chlorofluorocarbons and halons, are presented below.

These substances had been used extensively as cleaning solvents, refrigerants, and aerosol propellants. Raytheon used them and other ODSs for circuit card assembly and other electronic cleaning, and metal degreasing. Terpene-based cleaners and mildly alkaline aqueous solutions were developed as alternate cleaners.[142]

Similarly, Sandia National Laboratories and AT&T have tested and used terpene-based and decyl acetate–based cleaners for manufacturing printed wiring board. To eliminate the need for cleaning, these organizations are developing low solids flux technology, which leaves little or no post-solder residue.[143]

Companies participating in the Colorado Pollution Prevention Partnership, a non-profit, voluntary alliance of government, business, and public interest groups, committed themselves to reducing by 70 percent the use of trichloroethane (TCA), another ODS used to clean products and metal surfaces, by December 1991.[144] Pollution prevention measures used include:

- *Process modification.* Eliminating the need for TCA
- *Chemical substitution.* Finding safe alternatives
- *Revision of operating practices.* Reducing use at the source through education and management practices.

Xerox replaced chemical solvents with natural, biodegradable cleaners and water in machine-refurbishing operations. From 1982 to 1990 solvent air emissions at one facility dropped by more than 90 percent by substituting d-limonene (citrus-based cleaner) for solvents. Similar results were obtained in a photoreceptor, postlathing cleaning process by substituting citric acid cleaner for trichloroethane.[145]

Appendix: EPA's 33/50 Program

The EPA 33/50 Program is a voluntary pollution reduction initiative that promotes reduction of direct environmental releases and off-site transfers of seventeen high priority toxic chemicals. The program derives its name from its overall goals—an interim goal of 33 percent reduction by 1992 and an ultimate goal of a 50 percent reduction by 1995. The program uses 1988 TRI reporting as a baseline. In February 1991, EPA contacted TRI facilities, which reported using 33/50 Program chemicals since 1988, to solicit their participation in the 33/50 Program. As of April 1994, a total of 1,216 companies had elected to participate in the program.

CHEMICAL MANUFACTURERS ASSOCIATION'S RESPONSIBLE CARE PROGRAM

The Chemical Manufacturers Association (CMA), whose 185 members represent 90 percent of the industrial chemical production capacity in the United States, adopted the Responsible Care Program in 1990. This program sets guidelines and management practice codes that require all CMA members to improve worker as well as public health and safety by reducing all toxic emissions through practice and process changes and to communicate these efforts to the public. To implement the principles, the Responsible Care Program codifies six management practices, one of which is pollution prevention, which is also embodied in CMA's Pollution Prevention Code adopted in 1990.

To implement the Pollution Prevention Code, CMA facilities are required to take the following steps:

- Inventory the wastes they generate and the volume of releases to the land, air, and water and evaluate their potential effects on employees, the public, and the environment
- Seek employee and public input before developing and implementing plans for continual reductions
- Evaluate the reduction of waste releases at the source before evaluating recycling or treatment programs
- Include waste and release prevention objectives in the research and design of new or modified facilities, processes, and products
- Institute an ongoing program for promoting and supporting waste and release reduction by others.

3M'S POLLUTION PREVENTION PAYS PROGRAM

Begun in 1975, 3M's Pollution Prevention Pays Program encourages eliminating pollution at its source through technical innovation, including product reformulation, process modification, equipment redesign, and recycling and reusing waste materials.

To be recognized under this program, projects must *(a)* eliminate or reduce a pollutant, *(b)* benefit the environment through reduced energy use or the more efficient use of materials and resources, *(c)* demonstrate technical innovation, and *(d)* save money.[146] Through March 1992, a total of 3,450 Pollution Prevention Pays projects had been recognized throughout the company, 985 in the United States and 2,465 internationally. From 1975 to 1991, this program has helped 3M Corporation realize a total worldwide savings of $573 million in first-year savings and $1.4 billion in overall savings.[147]

Chapter 6: Waste Minimization and Reduction

Waste minimization, also commonly referred to as waste reduction, has been practiced within the manufacturing sector in varied forms for many years. Many have viewed waste as an indication of inefficient processes and use of materials; therefore, many manufacturers have tied the concepts of waste minimization to eliminating waste inefficiencies in the production process, considering time, material, and labor.[148] These process improvement strategies have developed into varied forms and concepts, including Total Quality Management, described in chapter 2.

The concepts of waste minimization have been integrally linked not only to TQM concepts but also to clean process, pollution prevention, source reduction technologies, and recycling, creating significant overlap between waste minimization and other waste management or avoidance strategies. This chapter, however, will focus only on waste minimization as defined by regulations, academia, and industry, ignoring its inherent overlap with the other concepts explained in this paper.

BACKGROUND

Waste minimization concepts have been around since at least 1972 with EPA's introduction of the Clean Water Act, which restricted effluent discharge levels to surface waters.[149] The concept of reducing waste emitted or released into the environment has also been enforced by the Clean Air Act and Resource Conservation and Recovery Act (RCRA). These regulations have commonly created a focus on environmental management practices within pollution control, treatment, and disposal technologies, which provide only end-of-pipe solutions for protection of human health and the environment. For many, this effect has caused great concern that end-of-pipe management of wastes serves only to transfer the health and environmental risks from one medium to another.[150] Others maintain that although treatment requirements have led to substantial progress in protecting human health and the environment, limits exist on how much end-of-pipe technologies can improve environmental protection in general.[151]

The regulatory inception of waste minimization concepts began, at least in direct programmatic form, with the Hazardous and Solid Waste Amendments of 1984 (HSWA), which amended RCRA to state that "the Congress hereby declares it to be the national policy of the United States that, wherever feasible, the generation of hazardous waste is to be reduced or eliminated as expeditiously as possible." EPA then began formulating a better definition and policy for their waste minimization program. Today, Carol Browner and EPA have made waste minimization concepts a priority in managing and repairing damage to human health and the environment.

Industry, as well, began developing waste minimization concepts and practices about the same time. With literature proclaiming that eradication of waste in manufacturing processes

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produces significant savings through lower waste management and regulatory compliance costs, liabilities, and risks, waste minimization concepts were slowly implemented, even though it was done in an uneven and mostly undocumented manner.[152] Although no exact figures exist on the amount of waste minimization actually taking place in industry, manufacturing facilities are taking a closer look at the waste resulting from their processes and ways to minimize these so-called "inefficiencies."[153]

MULTIPLE PERSPECTIVES ON WASTE MINIMIZATION/REDUCTION

As the concept of waste minimization gained adherents, so did the need for a clear definition of what it encompassed. Unfortunately, a uniform definition has not yet developed among government, academia, and the manufacturing sector.

EPA states that waste minimization has two components: source reduction and environmentally sound recycling. Source reduction is defined as:

> . . . any practice that *(a)* reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment . . . prior to recycling, treatment, or disposal and *(b)* reduces the hazards to public health and the environment associated with the release of such substances, pollutants, or contaminants.[154]

Source reduction includes such concepts as:

> . . . equipment or technology modifications, process or procedure modifications, reformulation or design of products, substitutions of raw materials, and improvements in housekeeping, maintenance, training, or inventory control.[155]

The second component and next preferred alternative to source reduction is environmentally sound recycling. Recycling is defined in the Federal Register (40 CFR §161.1[c]) and includes materials that are used, reused, or reclaimed, including processed to recover a usable product or regenerated.

The former Office of Technology Assessment (OTA) defined waste reduction (used interchangeably with waste minimization) in a broader context. OTA defined waste minimization as "in-plant practices that reduce, avoid, or eliminate the generation of hazardous waste to reduce risks to health and environment." Furthermore, OTA stated that "actions taken away from the waste-generating activity, including waste recycling or treatment of wastes after they are generated, are not considered waste reduction." Examples OTA used include concentrating hazardous substances to reduce volume or dilution of hazardous substances to reduce concentration.[156]

Other definitions state that waste minimization "refers to the reduction in volume and/or toxicity of a waste prior to discharge or disposal. . . ." Waste minimization techniques are divided into four categories presented in a hierarchy of desirable environmental practices. The first is source reduction, such as process modification, which "might include technology or equipment changes, procedure changes, or material substitutions. The second is recovery and reuse, which "involves the on-site or off-site use, with or without treatment, of a waste." Third, waste exchange "is basically a brokerage that handles waste materials that have the potential of being used as a raw material by another company." After the first three techniques have been exhausted, the fourth category—treatment, destruction, and disposal options—need to be considered.[157]

EPA, however, explicitly maintains the distinction between waste minimization and treatment, explaining that "treatment for the purposes of destruction or disposal is not part of waste minimization but, rather, is an activity that occurs after the opportunities for waste minimization have been pursued." In addition, EPA explains that waste minimization does not include the transfer of waste from one medium to another. Finally, EPA states that concentration activities conducted for reducing the volume of a hazardous waste and the dilution of hazardous waste to reduce its toxicity is not considered waste minimization.[158]

Waste minimization has also been defined as "changes to production process that reduce the use of toxic materials and the generation of hazardous and nonhazardous industrial air, water, and solid by-products." Clear distinctions have been made in which "waste minimization changes are not changes in treatment process; they reduce risk to human health and the environment and do not shift risks between the environment, workers, or consumers" and "waste minimization includes recycling when it is an integral part of the production process."[159]

Technical views within industry follow similar concepts but as applied to specific aspects of manufacturing. The basic characteristics of waste minimization have been viewed technically as follows:

- Waste minimization is a multidisciplinary area involving engineering chemistry, biology, fluid mechanics, mathematics, statistics, economics, and law. Consequently, cooperation among experts in these diverse fields is highly desirable.
- Waste minimization heavily depends on experience. Usually, the behavior of a process system that generates wastes cannot be described readily through formal mathematics models. The qualitative analysis of the mechanism of dealing with wastes is required.
- The available information pertaining to waste minimization is frequently uncertain, imprecise, incomplete, and qualitative. Quite often, it can be expressed only in symbolic form.[160]

CONSENSUS

As can be seen in chapter 5, a unified definition of waste minimization is lacking. Several important concepts can be delineated, however, from these multiple definitions. The following are the key components of waste minimization:

- Waste minimization is any practice or process change that reduces, avoids, or eliminates the use of toxic material and/or generation of hazardous substances/industrial wastes. These practices can be employed at the beginning of the process when product and process engineering decisions are made, during the process in which current process improvement and control can be incorporated, and at the end of the process when all recycling options can be considered.
- Recycling is partly waste minimization but consists of a hierarchy of preferred activities. Waste minimization programs should pursue recycling options that present the fewest opportunities for discharge into the environment. For example, direct in-process reuse presents fewer opportunities for discharge than storage and off-site shipment of wastes for recycling at other facilities. This hierarchy of options is illustrated within Polaroid's Toxic Use and Waste Reduction (TUWR) program as shown in figure 6-1.

FIGURE 6-1. HIERARCHY OF WASTE MANAGEMENT OPTIONS IN POLAROID'S TUWR PROGRAM

I. Recycling

- Polaroid on-site recycling: controlled reuse
- Polaroid off-site recycling: controlled reuse
- Polaroid recycling: other
- Vendor recycling: controlled reuse
- Vendor recycling: other

II. Treatment

- Polaroid on-site treatment (for recycling)
- Polaroid on-site treatment (for removal or "pH control" without recycling)
- Polaroid on-site incineration (beneficial)
- Polaroid on-site incineration (nonbeneficial)
- Vendor incineration (beneficial)
- Vendor treatment (nonrecycling/nonincineration)
- Vendor incineration (nonbeneficial)

III. Discharge

- Direct air emission (not piped to treatment for removal, incineration, or recycling)
- Direct sewer discharge (not piped to treatment for removal, "pH control," or recycling)
- Vendor land disposal

Source: Adapted from Ahearn, Fatkin, and Schwalm (1991)

- Waste minimization does not just include concentrating wastes to reduce the volume or diluting wastes to reduce toxicity. For example, if wastewater generated from a process contains high levels of lead (above regulatory levels, making it a hazardous waste as defined by RCRA), adding clean water to reduce the toxicity level below RCRA requirements does not constitute waste minimization. In fact, this practice is considered treatment and requires a permit under RCRA.
- Waste minimization does not include the transfer of wastes from one medium to another. For example, evaporating wastewater so that small amounts of hazardous solids are left does not constitute waste minimization.
- Waste minimization does not include treatment for purposes of destruction or disposal. For example, incineration of large amounts of sludge material, even if the incineration reduces the toxicity and amount of waste to be disposed, does not constitute waste minimization.
- Waste minimization practices does incorporate several techniques, including the following:

  Inventory management. This is direct control of the materials used in a manufacturing process to reduce the amount of hazardous materials in stock through material purchase review and control procedures. Inventory management can be carried out by approving the purchase of materials only after alternative, less hazardous materials have been considered. Once a material has been approved for purchase, strict inventory management systems need to be set up to ensure that only the exact amount needed is purchased. In addition, the development of new products should include evaluation of

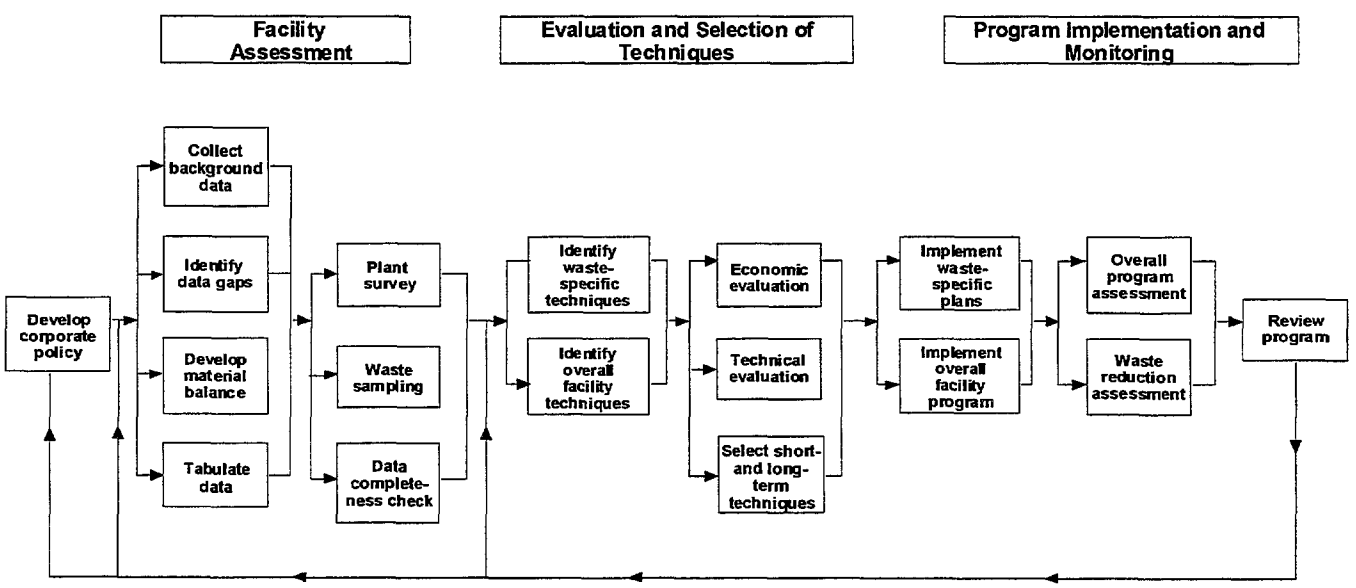
the hazardous nature of the materials needed, comparing alternatives, and a complete review of the manufacturing process to reduce the hazardous materials used.

Production-process modification. This is the change of materials used in a production process and/or the change of a process to use an input material more efficiently. It can include changes in the use of operational and maintenance procedures, a material change, or change in process equipment modifications. Operational and maintenance procedures require the assessment of the production process and maintenance schedules to create more efficient use of materials and prevent the loss of materials. Material change includes assessment of alternative, less hazardous chemicals used in the production process. Process equipment modifications implement the use of up-to-date or more efficient equipment to take advantage of advances in process technology.

Volume reduction. This involves techniques to separate usable materials from unusable materials, reducing the volume of waste sent for disposal through greater reuse and recycling. This practice, however, does not include the volume reduction of wastes to reduce the amount of waste defined as hazardous and, therefore, requiring stricter and more costly controls. Volume reduction is waste minimization only to the extent that it separates materials for recycling purposes.

Recovery and reuse. The recycling of materials through on-site recovery and reuse, off-site recovery, and interindustry exchange. On-site recovery and reuse incorporates many techniques to capture waste materials, either by recovering usable products through separation or treatment or by placing them directly back into a process as a material substitute. Off-site recovery is used when on-site recovery operations are not available and can occur through such practices as tolling agreements in which a vendor picks up waste, recovers usable products, and resells them as virgin products. Interindustry exchange is the transfer of waste to another industry, which can use

FIGURE 6-2. STRATEGY FOR DEVELOPING AND IMPLEMENTING A WASTE MINIMIZATION PROGRAM



Source: Freeman (1989).

the waste as a virgin product with or without recovery.[161]

- A waste minimization program should include several critical elements in its implementation (see figure 6-2 on preceding page): *(a)* a facility assessment providing the economic and technical information to assist in selecting waste minimization techniques, *(b)* actual selection of the technique, which needs to fit the criteria as developed within the facility assessment, and, *(c)* implementation and monitoring of the program necessary to ensure that all opportunities are carried out in an efficient manner.[162]

MEASUREMENT AND OBSTACLES TO IMPLEMENTATION

Several suggestions for developing methods to measure the success of waste minimization programs have been made. One method centers on the analysis of the optimization of the manufacturing process. The fundamental reference for process analysis is the "mass balance," which is determined using a single process device or a single chemical species. Given the amount of waste produced, the percentage change in waste is then compared with other variations in process and the waste produced. Waste minimization, however, must be evaluated in the "context of vigorous, potentially expanding, industrial activity."[163] In addition, "measurement systems that do not relate waste generated to units produced can distort waste reduction achievements." For example, a slowdown in production reduces the amount of waste generated, even though the proportion of waste to product remains the same.[164]

IMPLEMENTATION OBSTACLES

The implementation of waste minimization programs can present challenges in addition to measurement. Because waste minimization requires coordination among several steps within a manufacturing process, upper management needs not only to be aware of the goals of waste minimization but integrally involved in planning and coordination, product development procedures, and training programs[165]; thus, all levels of the organization need to be brought into any waste minimization program, as demonstrated in the Polaroid example below.

Furthermore, the waste minimization concepts of process redesign and incorporation of new technology hinge on the speed of technology advancement. Technology improvement within the manufacturing process may not advance as rapidly as the production of goods, thus, creating an obstacle for developing more efficient processes.

IMPLEMENTATION EXAMPLES

Waste minimization has been integrated successfully into various types of manufacturing processes. One example of waste minimization that shows the integration of various aspects of waste minimization is the strategy adopted by the Polaroid Corporation. Polaroid, the manufacturer of instant image-recording fields,developed its TUWR program mentioned above.

The success of Polaroid's TUWR program depends on the commitment of senior management to implement clear goals and measurment of progress toward them. The primary goals of the program focus on efforts to reduce sources of waste and emissions from all company operations. To do this, they have involved each employee in meetings to set environmental goals and have developed practices within the company to anticipate new regulations.

To achieve the goals of TUWR, Polaroid groups all materials used by the company into five categories. These categories depend on the materials' toxicity, using numer-

ous "risk factors and chemical and physical properties to assess environmental impact from releases of the material both as single events, such as spills, and from routine low-level emissions." First, Polaroid has established criteria by which to measure the amount of minimization achieved. Second, it has developed comparisons for waste reduction based on normalized production levels. Third, the wastes or by-products generated from a process are counted only at the process "exit," before treatment occurs[166]; thus, better abatement equipment does not count toward waste minimization, and recycling is only counted if rigorous criteria, such as reuse by Polaroid, are met.

The priority of the TUWR program is to first reduce the use of toxic material in the manufacturing process. Once this option has been pursued, Polaroid has developed a hierarchy of waste management options (see figure 6-1).

An example of the application of this process by Polaroid has been in their production of photographic film. The process formerly used dyes (listed in their category II), which produced significant levels of waste with low recyclability opportunity. Through extensive research, Polaroid was able to develop a substitute that reduced the waste produced by 80 percent. In addition, the waste produced was more easily recycled. The savings to Polaroid for this specific waste minimization effort has been approximately $1 million per year.

Chapter 7: Recycling

Recycling, also referred to as reuse or reclamation, is one of the most recognized improvements to environmental management practices for wastes among the general public today. It can occur along a continuum extending from in-process, closed-loop recycling through to recycling after treatment, storage, and transportation. Although not in this continuum, postconsumer recycling is considered a part of this management practice through design for recycling (explained later in this chapter). The fervor for recycling has greatly increased within the past few decades. EPA states that of the 207 million tons of municipal solid waste generated in the United States in 1993, 22 percent was recycled, up from 17 percent in 1990.[167]

Industry has, as well, been increasing its use of recycling concepts and technology. For example, in 1989 the Mehoopany plant of the Proctor & Gamble Paper Products Company won the Governor's Waste Minimization Award for recycling 26 percent of the plant's total waste, saving the company $4.4 million annually.[168]

BACKGROUND

Waste generation on the part of manufacturers and consumers has been a problem driven by two social forces, a throw-away mentality and the NIMBY ("not in my back yard") syndrome. Waste generated by both consumers and manufacturers has increased rapidly, compounded by increasingly full landfills and consumers who do not want new landfills in their backyards.[169]

Even with a throw-away mentality, industry had begun to view recycling as a standard for greater efficiency. Recycling developed from many of the concepts of efficient use of resources through productive reuse of generated waste. In addition, recycling has been used by industry as a marketing tool to the general public, which is increasingly conscious about using recycled products, or buying from companies in which recycling is a large part of the manufacturing culture.

These concepts started to appeal more broadly to the general public, which looked for activities that could be done on a day-to-day basis in the home or workplace and would promote conserving resources and protecting the environment. As stated in chapter 1, municipal solid waste recycling has jumped from 17 percent in 1990 to 22 percent in 1993.[170]

As recycling was increasingly adopted by industry, businesses, and households, distinctive types began to develop within the manufacturing industry, including postconsumer, closed-loop, and on-site/off-site recycling. Recently, new concepts have emerged encompassing several of these concepts, such as design for recycling, which targets postconsumer recyclability of products and packages.

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MULTIPLE PERSPECTIVES ON RECYCLING

Recycling has taken on many forms within the manufacturing industry and can happen at multiple stages of a process. Several industry perspectives offer, however, a similar view on the general concepts of recycling.

The concept of recycling can be defined simply as a process in which an input can be used again, creating less need to use a virgin material. Recycling can further be defined in the context of economics in which the use of the recycling process increases the overall process productivity.[171]

Expanding on this economic view is a more applied manufacturing consideration of recycling technologies and processes, which asks at what concentrations it is economical to extract and reuse recyclable content from a waste stream.

The U.S. regulatory view of recycling comes mainly from RCRA. RCRA maintains that recycling is the use, reuse, or reclamation of a material (RCRA §261.2[7]). Use and reuse is considered the employment of a material in an industrial process or as an effective substitute for a commercial product. Reclamation is similarly defined as processing a material to regenerate or recover a product.

Beyond the general definitions of recycling, the concepts can be applied to numerous stages during the process and take several forms. Hirschhorn and Oldenburg categorize recycling in terms of "secondary pollution prevention" into two types, internal recycling and on-site/off-site recycling. Internal recycling, also known as closed-loop or in-process recycling, refers to reinserting into the same manufacturing process without typical waste treatment a material that has been used for its original purpose and could become a waste. This typically includes the reuse of waste gases and/or liquids. In addition, because the waste does not exit the process, it has little chance of discharging into the environment. On-site/off-site recycling is slightly different. This type of recycling usually consists of liquids and solids and requires the movement of wastes out of the process and into another on site or transportation to another site. Because of the out-of-process movement of the waste material, the likelihood of discharge is greatly increased, thus, making this form of recycling less desirable.[172]

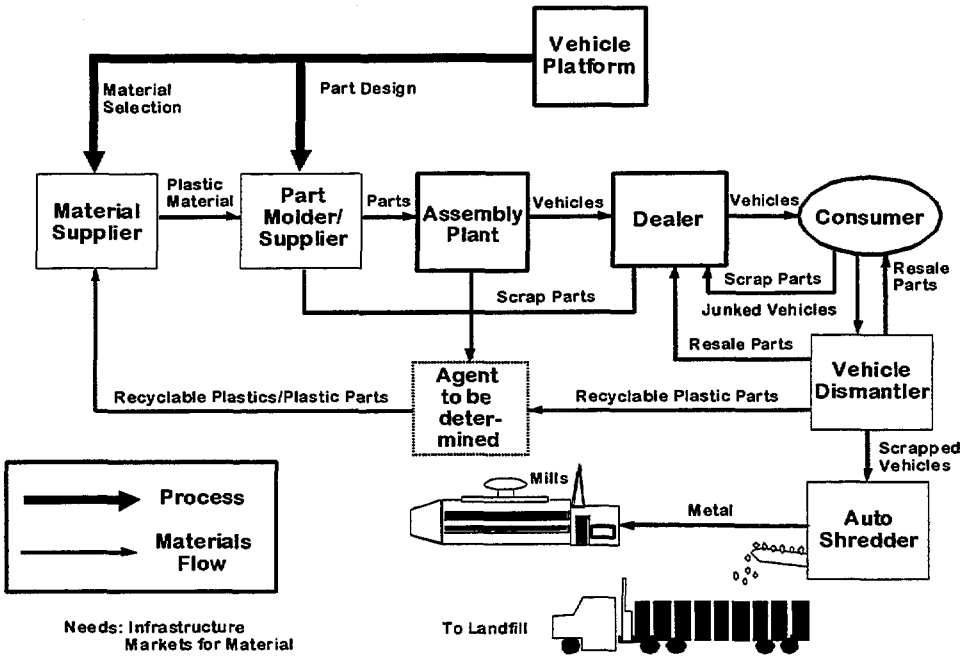
These points of view are supplemented by the following more specific descriptions of the different types of recycling and how they can be applied to manufacturing situations:

Closed-loop. Material reused without exiting a process or the process is completely enclosed, reducing possible exposure to environmental pathways (i.e., water, air, and soil).[173] For example, spent solvents are frequently piped to surge equalization tanks, piped from the tank to distillation units, and then returned to the original manufacturing process for reuse.

On-site/off-site. Waste exits the process to be used directly in another process or reclaimed or regenerated for use in the same or a different process (this includes waste brought to another facility that has legitimate use for the waste). For example, many industry facilities have "tolling" agreements through which certain waste materials, such as spent solvents, are picked up by the tolling company and recycled off site, thus reducing the cost for on-site recycling equipment.[174]

Postconsumer. Reuse of material generated from residential and consumer waste.[175] For example, the automobile industry has developed the Vehicle Recycling Partner-

FIGURE 7-1. RECYCLABLE VEHICLE PROCESS



ship to recycle about 75 percent of a vehicle through the process shown in figure 7-1 above.)[176]

"Design for recycling" is a new concept within recycling that is intricately related to the clean product, clean process, and packaging design technologies, discussed in chapter 4, as well as the broader emerging concepts of industrial ecology. The basic premise of the concept of industrial ecology is "one in which the cyclization of material at their highest possible purity and utility level is of prime importance"; thus, design for recycling involves designs that allow products, when they have completed their useful life, to "reenter the industrial flow stream and become incorporated into new products."[177] Postconsumer recycling cannot occur unless the materials that make the product can be efficiently recovered to make new products (see Xerox example below).

Recycling has many times been used as a way to skirt responsibility to meet cumbersome and expensive regulations. This activity, termed "sham recycling," includes such things as processing a waste material into a new product in which the waste material serves no or little purpose in the product (does not substitute for a virgin material) to avoid having to treat and dispose of the waste properly and/or burning the waste material for energy recovery when the waste has little or no energy value. Both of these examples along with other possible examples are not genuine recycling. In addition, Hirschhorn and Oldenburg assert that any type of burning of a waste, even if it is for legitimate energy recovery, should not be considered recycling, better resembling waste management, which has greater likelihood for releasing hazardous substances into the environment.[178]

CONSENSUS

Most of the perspectives on recycling are similar, thus, providing a fairly clear consensus on what constitutes recycling, namely, that recycling incorporates the following two concepts:

- Reuse of a material, directly or indirectly in manufacturing a product, creating the need for fewer original resources (i.e., reusing a solvent to clean objects in the printed circuit board industry so that the use of virgin solvents is reduced).
- Processing of a material to make it amenable for reuse (i.e., filtering impurities from solvent for reuse, reducing the need for the use of virgin solvents).

Recycling can be done at many stages of the industrial process, following a continuum from in-process recycling—in which a waste does not exit the process, is not stored, and requires no treatment before reuse—to waste that must be taken out of the process, stored, transported, and treated before it can be reused. Much recycling exists between these two extremes. Examples are waste reuse in a different process at the same facility or waste reuse in the same process but after undergoing treatment to reclaim the material. Both industry and government have set preferences on those recycling activities that present less potential for endangering human health and the environment. Polaroid has developed a hierarchy for determining which practices are preferred under their TUWR program (see figure 6-2). EPA has expressed its preferences by regulating recycling that is not closed-loop more strictly and requiring storage, transportation, and/or treatment before reuse.

Postconsumer recycling falls outside of this continuum but is included within this management practice. Although most consumer products do not pose the level of hazard of industrial wastes, concerns over landfill space and resource conservation have increasingly emphasized recycling. The manufacturing industry has significantly affected postconsumer recycling by developing products that are amenable to recycling yet provide longer productive lives. These concepts are embedded in design for recycling as described below in the Xerox Corporation example.

MEASUREMENT AND OBSTACLES TO IMPLEMENTATION

MEASUREMENT

Measurement for recycling can be viewed from a number of perspectives. The first is the manufacturing view, which calculates the cost-effectiveness of recovering a material for reuse in a process. If the cost of recovering a used material exceeds the costs of using a virgin material, manufacturers will be less likely to pursue recycling as the chosen environmental management method. If the opposite is true, that recycling is the most economical choice, manufacturers will be more likely to recycle. Beyond the choice between recycling and alternative waste management, progress toward recycling goals can be based on the unit of waste recycled per unit of product produced (i.e., a pound of recycled waste per pound of product).[179] Furthermore, setting benchmarks can push industry toward recycling goals, as exemplified by the Xerox example on continuous improvement in chapter 3, page [pgref5].

The second point of view is from the regulatory side, which calculates the amount of recycling taking place as a percentage of the total amount of waste produced. For example, EPA tracks the amount of consumer solid waste that has been recycled, such as aluminum, plastic, and paper, setting overall goals and strategies for achieving higher levels of recycling.

IMPLEMENTATION OBSTACLES

Obstacles to the development of recycling technologies, including the actual process of recycling, include the problem faced from both the manufacturing and regulatory perspective: recycling is more costly under certain circumstances than use of virgin materials and resources (in terms of costs related to consumption of both time and money). This presents a strong disincentive to recycling and in many cases provides

an incentive to take the more economical approach of using virgin materials. Hirschhorn and Oldenburg state that, in August 1989, an overabundance of one million tons of to-be-recycled newsprint existed nationwide.[180] Even if much of the collection and separation steps have been taken for recycling, market demand still dictates the amount of recycling that occurs. The obstacles created by lack of demand are beginning to be addressed as regulatory entities require consumers to recycle—creating a greater supply of recyclable materials—and require government contractors to procure products with certain amounts of recycled content, creating greater demand for recycled products. For example, Executive Order 12873 sets forth requirements that EPA set procurement guidelines for products containing recovered material content.[181]

Hirschhorn and Oldenburg state three more obstacles to the effective use of recycling technology. The first comes from the problem of recycled materials not meeting the specifications needed to manufacture new products. They use the example of paper fibers becoming shorter during recycling, creating a weaker paper. A second obstacle is the difficulty of recycling materials from the complex products that are on the market today. Recycling of aluminum, glass, paper, and plastic is simple, but, as products become more complex, separation and reuse will become more difficult and inefficiencies will be a significant concern. A third obstacle is that the process of recycling creates environmental hazards and problems of their own. Hirschhorn and Oldenburg use the example of a mercury battery recycling plant in New York, which was found to have significant levels of mercury in the soils surrounding the plant.[182]

IMPLEMENTATION EXAMPLES

Abundant examples exist to show the types of recycling taking place in the manufacturing industry:

On-site or off-site recycling. In manufacturing printed circuit boards using cupric chloride acid solutions, unwanted copper is etched away. When the solutions contain high levels of dissolved copper, they become ineffective in etching copper from the circuit boards. During regeneration of the solution, the copper is usually precipitated as copper oxide and then landfilled. Circuit board manufacturers have identified this as an opportunity to recycle the copper and reduce the landfilling costs. By using an electrolytic divided-cell technology developed in the United Kingdom, circuit board manufacturers were able to regenerate the solution and recover the copper as pure flakes. The general economic benefits of this procedure may save the average company $50,000 in copper costs, $80,000 in other material costs, and $25,000 in disposal costs per year.

Postconsumer recycling and design for recycling. The Xerox Asset Recycling Management program has focused on developing a corporate culture and strategy that treats all products on rental sites or on site as physical assets. This consideration has led Xerox to set up the following hierarchy of objectives for managing these assets when they have reached the end of their useful life:

- Distributing returned equipment for reuse by new customers, as long as it is in optimal working order
- Restoring equipment through remanufacturing to its original state
- Converting the equipment or major assemblies from the equipment into another product, for example, using the electromechanical elements of a copier in a printer
- Dismantling equipment to salvage parts for use either on the new product assembly line or as spare parts for field repairs

- If parts are not salvageable, recycling their source materials either at Xerox or externally through suppliers or recyclers. The latter may combine recycled source materials with virgin material into a blend that is used in Xerox parts."

To implement these objectives, Xerox pursued design for recycling by building cooperation between design and manufacturing engineers and upper management in a joint task force. The task force followed these guidelines: "extended product and component life, that is, use of more robust materials and design to make asset recovery practical; selection of materials that are relatively easy to recycle at the end of product life; simplification of materials to facilitate recycling; easy dissassembly as well as easy assembly; remanufacturing convertibility, meaning that a basic product configuration is convertible to a different use, for example, a copier to an electronic printer; and use of common parts to enable future reuse in different models and configurations."[183]

Chapter 8: Pollution Control

Pollution control technology renders hazardous substances harmless before they enter the environment. The most commonly cited examples of this approach are end-of-pipe solutions to reducing pollution, including catalytic converters attached to automobiles and sewage treatment plants and scrubbers on utility smokestacks, which convert pollutants to less noxious or harmless substances after they have been generated.

The catalytic converter is a good example of a pollution control device. Catalytic converters remove some of the polluting materials produced by automobile engines. Wastewater treatment plants are another example. Most treatment plants prevent dangerous organic wastes (from animal and plant matter) from being discharged into water bodies by using bacteria and oxygen to break down the organic wastes.

This chapter presents different perspectives on pollution control, highlighting the difference between pollution prevention and pollution control. Throughout this paper, pollution control is distinguished from recycling and waste minimization, two other tools used in environmental management.[184] Implementation examples for pollution control at the end of this chapter present instances in which end-of-pipe controls may offer a "second-best" choice.

BACKGROUND

In the early days of environmental regulation and corporate environmental management, pollution control was the most prevalent technological approach. Environmental degradation caused by acid precipitation, toxic wastes in rivers and lakes, urban smog and other health hazards resulting from auto exhausts, discharge of untreated sewage into water bodies, hazardous wastes in landfills, and agricultural runoff brought about an awareness of the need to control pollution and emissions. Restrictions on the use of materials and mandatory pollution control equipment to reduce air, water, and land discharges were established. As a result, federal, state, and local governments passed statutes limiting the amount of pollution that automobiles, industrial facilities, and sewage treatment plants can release into the environment.

The federal government passed the first significant pollution control law in 1899, which made it illegal to dump any liquid wastes, except those from sewers, into navigable waters. The law had the potential of controlling water pollution effectively but was infrequently enforced. Air pollution problems in industrial cities became serious and prompted the first Clean Air Act in 1955. In 1970 the authority for implementing fifteen federal pollution control programs was consolidated under the

newly formed U.S. Environmental Protection Agency.

Pollution control efforts in the industrial sector began in earnest in the 1970s when Congress required technology-based standards for water under the Clean Water Act and subsequently for air and hazardous wastes under the Clean Air Act and the Resource Conservation and Recovery Act, respectively. Most state and local governments have also developed pollution control programs. The corporate response to these laws has been "a technically based management approach that was tactical and defensive," designed to achieve simple compliance with a handful of regulations—usually by achieving some level of posttreatment or end-of-pipe treatment for existing processes.

In recent years, a perceptible shift has occurred away from pollution control toward prevention. The high cost of retrofitting abatement equipment in existing facilities, inefficiency associated with allocating resources to control already generated pollution, and concern about the environmental impact of the command and control approach have led government, business, and technology leaders to espouse pollution prevention techniques over pollution control.[185]

MULTIPLE PERSPECTIVES ON POLLUTION CONTROL

Hunt and Schecter identify investment in "end-of-pipe" and "out-the-back-door" equipment as pollution control. They state that "the control of pollution in this way requires labor hours, energy, materials, and capital expenditures. Such an approach—for example, wastewater treatment or air pollution abatement—removes pollution from one source but places pollutants somewhere else, for example, a landfill."[186]

Hirschhorn and Oldenburg characterize the traditional end-of-pipe control strategy as the "strategy of the cork." This approach often leads to a technological solution to emissions, comparable to a cork plugging up the release of pollutants. Hirschhorn and Oldenburg discount claims made by advocates of pollution control who consider that improved technology and stringent regulations "press the cork in tighter."

> True, some releases and effects are curtailed [through pollution control]. But the original toxic or destructive environmental wastes remain hazardous or are transformed into different hazardous substances to some degree. In most cases, environmental releases still occur, either routinely (around loose corks and at places where the government has not required corks) or when control equipment fails (when the corks pop).[187]

In distinguishing pollution prevention from pollution control, Hirschhorn and Oldenburg point out that prevention emphasizes sources, whereas control emphasizes adverse effects. Typically, pollution control decisions are made in three stages:

- Determine what is to be protected (e.g., water quality, human health, and so on)
- Determine the level and nature of risk to what is being protected and the acceptable level of risk
- Set environmental standards for acceptable levels of emissions or releases.

Helfand defines pollution control as taking generated pollution and converting it to less noxious or harmless substances. In the economic model used in her analysis, pollution control is characterized as a material input. Production processes use many inputs, including raw materials, labor, and energy. Of these inputs, two are pollu-

tion-related: one contributes to pollution (for which reduction of use would constitute pollution prevention) and the other abates pollution (a "tailpipe" technology that can also contribute to production). For example, power plants that burn coal (the polluting input) to generate electricity may use a scrubber to take out sulfur dioxide (SO_2) at the end of the pipe to help reduce acid precipitation and damage to human health.

EPA's strategy for pollution control in the 1970s was to prescribe the use of certain technological solutions to reduce emissions to the air and water. The concepts of best demonstrated available technology and best available technology, among others, were written into environmental statutes and interpreted as requiring specific control equipment or processes to control hazardous emissions generated by specific industries. For example, scrubbers were prescribed for existing coal-using power plants to reduce air emissions and pretreatment methods were prescribed for industrial wastewater prior to discharging it to publicly owned treatment works. Under the revised Clean Air Act, new emission sources must install maximum available control technology, based on the average of twelve best-performing plants in each industry.[188]

Examples of pollution control abound. Figure 8-1 illustrates some common problems that have been addressed using pollution control practices.

CONSENSUS

Consensus appears to exist on the following points on pollution control and prevention:

Pollution control is a downstream effort. Pollution control has been characterized as a downstream, end-of-pipe, and back-end approach. For example, to control SO_2 emissions from coal-burning power plants, utilities install end-of-pipe, flue-gas desulfurization equipment.

It often addresses emissions to a single medium. Pollution control efforts curb pollution, usually the most serious pollutant, in one medium. For example, coal-burning electric power plants emit both SO_2 and NO_x through smokestacks; however, be-

Problem	Solution
High fecal coliform level	Sewage treatment
High biochemical oxygen demand (BOD)	Industrial wastewater treatment
Littering	Refuse collection
Solid waste	Incineration
Illegal dumping in sewers	Off-site recovery and recycling of wastes
Aluminum potliners	Landfilling
Smog	Catalytic conversion and oxidation
Industrial dust	Particulates control
Acid precipitation	Flue-gas desulfurization
Smog	Nitrogen oxides control technology
Smog	Volatile organic compound control and destruction

Source: Adapted from Fletcher and Sobin (1994).

FIGURE 8-1. POLLUTION AND SOLUTION: SOME EXAMPLES OF THE CONTROL APPROACH

cause atmospheric SO_2 contributes to acid precipitation more than NO_x, pollution control efforts addressed SO_2 emissions first.

It is often the most effective technological approach. Pollution control techniques often result in installation of the most advanced and effective technology to reduce emissions of the harmful pollutants concerned (see example below).

It is a defensive or reactive approach. Pollution control is often driven by compliance standards promulgated through environmental regulation. Regulators and public safety watchdog groups are often the most significant forces behind pollution control efforts.

It is more effective for identified and large point-source generators. Pollution control approaches have been successful in cleaning up large, identified sources of pollution, such as refineries, thermal power plants, and municipal sewer systems. For small point sources and nonpoint sources, pollution control efforts neither exist nor are economical. For example, chlorinated organics are released into the environment by a diverse group of small point sources, including dry cleaning, paint stripping, and degreasing operations. These and other small sources are so numerous and widespread that often control of this pollution by mandating treatment technologies is impractical and uneconomical.

MEASUREMENT AND OBSTACLES TO IMPLEMENTATION

Most control equipment is designed to monitor and measure pollutant levels.[189] As for all equipment, however, measurement errors occur and equipment often fails.

IMPLEMENTATION EXAMPLE: COAL-FIRED GENERATING UNIT OF ORLANDO UTILITIES

The new 460-Mw unit of the Orlando Utilities Commission (OUC) is considered the cleanest-burning conventional coal-fired generator. A wet limestone scrubber removes 95 percent of the unit's SO_2 emissions. SO_2 releases amount to about 0.1 pound per million Btu, which is less than half of the discharges of the conventional unit, which generates less than one quarter of permit allowances.

The principal innovation of the new unit is installation of a selective catalytic reduction (SCR) system that injects ammonia to decrease NO_x emissions. The SCR unit, which costs $10.1 million, together with low NO_x burners in the wall-fired, pulverized coal boilers will limit emissions to levels considerably less than permit allowances and far less than conventional oil-fired units, according to OUC. Permits restrict the discharge of NO_x to 0.17 pounds per million Btu of heat input. The actual releases generated by the new unit are 0.1 pounds, based on a 30-day rolling average.

One disadvantage to this approach is that the installation of control equipment creates a solid waste management problem. OUC's control equipment generates fly ash and bottom ash in addition to sludge from the scrubber. Although much of the fly ash and bottom ash waste is sold, some is mixed with scrubber sludge and lime for disposal on site. According to OUC's environmental director, fly ash that is contaminated by ammonia injections by the SCR system must be fixated with scrubber sludge and landfilled.

Chapter 9: Treatment and Disposal Technologies

Waste treatment and disposal have developed and matured into the primary mechanism for waste management within the manufacturing industry. Treatment technologies include physical and chemical treatment, thermal treatment, and biological treatment. Treatment of waste usually occurs before disposal to remove contaminants or to recover usable materials from a waste. Disposal technologies include landfills, deep-well injection, and surface impoundments and are considered the final disposition of a waste.

BACKGROUND

Waste disposal has long been a management practice mostly used by the manufacturing industry. Prior to regulatory requirements, disposal was the cheapest management practice because few restrictions on land disposal existed. The cheap cost and the lack of any requirement to treat wastes before disposal meant treatment was not a part of the waste management system.

With the development of regulatory structures for managing solid wastes, which set standards for the treatment and disposal of all varieties of wastes (hazardous wastes, radioactive wastes, sewage, air emissions, and industrial wastewater), industry began to focus its waste management practices on treatment and disposal technologies. The regulatory requirements were such that the development of environmental management was focused at the end of the pipe—after the waste was generated.

The treatment and disposal regulations that were developed throughout the 1970s and culminated in numerous broadly based requirements in the early 1980s, created great market demand for treatment and disposal technologies. The regulation-driven market produced a broad spectrum of new methods and technologies for treatment and disposal, ranging from incinerators and chemical neutralization for treatment to landfills and deep-well injection for disposal. In addition, EPA's stringent requirements that treatment technologies be based on best demonstrated available technology kept market demand for treatment technologies thriving.

Today, given concern over available space for land disposal and increasing worries about complete contaminant destruction, treatment and disposal technologies are entering new eras. Technologies on the horizon include such techniques as plasma-arc devices, which create extremely high temperatures for destruction/removal efficiencies beyond 99.9 percent[190] and greater efficiencies in landfill space.

MULTIPLE PERSPECTIVES ON TREATMENT AND DISPOSAL

The definitions for treatment and disposal have come from a number of sources, mostly regulatory, but seem to have numerous similarities.

For regulatory compliance purposes, treatment and disposal were typically defined to distinguish when someone was subject to particular regulations and, thus, required such compliance items as a permit or a specified technology. RCRA defines treatment as "any method, technique, or process, including neutralization, designed to change the physical, chemical, or biological character or composition of any hazardous waste so as to neutralize such waste or to recover energy or material resources from the waste or to render such waste nonhazardous or less hazardous; safer to transport, store, or dispose of; or amenable for recovery, amenable for storage, or reduced in volume."[191] Treatment can take place on the same site at which the waste is generated but typically incorporates transportation to a facility that is permitted to treat specified wastes. In addition, the treatment typically occurs for the purpose of meeting RCRA requirements of land disposal restrictions, Clean Water Act requirements for effluent contaminant levels, and Clean Air Act requirements for contaminant emissions. Certain contaminant levels are required of these different media for the waste to be discharged into the environment, such as land, water, or air.

Some treatment occurs for purposes of making the waste amenable for recovery or recycling. This type of treatment is usually separated from the production process, and because it can present the same potential for releases as treatment for disposal, recycling must follow similar regulations.

Disposal has been defined in RCRA as "discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water so that such solid waste or hazardous waste or any constituent thereof may enter the environment or be emitted into the air or discharged into any waters, including ground waters."[192] Disposal from the RCRA point of view is an activity that many times sequentially follows treatment, but waste is sometimes disposed of without treatment. For example, the wood-preserving industry typically uses numerous types of preservatives to extend the life of wood, such as creosote, chlorophenol, arsenic, and chromium. Once these preservatives have been used, the spent wastes are by definition RCRA hazardous wastes. RCRA requires that before a hazardous waste is disposed of, certain treatment requirements be met. These treatment requirements are usually performance based (use of any technology to meet specified levels for constituents) but can be technology based as well (use of a specified technology to meet treatment requirements). If the treatment requirement for spent wood preservatives is performance based and the waste already meets the treatment levels when generated, the waste can be disposed of without treatment. This is not typically the case, however; most hazardous wastes will need some form of treatment before disposal.

These examples are consistent across environmental waste media, such as air and water. The Clean Water Act requires that wastewater discharges to surface water meet certain pretreatment requirements. These levels must be met before effectively "disposing" of wastewater into waterways in accordance with the standards. In addition, wastewater can be sent to a publicly owned treatment works where primary, secondary, and tertiary treatment occurs. Similar standards exist under the Clean Air Act, which states that emissions must be treated to specified levels through use of control technologies such as scrubbers and carbon filters before exiting into the environment.

Outside the context of regulatory waste treatment and disposal programs, several types of waste can be disposed of without treatment. Municipal solid waste is an example of a waste for which treatment need not occur before it is placed in landfills. Recently, however, incinerators have been used as an alternative to landfills for municipal solid waste; thus, treatment can occur in these waste streams, reducing the volume of waste to be disposed of in landfills and converting the rest of the waste into air emissions, which are effectively disposed of in the air.

EPA as well has defined treatment and disposal in a generic context, unrelated to the above programs. Treatment is defined as any method, technique, or process designed to remove solids and/or pollutants from solid waste, waste streams, effluents, and air emissions. Disposal is generically defined as final placement or destruction of toxic, radioactive, or other wastes; surplus or banned pesticides or chemicals; polluted soils; and drums containing hazardous materials from removal actions or accidental releases. Disposal may be accomplished by using approved landfills, surface impoundments, land farming, deep-well injection, ocean dumping, and incineration.[193]

Freeman further discusses disposal as the "elimination of the waste or the hazard potential of the waste." He further states that the classical view of disposal has typically been transferring waste from one medium to another.[194] For example, air emissions are captured in activated carbon and then disposed of on land as a solid waste, or, as discussed above, municipal solid waste is incinerated and partially converted to air emissions.

CONSENSUS

Treatment and disposal have always been viewed as a form of end-of-pipe environmental management, even though until recently it was considered the preferred management method. The following important concepts define the boundaries of treatment and disposal:

- *Treatment.* The management of waste before disposal to change the physical or biological composition of a waste to reduce its potential hazards to human health and the environment.
- *Disposal.* The management practice (usually occurring following treatment to meet contaminant standards) in which waste is placed into units (usually regulated to prevent release into the environment) and that is considered to be the final disposition of the waste.

Different types of treatment technologies include the following categories: physical and chemical treatment, thermal processes, and biological processes. A description of each of the main technologies in these categories follows:

PHYSICAL AND CHEMICAL TREATMENT

- *Filtration and separation.* This method separates solid particles from a fluid through use of a porous medium. (This can also be called primary treatment of wastewater.)
- *Chemical precipitation.* This process converts a soluble waste to an insoluble form either by a chemical reaction or by changes in the composition of the solvent to diminish the solubility of the substance in it.
- *Photolysis.* This method to photodegrade wastes by applying techniques, such as commercial high-intensity light sources, effectively removes the wavelength from natural light to allow for large-scale photodegradation.

- *Chemical oxidation and reduction.* This involves adding or removing electrons from an ion, atom, or molecule to treat metal-bearing waste, such as sulfides, cyanides, and chromium, and many organic wastes, such as phenols, pesticides, and sulfur-containing compounds.
- *Solidification/stabilization.* This is a process designed to either improve waste handling and physical characteristics, decrease surface area across which pollutants can transfer or leach, or limit the solubility of or detoxify the hazardous constituents.[195]

THERMAL PROCESSES

- *Liquid injection incinerator.* This common system relies on high pressure to prepare liquid wastes for incineration, breaking them up into tiny droplets to allow for easier combustion.
- *Rotary kilns.* An incinerator with a rotating combustion chamber keeps waste moving, thereby allowing it to vaporize for easier burning.
- *Fluidized-bed thermal oxidation.* An incinerator uses a bed of hot sand or other granular material to transfer heat directly to waste. This method is used mainly for thermally oxidizing municipal sludge to ash.[196]
- *Cement kilns.* These are cement production systems that can use wastes such as still bottoms, solvents, tars, tires, and refuse as effective substitutes for coal, petroleum coke, oil, and natural gas. Cement kilns burn at such high temperatures that complete destruction of organic constituents is ensured.[197]

BIOLOGICAL PROCESSES

- *Aerobic processes.* In this process microbes decompose complex organic compounds in the presence of oxygen and use the liberated energy for production and growth (this can also be called secondary treatment of wastewater).[198]
- *Anaerobic digestion.* In this sequential, biological destructive process, hydrocarbons are converted in the absence of free oxygen from complex to simpler molecules and ultimately to carbon dioxide and methane.[199]
- *Composting.* This is a controlled biological decomposition of organic material in the presence of air to form a humus-like material.[200]

COMBINED METHODS

- *Tertiary treatment.* This advanced cleaning of wastewater goes beyond the secondary or biological stage, removing nutrients such as phosphorous, nitrogen, and most BOD and suspended solids.[201]

The following are examples of disposal technologies[202]:

- *Landfills.* This technology contains and isolates wastes that are not presently recoverable to ensure present and long-term environmental protection; typically waste is spread in layers and covered to minimize air emissions.[203]
- *Deep-well injection.* This technology deposits raw or treated, filtered, hazardous waste by pumping it into deep wells, containing it in the pores of permeable subsurface rock.
- *Surface impoundments/lagoons.* This technology treats, stores, or disposes of liquid wastes in ponds.[204]
- *Ocean dumping.* This technology places wastes into oceans.
- *Surface water discharge.* This technology places wastes into waterways such as ponds, rivers, or lakes.

Historically, disposal has placed waste directly into environmental media (without prior treatment of contaminants or providing containment controls once contaminants have entered the environment), allowing the disbursement of harmful contaminants and endangering human health and the environment. Recently, however, with the advent of strict controls on harmful wastes, treatment and disposal technologies are ensuring to the greatest extent possible that contaminants are destroyed before release or, if complete destruction is not feasible, are contained in protective units, such as lined landfills, or captured by units such as carbon filters.

MEASUREMENT AND OBSTACLES TO IMPLEMENTATION

MEASUREMENT

Measurement for treatment and disposal centers around consideration of the levels of constituents within the waste or waste stream. As stated above, RCRA (similar to Clean Air Act and Clean Water Act) regulations require that, before a waste is disposed of, it must meet specified levels for each constituent of concern; thus, most measurement occurs during determination of constituent levels in wastes.

In addition, Freeman compares differing practices in measurement of treatment and disposal alternatives. The process of measurement for useful comparison includes estimating releases from the chosen method (termed by Freeman as the "black box") into the environment as a specified amount over a unit of time. Typical regulatory practice for this is shown within the RCRA requirement that treatment achieve a specific destruction removal efficiency.[205]

The amount of wastes being disposed of can also be measured for regulatory purposes. For example, RCRA does not regulate treatment and disposal of hazardous wastes at facilities that generate small amounts of hazardous wastes per month.

IMPLEMENTATION OBSTACLES

The biggest obstacle to using treatment and disposal technologies is the cost of using management practices. The current regulatory framework across all media greatly increases the costs of treating and disposing of waste. Many authors have discussed various comparisons of cost savings if other management practices, such as pollution prevention and recycling, are pursued (see examples used in chapters 5, 6, and 7).

Another obstacle to using treatment technologies is that complete destruction of contaminants is not yet feasible. Technology is moving close to complete destruction for several types of waste (such as plasma-arc units), but current technologies have yet to demonstrate complete destruction for all contaminants in various physical states.

IMPLEMENTATION EXAMPLE

Industry has and will continue to produce some wastes, even with the pursuit of practices that prevent their generation. The example below of wastes that present a considerable danger to human health and the environment demonstrates how their use has been greatly reduced and controlled. The example shows not only the practice of treatment and disposal but the need for continued existence of this management practice.

PCBs are a group of chemicals that, because of their great electrical insulating properties, have been used extensively in manufacturing electrical equipment. PCBs, however, easily enter the human body and have been found to cause adverse reproductive effects, developmental toxicity, and tumor development.[206] In addition, PCBs persist in the environment once released and take several decades to decom-

pose. Because of their harmful potential, treatment and disposal of PCBs have been strictly regulated under both the Toxic Substances Control Act and RCRA.

Treatment of PCBs in concentrations below 50 parts per million (ppm) is not required but they can be disposed of in a landfill with a permit under RCRA. Several options exist for treatment and disposal of PCBs in concentrations above 50 ppm; concentrations greater than 500 ppm are most stringently regulated. PCBs can be treated and disposed of in high-efficiency boilers or incinerators or through other EPA-approved alternative methods of treatment and disposal, such as physical, chemical, and biological treatment; chemical detoxification is the most common.[207]

Chapter 10: Remediation

Serious environmental health problems across the globe have existed for many decades. Several serious problems, such as Love Canal, Bhopal, Chernobyl, and Valley of Drums, however, began attracting widespread media and public attention in the late 1970s and throughout the 1980s.[208] Growing public and government concern and direct action encouraged a great increase in available remediation technologies, which addressed problems stemming from immediate emergency situations to long-term problems from past handling of wastes.

Remediation is commonly defined as a process that renders hazardous substances harmless after they have entered into the environment. Remediation technologies address all media—air, water, and soil—through technologies such as soil-vapor extraction, bioremediation, thermal desorption, soil washing, and abatement.

BACKGROUND

Early remediation activities usually only occurred when contaminating entities were pressured to carry them out by either local government or citizen interest groups. The types of remediation technologies used were usually encapsulation technologies, which only reduced the likelihood of contaminant migration. An example of this is during the early stages of Love Canal, when Hooker Electro-Chemical Company was pressured by the city of Niagara, New York, to cover the waste site to be used to accommodate urban expansion (see more details on Love Canal in this chapter's case study).[209]

As stated above, several serious environmental health problems in the early 1970s exposed the larger problem of managing wastes once they are generated. For many decades, the production of hazardous and toxic wastes was obviously not managed appropriately and threatened our health and the environment. To respond to this issue of "righting the wrongs" of past management mistakes, the U.S. government passed legislation, the Comprehensive Environmental Response, Compensation, and Liability Act, in 1980 to respond to released or threatened releases that might endanger public health, welfare, or the environment.[210]

This regulatory framework for remediation created an increasing demand for remediation technologies, which are expected to be necessary for the next twenty to thirty years.[211] Each remediation scenario presented its own unique parameters and problems, encouraging development of multiple and creative remediation technologies. Until recently, however, perspectives on technologies and processes under remediation have centered around the Comprehensive Environmental Response compensation and Liability Act (CERCLA), also known as Superfund.

DEFINITION OF REMEDIATION

Remediation technologies have generically been defined as "those that render harmful or hazardous substances harmless after they enter the environment." These technologies either remove potential risks or make them more manageable. Remediation addresses all types of environmental concerns—from acute site-specific problems, such as those addressed under the Superfund program, to less acute broader problems, such as ozone layer depletion. In addition, remediation addresses emergency concerns, such as spill cleanup and accidental emission releases. Ideally, restoration technologies should be combined with remediation technologies. The restoration technologies are used to restore ecosystems that have declined naturally or through human interruption. Common restoration technologies include reforestation and creation of wetlands.[212]

As stated above, perspectives on remediation technologies have historically been formed and developed through the regulatory process, which provided the original incentives for developing and manufacturing remediation technologies.

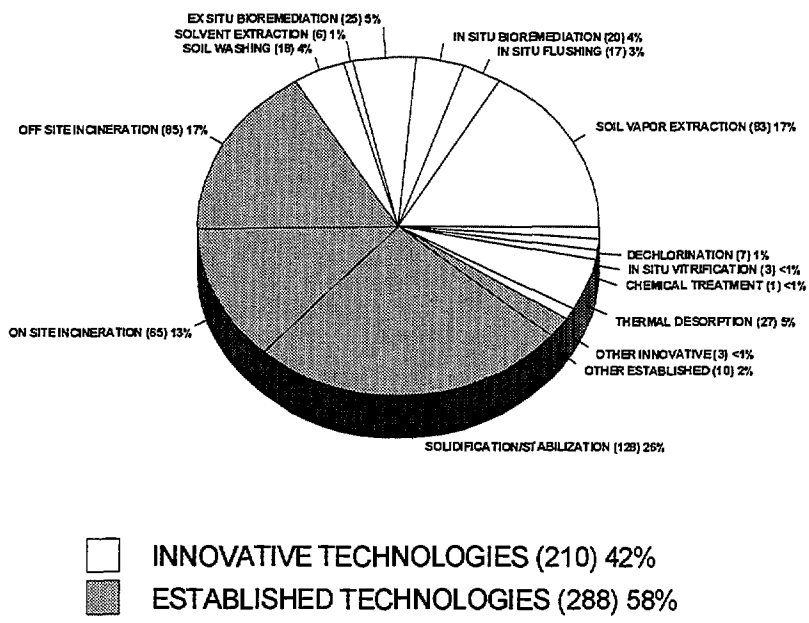
REMEDIATION TECHNOLOGIES

Remediation technologies are constantly being developed for application to varied conditions at different sites and for more cost-efficient operation. Differing remediation technologies are also applied to differing types of media, such as soil, groundwater, and surface water. (Air remediation is commonly employed using prevention strategies on emissions.) The following diagram exhibits the most common types of remediation technologies in decreasing order of use at the national priority hazardous waste sites in the United States.[213]

ESTABLISHED TECHNOLOGIES

The following, either established or innovative, are considered common methods of treatment and stabilization:

FIGURE 10-1. SUMMARY OF ALTERNATIVE TREATMENT TECHNOLOGIES THROUGH FISCAL 1991



Source: Kovalick and Kingscott (1993).

- *On-site/off-site incineration.* This treatment method uses controlled-flame, high temperatures to degrade a material to less harmful substances, such as CO_2, water vapor, SO_2, NO_x, HCl gases, and ash. The most common types of this thermal technology are liquid injection, rotary kiln, and fluidized bed.
- *Solidification/stabilization.* This process uses additives to alter the material to make it nonhazardous or meet RCRA land disposal requirements. Some of the most common forms are cement solidification, silicate-based processes, sorbent materials, thermoplastic techniques, surface encapsulation, and organic polymer processes.[214]

INNOVATIVE TECHNOLOGIES

The following are alternatives to the common or conventional remedies:

- *Soil vapor extraction.* This process physically removes volatile compounds using vapor extraction wells alone or in combination with air injection wells. The air strips the volatile compounds from the soil and carries them to the screened extraction well. Air emissions are controlled mostly by activated carbon.[215]
- *Ex situ/in situ bioremediation.* This process uses microbes to break down organic contaminants into harmless substances. The contaminated medium can be treated in place or excavated and treated.
- *Thermal desorption.* This process uses heat to remove organic contaminants from soil for further treatment.
- *Soil washing.* This process segregates and reduces the volume of wastes by spraying and rinsing with a washing fluid. Contaminated fluid is treated using conventional wastewater treatment technology. The technique is potentially effective in treating organic and inorganic wastes found in soils.

REMEDIATION PROCESS

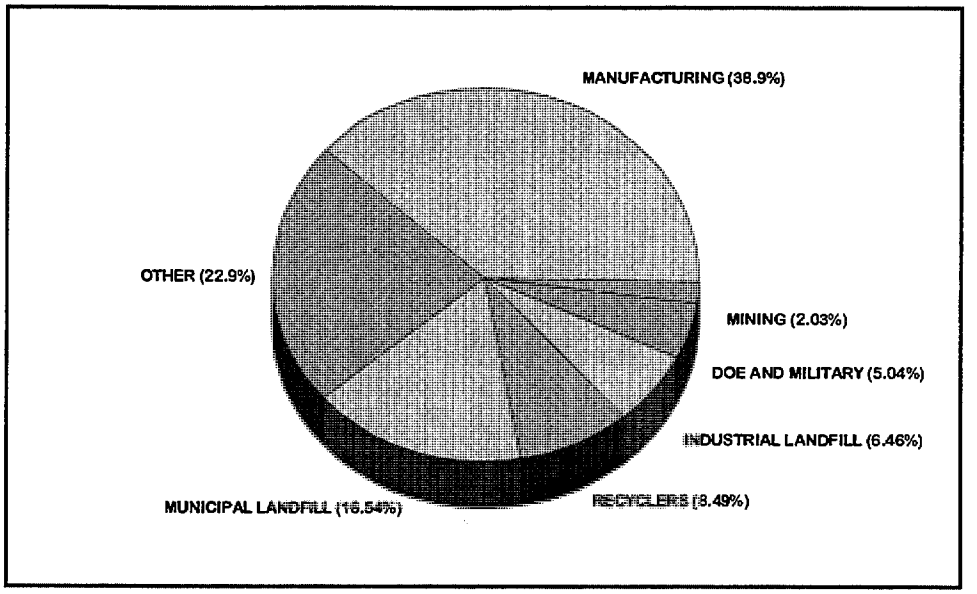
The regulatory perspective looks at remediation as a problem-solving process. The objective of the process is to "control short- and long-term threats to public health and the environment from uncontrolled releases of hazardous substances." This is the EPA Superfund process, which responds to emergencies as well as long-term cleanup activities. Both of these activities are initiated through reports from state and local governments, businesses, the Coast Guard, and citizens.

Most remediation activities have taken place in the United States at abandoned Superfund sites, which usually follow a generic process involving the following stages:

- Report and investigation of site
- Evaluation of immediate or long-term threats of hazardous constituents
- Negotiations with "potentially responsible parties"
- Detailed studies to assess extent of contamination and evaluate effective cleanup technologies
- Selection of cleanup method and public comment
- Design of specific cleanup plan and its implementation.

This process is supported under RCRA, which addresses active facilities managing hazardous waste. "Site remediation incorporates the use of specific technologies such

FIGURE 10-2. INDUSTRIES ASSOCIATED WITH SUPERFUND SITES



as capping, slurry trenching, and groundwater treatment to address specific problems identified in the site-investigation process." Freeman discusses the remedial investigation and feasibility study process and how technologies and alternatives are adapted to address specific site problems.[216]

APPLICATION OF REMEDIATION

Application of remediation, both technology and the process discussed above, typically comes under the RCRA and Superfund regulatory structures. The RCRA corrective action program allows EPA to require cleanup or "corrective action" at hazardous waste management facilities. These facilities can include both manufacturing facilities generating the waste and those that only treat, store, or dispose of wastes. The Superfund program addresses potential harm to human health and the environment through cleanup of abandoned or uncontrolled hazardous waste sites through emergency response or long-term actions. The most significant activities related to typical sites under the Superfund program are shown in the following figure.[217]

Remediation does not always come under the auspices of RCRA or the Superfund program addressing specific sites; nor does it always use the technologies listed above. Variations on remediation and its applications can take place within broad arenas or less acute scenarios, such as the much-talked-about emerging problem of ozone-layer depletion. Although air remediation is difficult to pursue once pollutants have entered the air, preventive steps have already begun to remediate this potentially serious problem through strict global restrictions of carbon monoxide emissions. Under the Montreal Protocol, CFC use was to be reduced by 50 percent by the year 2000. This preventive step is expected to promote natural remediation in the atmosphere, replenishing the ozone hole within fifty years.

In addition, remediation can occur within broad geographical areas encompassing ocean waters and land, as exemplified in the 1989 Exxon Valdez oil spill. Immediate response centered around containing and cleaning up the spill and rescuing wildlife. The remediation technologies initially used included booms and skimmers to capture and remove oil slicks and later hand washing, high-pressure hot-water washing, and fertilizer bioremediation. Restoration in the area has included repairing the original habitats and local wildlife.

Other types of remediation take place under other nonpoint source conditions such as lead, asbestos, and radon abatement within housing stock. For example, the Lead-Based Paint Poisoning Prevention Act requires the Department of Housing and Urban Development to inspect HUD homes for lead-based paint; if the lead levels are above 1.0 milligrams per square centimeter, abatement is required. Abatement or remediation for this contamination usually includes the use of high-pressure sprays to loosen and remove the paint, which is then treated and disposed of as a hazardous waste.

MEASUREMENT AND OBSTACLES TO IMPLEMENTATION

MEASUREMENT

In the United States, many environmental statutes (e.g., RCRA, Superfund, Safe Drinking Water Act, and Clean Water Act) allow EPA to delegate program enforcement authority to the states for cleaning up waste sites to the established cleanup criteria and requirements. These criteria and appropriate requirements are based on some measure of human health and ecological risk to the exposed individuals or ecosystems through various exposure pathways. The issue of acceptable levels of risk has been debated for various contaminants. Superfund has established that a potential cancer risk greater than one in ten thousand and a noncancer health risk greater than a hazard quotient of 1 warrants remediation at a hazardous waste site; thus, the selection of remediation technologies is based on whether the technology can remediate the media (soil, water, and air) to reduce contaminant concentrations that relate to the acceptable levels of risk in the media.

Selection criteria for remediation are based on the following nine Superfund National Contingency Plan criteria:

- Protection of human health and the environment
- Compliance with applicable or relevant and appropriate requirements
- Long-term effectiveness
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Costs
- State acceptance
- Community acceptance.

In addition, remediation cleanup levels, which have been set through the above risk assessment processes, are a way to measure compliance with the requirements for specific contaminant levels in soils and water. Measurement for remediation, however, has historically divided and continues to divide regulators, industry, interest groups, academia, and the public. The issue centers around the question of "how clean is clean?" "Clean" can be defined along a continuum extending from as-is condition to 100 percent restoration to preuse condition. Because this continuum is long, containing many points at which a problem could be considered remediated or "clean," the debate may never be completely resolved.

IMPLEMENTATION OBSTACLES

Many obstacles to remediation exist—from characterization of contamination and selection of remediation technology to application of that technology and the extent of activity to consider remediation complete. Because variables are completely different with each problem that occurs, these questions are always open to debate. For example, an issue under intense debate in the Superfund remediation program is

whether risk-benefit analysis justifies cleanup actions. This analytic methodology is plagued with difficulties in measuring risk and benefits. Measurement challenges for risk include developing methods for measuring risk to populations and ecosystems, whereas the challenge to benefit analysis includes measuring long- and short-term social and economic benefits and assigning monetary values to various benefit categories.

Other obstacles include the factors influential in developing much-needed innovative remedial technologies such as: market demand, technology that creates market demand (e.g., bioremediation), and government regulations.

IMPLEMENTATION EXAMPLE

With the advent of Superfund, many examples exist in which remediation technologies have returned an area of concern to reusable condition. Many of these include direct application of the remedial process and evaluation and application of appropriate technologies. Each remedial project, however, is unique and requires different applications of process and technologies. The following example illustrates one of the most well-known and cited remediation projects in the United States—Love Canal.[218]

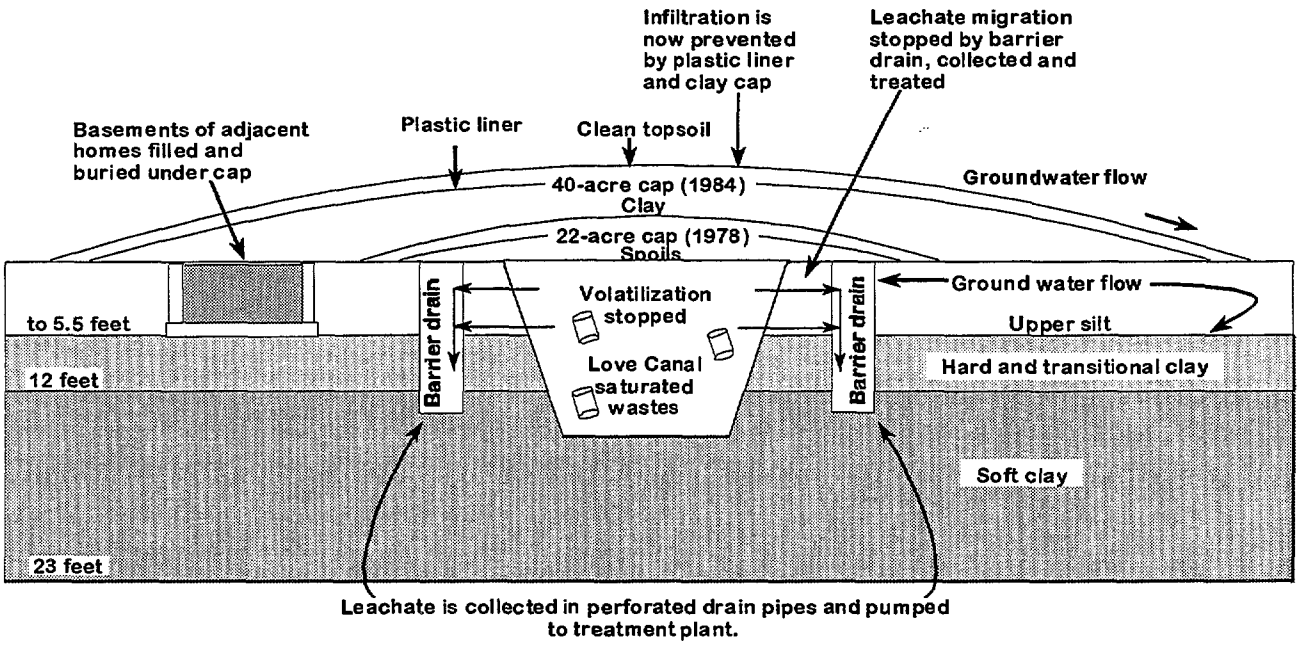
Love Canal dates back to the late 1800s when entrepreneur William Love dug a canal to connect the upper and lower Niagara river to produce cheap hydroelectric power for the area. The canal was eventually abandoned when the area began using other sources of electrical power, until it was purchased by Hooker Electro-Chemical Company. Between 1942 and 1953, the company dumped 21,800 tons of toxic chemicals on the site.

To accommodate a rapidly expanding metropolitan area, Hooker covered the waste disposal site with a protective clay cover and sold the property to the school district. The development of homes and schools above the site only disrupted the cap in a minor way but an expressway later built across the area greatly disrupted the site. The dynamics of nature and expressway construction created a bathtub effect within the canal. Rainwater built up and overflowed into basements and water and sewer lines of local residents.

Emergency measures were taken, including evacuating all local residents, destroying the home closest to the canal, and, in 1978, placing a 22-acre cap over the canal area. Because of serious pressure from local residents, however, further remediation measures were pursued. To date, these include:

- Decontaminating local storm sewers
- Dredging 3,000 feet of creek bed contaminated from storm water runoff
- Returning contaminated soils from the school and three other hotspots to the landfill
- Installing containment measures surrounding the landfill, such as those seen in figure 10-3.

These remediation measures were apparently used because other measures beyond containment were not economically or technically practicable. The preferred measures for removing contaminants and incineration were nearly impossible to implement because the more than 200 contaminants present in the "soup" made the destruction efficiency required by Superfund difficult to achieve.



Not to scale.
Source: Adapted from New York Department of Environmental Conservation. 1992. *Love Canal Inactive Hazardous Waste Site: A Remedial Chronology.* Buffalo, N.Y.

FIGURE 10-3. REMEDIATION TECHNOLOGIES USED AT LOVE CANAL

The lack of ability to fully remediate the Love Canal site means the site will require constant maintenance over the years and replacement of current containment technologies. Restoration, therefore, must be left incomplete for the time being. The Love Canal Area Revitalization Agency, however, has been renovating homes north and west of the canal and selling them to the public for 10–15 percent below market value. They are hoping as well that environmental companies will be drawn to the area technology park. Health studies at the end of the 1980s indicate that the area is safe for residency, however, the revitalization agency's principal hurdle will be to overcome the lasting stigma of the area.

Chapter 11: A Synthesis of Concepts

This paper has focused on the nine environmental management elements introduced by US-AEP's environmental management ladder concept. This chapter synthesizes these nine elements by providing a brief overview of the elements and discussing the interrelationships among them. The chapter then introduces an alternative approach to the ladder concept, integrating the relationships among the concepts, and shows a preferred progression of practices for industrial development.

For each of the nine environmental management practices, the preceding chapters explored multiple perspectives on each concept, developed a clear definition, identified common themes for each concept, and brought out issues related to measurement and implementation. Figure 11-1 summarizes the important components of each environmental management practice and its application, allowing for easy comparison among the elements:

FIGURE 11-1. SUMMARY OF ENVIRONMENTAL MANAGEMENT PRACTICES

TOTAL QUALITY MANAGEMENT

Definition	An organizationwide strategy for long-term success by exceeding the expectations of the customer and continually improving the organization's culture, products, processes, and services.
Theme	• Committed/involved management • Focus on customer satisfaction • People involvement/teaming/empowerment • Continuous improvement initiative • Measurement in all areas
Related concepts	• Management systems • ISO 9000
Application example	Motorola has put in place a program that incorporates TQM concepts. The company has called for a tenfold improvement in quality in the next five years through TQM concepts to improve quality, provide product innovation, and perform strategic long-range planning.

(continued)

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FIGURE 11-1. SUMMARY OF ENVIRONMENTAL MANAGEMENT PRACTICES (CONTINUED)

TQEM

Definition	Approach using the concepts of TQM to improve the environmental sustainability and quality of processes and products continuously through the use of pollution prevention, sustainable development, and environmental responsibility to move beyond regulatory compliance.
Themes	• Management approach • Customer satisfaction • Pollution as defects • Beyond compliance • Continuous improvement • Environmentally responsible workplace • Environmental communication
Related concepts	• Environmental management systems • ISO 14000
Application example	Xerox developed and put in place an Environmental Leadership Steering Committee, which is reviewing and guiding practices within the company for greater environmental accountability. Concepts used include design for environment, recycling of waste, teamwork, communication, and measurement of progress.

CLEAN TECHNOLOGY

Definition	The design and production of environmentally friendly products, processes, and packages that conserve energy and resources, eliminate use of toxic materials in products, and reduce the amount and toxicity of waste (includes clean products, processes, and packages).
Themes	• Conserve energy and raw materials used • Eliminate toxic substances • Reduce amount of waste and pollutants from processes and products • Pursue above goals by substituting input materials, process redesign, and product reformulation
Related Concepts	• Cleaner production • Industrial ecology • Design for environment • Sustainable manufacturing
Application example	Xerox replaced chemical solvents with natural, biodegradable cleaners and water in machine-refurbishing operations. Solvent air emissions at one facility were reduced by more than 90 percent from 1982 to 1990 simply by substituting citrus-based cleaner for solvents.

POLLUTION PREVENTION

Definition	Reduction or elimination of the production of pollutants through activities at the design stage of a product or through process modification.
Themes	• Activity using product reformulation, process modification, equipment redesign, and resource recovery

(continued)

FIGURE 11-1. SUMMARY OF ENVIRONMENTAL MANAGEMENT PRACTICES (CONTINUED)

	• Upstream effort • Multimedia effort • Comprehensive approach • Proactive approach
Related concept	• Source reduction
Application example	Xerox replaced chemical solvents with natural, biodegradable cleaners and water in machine-refurbishing operations. Air emissions from solvents at one facility were reduced by more than 90 percent from 1982 to 1990 simply by substituting citrus-based cleaner for solvents.

WASTE MINIMIZATION

Definition	Practice used to minimize the amount of waste produced from a process through changes to the process or the product itself or through reuse of materials in a production process.
Themes	• Avoid or eliminate wastes through process or product change or through reuse and regeneration • Reuse materials directly or indirectly in a process through in-process reuse, on-site reclamation and reuse, or off-site reclamation and reuse
Related concept	• Waste reduction
Application example	Polaroid developed the Toxic Use and Waste Reduction Program, which implements several types of technology improvement initiatives, chemical substitution, and greater recycling of wastes.

RECYCLING

Definition	Reuse of a material directly or indirectly in manufacturing products, both on-site and off-site and in-process and out-of-process.
Themes	• Avoid or eliminate material disposal through reuse and regeneration • Reuse materials directly or indirectly in a process through in-process reuse, on-site reclamation and reuse, or off-site reclamation and reuse
Related concepts	• Reuse • Reclamation • Regeneration
Application example	Xerox developed the Asset Recycling Management program, which collects used cartridges for refurbishing and recycling of parts.

POLLUTION CONTROL

Definition	Approach prohibiting the release of contaminant into the environment by converting contaminants into less harmful substances.

(continued)

FIGURE 11-1. SUMMARY OF ENVIRONMENTAL MANAGEMENT PRACTICES (CONTINUED)

Themes	• Downstream effort often addressing a single me dium or contaminant • Reactive approach, often known as end-of-pipe • Technologies that extract and collect contaminants before release into the environment • Most effective for large point-source generators
Related concept	• End-of-pipe controls
Application example	Fossil fuel-burning facilities emit significant amounts of sulfur dioxide. Stack scrubbers are installed to remove most of the sulfur dioxide before it is released into the environment.

TREATMENT AND DISPOSAL

Definition	Treatment is a management practice that changes the physical or biological composition of waste to reduce its potential hazards; disposal is placement of waste into a unit that serves as the final disposition of the waste.
Themes	• Downstream effort often addressing a single me dium or contaminant • Reactive approach, often known as end-of-pipe • Technologies that collect and treat wastes and pre-vent residual wastes from entering the environment after final disposition • Most effective for large point-source generators
Related concept	• End-of-pipe controls
Application example	Electrical equipment manufacturing facilities have historically generated large amounts of waste PCBs. These PCBs have strict treatment requirements involving tech nologies such as incineration. They must then be disposed of in units designed to prevent their escape into the environment.

REMEDIATION

Definition	The process by which contaminants posing harm to human health and the environment are cleaned up, restor ing media to usable condition.
Themes	• Reaction to a historical release of contaminants into environmental media, such as air, water, and soil, or emergency spill situation • Cleanup process to protect human health and the environment • Process to restore media to preuse condition
Related concepts	• Restoration • Cleanup • Corrective action
Application example	Love Canal, an area of significant contamination from decades of waste dumping, recently underwent remediation to prevent further harm to human health and the environment and return the area to usable condition. Technologies used include extraction of contaminants from surrounding neighborhoods and containing the hotspots using liners and leachate collection systems.

INTERRELATIONSHIPS OF ENVIRONMENTAL MANAGEMENT PRACTICES

This paper was originally based on the premise that each of these environmental management concepts was linked in a hierarchical order, conceived of as a ladder. As the definition of each concept unfolded, however, the need to view these concepts in two ways emerged. The first is to understand the overlaps and interrelationships among the different environmental management practices. The second way is to understand the elements of the ladder as a preferred progression of environmental management practices for industrial development. Figure 11-2 below depicts our view of the interrelationships among the defined concepts. The boxes group similar concepts as they relate to their differing focus; the arrows indicate the practices that are used to implement each other, and their weight indicates the relative strength of the relationship.

ORGANIZATIONAL/INSTITUTIONAL PRACTICES

The figure breaks the nine individual concepts into two groups. The first grouping, organizational/institutional practices, includes TQM/TQEM and clean technology These concepts are distinguishable from the other concepts in that they focus on activities that promote changes on a large scale and not specifically on a particular waste. These activities span a company's management and decision-making processes based on TQM/TQEM to changes in its operations and production, such as product reengineering and "designs for environment" based on clean technology. In addition, these concepts differ in their emphasis on corporate cultural changes and their effects not only on waste elimination but energy and resource conservation.

TQM AND TQEM

The first relationship within organizational/institutional practices is the significant overlap between TQM and TQEM. As discussed in chapter 3, TQEM is the application of TQM ideas and techniques to environmental management. TQEM evolved from the realization that corporate environmental management could benefit from quality management and vice versa.

TQEM AND CLEAN TECHNOLOGY

The second important relationship is the interplay between TQEM and clean technology. From an environmental perspective, TQEM and clean technology are mutually reinforcing. TQEM concerns broad management culture and practice issues,

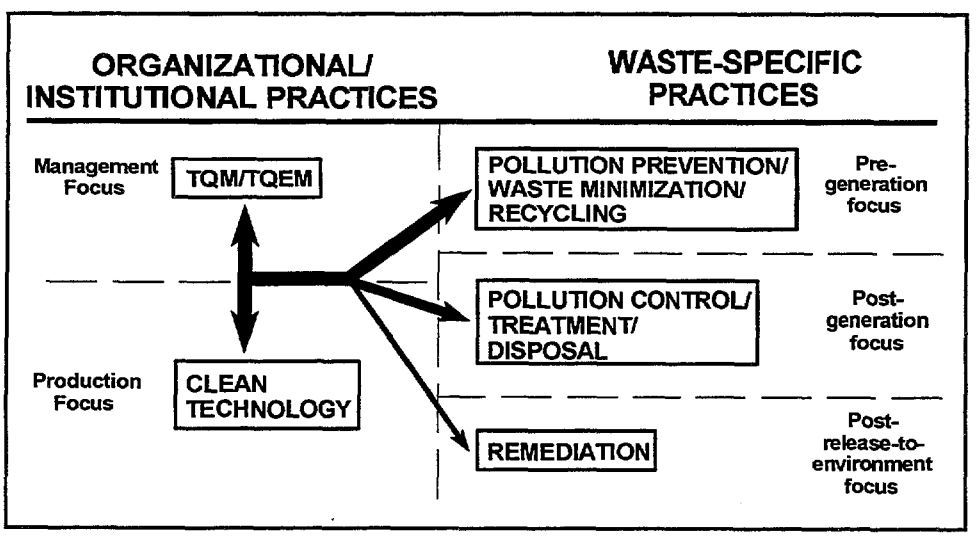

FIGURE 11-2. OVERVIEW OF INTERRELATIONSHIPS AMONG ENVIRONMENTAL MANAGEMENT PRACTICES

whereas clean technology is more directly related to investment, operation, and maintenance issues. TQEM practices reinforce the environment-friendly features of clean technology and minimize adverse environmental impact. For example, good environmental management practices can play an important role in key industrial activities in energy use, wastewater discharge, management of industrial chemicals, and management of solid waste.

ORGANIZATIONAL/ INSTITUTIONAL PRACTICES AND WASTE-SPECIFIC PRACTICES

The arrows in figure 11-2 show another relationship involving TQEM and clean technology. Both programs use the concepts of waste-specific activities in the second column. For example, as part of its TQEM system, an existing large manufacturer of chemicals may implement site remediation of its contaminated property. Furthermore, that same industry may implement, as part of its overall cleaner production initiatives, in-process recycling to reduce the amount of a specific waste produced and the amount of virgin materials needed.

As already mentioned, the weight of the arrows indicates the strength of the relationship between TQEM/clean technology and each of the three groupings of waste-specific activities. The thickest arrow to the pregeneration focus grouping indicates that TQEM and clean technology emphasize the use of these practices. As discussed in chapter 3, clean technology shifts the emphasis from end-of-pipe management practices to reduction and prevention of wastes and use of toxic materials. Although both TQEM and clean technology focus on waste before it is generated, pollution controls, treatment, disposal, and remediation options are needed under certain circumstances.

WASTE-SPECIFIC PRACTICES

The second grouping of environmental management practices includes waste-specific practices, encompassing pollution prevention, waste minimization, recycling, pollution control, treatment, disposal, and remediation. These six practices clearly differ from the other concepts by concentrating on specific waste streams or production processes, as opposed to focusing more broadly on management or production processes. These environmental management practices are divided into three groups based on whether they focus on waste before or after it is generated, or after it has entered the environment.

POLLUTION PREVENTION, WASTE MINIMIZATION, AND RECYCLING

The first group includes pollution prevention, waste minimization, and recycling, all of which focus on activities before a waste is generated. They have much more in common, however. First, pollution prevention and waste minimization are nearly identical. As discussed in chapters 5 and 6, both pollution prevention and waste minimization seek to reduce the amount of waste from a production process. Both can be pursued through product reformulation, process modification, equipment redesign, and resource recovery. Pollution prevention differs from waste minimization chiefly in that it focuses more on the beginning of the process through process engineering changes, whereas waste minimization focuses more on in-process and end-of-process changes through activities such as recycling.

How recycling fits with pollution prevention and waste minimization has been extensively discussed in both government and industry programs. For example, several U.S. Environmental Protection Agency (EPA) memos and its statement of principles have attempted to clarify the role of recycling in pollution prevention. A recent paper by John Cross, deputy director of EPA's Pollution Prevention Division, states that of the three common types of recycling—in-process or closed loop, out-of-pro-

cess, and off-site recycling—only the first is considered equivalent to pollution prevention. Some in-process recycling, for example, energy recovery through incineration, is excluded from the domain of pollution prevention.[219] Industry has as well clarified the role of recycling in pollution prevention and waste minimization programs. For example, Polaroid (see figure 6-1) has developed a hierarchy of preferred types of recycling, from on-site controlled recycling to off-site vendor recycling.

POLLUTION CONTROL, TREATMENT, AND DISPOSAL

Pollution control, treatment, and disposal have been grouped together as practices that focus on managing wastes after generation. As discussed in chapters 8 and 9, pollution control and treatment perform similar functions and are nearly identical in practice. Both practices perform an end-of-pipe function to prevent harmful contaminants from entering environmental media. In most cases, both of these practices are performed to meet standards set by regulations.

Disposal differs significantly from pollution control and treatment in that it manages a waste after it has come "out of the pipe." Depending on regulatory controls and the characteristics of the waste, disposal can place waste directly into the environment or into units that prevent the waste from entering the environment. Disposal, however, is linked to pollution control and treatment not only because it focuses on waste after its generation but also because the other two practices inevitably produce their own wastes that require disposal.

REMEDIATION

The third group, defined by its focus on waste after it enters the environment, only includes the environmental management activity of remediation. Remediation is unique in that it is only employed once a waste or contaminant enters the environment and poses a threat to human health and the environment. Many argue that, because disposal often places waste directly into environmental media, it should be considered similar to remediation. However dependent on disposal practices and/or the characteristics of a waste remediation is, disposal does not always require the follow-up that characterizes remediation; thus, the goal of remediation is to solve problems that pose threats to human health and the environment after they have been created.

Figure 11-2 and the discussion above have provided an overview of the interrelationships among the various environmental management practices that have been discussed individually within this paper. Emerging concepts such as "industrial ecology" and "sustainable manufacturing," constantly change the interrelationships among these practices. In addition, it is virtually impossible to illustrate all of the potential overlaps and relationships among concepts that are applied in widely varying circumstances and for widely varying purposes. This discussion, however, is meant to provide the initial framework and understanding for the application of environmental management practices toward a "clean revolution."

TOWARD AN INTEGRATED APPROACH: A SUGGESTED HIERARCHY OF CHOICES

This chapter describes the industrial environmental management concepts from a slightly different perspective, exploring whether, in addition to the interlinkages among these concepts, any hierarchical relationship exists among them. Our suggested approach, presented below, is only indicative and not a prescribed strategy for environmental management. The suitability of this or any hierarchy for organizations or countries participating in US-AEP programs depends on a number of objective conditions, including regulatory framework, the level of industrialization, as

well as the role, sphere of influence, and instruments available to the decision maker. We do not address these issues as they relate to industrial policy in this study and expect that the questions that we raise in this chapter will be fully debated in a separate study.

"A hierarchy means an ordered list of preferences."[220] The idea of a hierarchy in environmental management options gained ground in the 1980s. Pollution prevention—considered to be better for the environment than pollution control, both in government environmental policy circles, and corporate environmental management practices—gained ascendancy during this time. This preference for pollution prevention and its superiority over recycling, treatment, and disposal was formally recognized in the Pollution Prevention Act of 1990, which led to EPA's "pollution prevention" hierarchy (see chapter 5).

The pollution prevention hierarchy primarily focuses on environmental management decisions at the level of the individual plant or a single manufacturing process. As discussed above, however, many now recognize that environmental management policy needs to look beyond the single manufacturing process or plant and consider the environmental management scorecard of a corporation's entire operations. In addition, the role of the government in industrial planning and policy calls for a framework that allows for a perspective beyond company-by-company actions.[221] Similarly, industrial leaders, regulatory agencies, and technological visionaries are also searching for a goal broader than pollution prevention. In the United States, EPA recognizes the need for going beyond a hierarchical structure that has pollution prevention at the apex in its blueprint[222] and calls for an evaluation of the "total environmental impacts of products over their entire life cycle."

We identified two concepts—TQEM and clean technology—n the environmental management ladder that consider environmental issues beyond simply waste management. These two environmental management options consider issues of sustainable development from the perspective of decision makers in the corporation and, frequently, beyond the individual corporation. Issues that we identified as going beyond the scope of waste management or pollution prevention are energy efficiency, human and ecological health, resource conservation, and disposal of postconsumer waste. The concepts of TQM and TQEM, however, are part of the broader business management strategies of environmental management systems (EMS); therefore, although we have only pursued the concepts of TQM and TQEM as management tools, other EMS may be more suitable to specific organizations or situations; TQM and TQEM should not be touted as the ultimate goal in environmental management.

Our suggested strategy for a hierarchical preference for environmental practices, shown in figure 11-3, builds on US-AEP's "ladder" concept. We have, however, grouped several of the individually discussed environmental management practices together based on this chapter's earlier discussion of the interrelationships among them. Although many may argue that, within each grouping, one activity may protect human health and the environment more than another, we argue that the most effective practice is based more on site- and waste-specific conditions.

A great effort has been made to get away from poor management of wastes requiring the cleanup of contaminated media after the wastes have entered the environment, which, including human health, they might otherwise adversely affect. This effort has also gone beyond the reactive practices of end-of-pipe management to more proactive strategies to prevent waste from being generated.

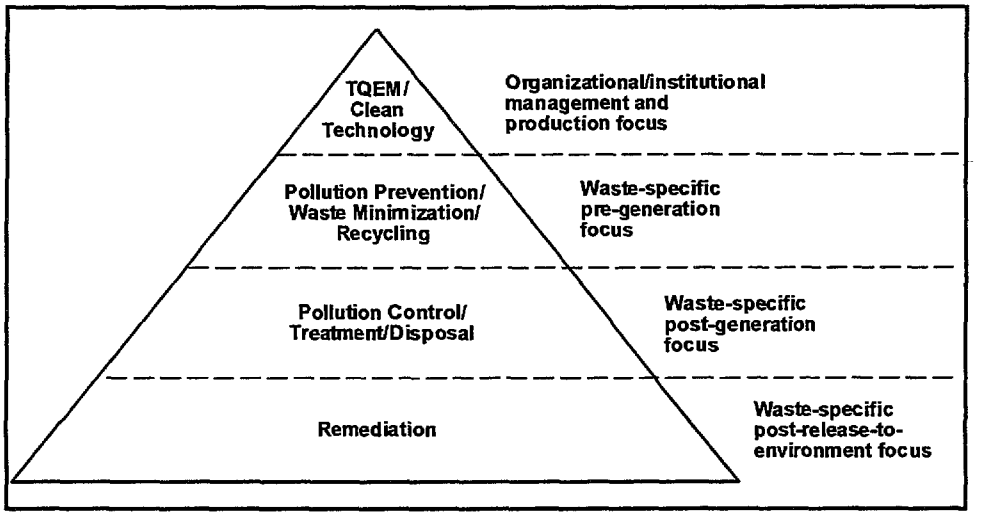

FIGURE 11-3. A SUGGESTED HIERARCHY OF ENVIRONMENTAL MANAGEMENT PRACTICES

Some hierarchies of environmental practices have ended with pollution prevention, but a broader attack on environmental management is necessary—one that pushes for corporate culture change, product life-cycle assessment, and design for environment. These concepts move beyond pollution prevention (although this is the best practice among waste-specific activities) to instituting *(a)* organizationwide practices that focus on broad management and operational change in corporate decisions and *(b)* national policy for economywide decisions. At the top of the hierarchy, therefore, are TQEM and clean technology, which both emphasize efficient use of energy, conservation and long-term sustainability of the ecosystem, and the environmental impact of products during their entire life cycles (that is, from "cradle to grave"), from mining and manufacturing to use, reuse, and disposal.

How does an organization using this hierarchy make decisions that are different from a hierarchy that stops at pollution prevention? Consider the case of a utility company investing in a new thermal power plant to generate electricity. Suppose that the plant can use high sulfur coal from a nearby mine, low sulfur coal brought in from another region of the country, or imported natural gas. It also has a number of alternatives to reducing emissions of SO_2 in particular, high stacks, a scrubber, and a new cutting-edge abatement technology. Assuming that all the options are financially viable and cost-effective, a clean technology strategy would require the company to incorporate environmental impacts, particularly resource conservation and energy use, in its decision matrix. Relevant cleaner technology concerns are the pollution problem at the mine's mouth, pollution during transport of coal, SO_2 and NO_x emissions, storage of coal, and solid waste disposal problems, among other concerns.

A danger exists, however, that as the framework of the hierarchy widens, simple decisions on environmental management may get bogged down in endless rounds of "sustainability checks" to cover various environmental impacts. To avoid this gridlock, system boundaries need to be well defined and would generally include the following:

The main production sequence (i.e., extraction of raw materials up to and including final product disposal)

- Transport operations
- Production and use of fuels
- Generation of energy (i.e., electricity and heat, including fuel production)

- Disposal of all process wastes
- Manufacture of transport packaging.

RESTRICTIONS ON USE OF THE HIERARCHY

The hierarchy may not apply to all situations. This is recognized even by those who advocated the earlier pollution prevention hierarchy. Furthermore, the hierarchy is based on the assumption that a cleaner option is also the less expensive option. If this assumption is not valid, complex trade-offs may arise. The literature on "full cost pricing" addresses these issues, which are beyond the scope of this paper.

Choices among differing environmental management practices raise some additional relevant issues. An investor starting a new plant has more choices than an owner of an existing plant; an existing paper and pulp mill may not be able to switch to a clean technology as quickly as a new plant. Market forces also play an important role. If the cost of production is higher for the "green" paper, its marketability may be limited (unless customers demand "green" paper). Greener products often command a premium in the United States and other countries; however, in a country that does not have a strong environmental grassroots/government support, the higher cost may pose an insurmountable problem.

Perverse policy incentives, tax codes that reward wasteful practices, and command-and-control regulatory rules may lead to corporate behavior that conflicts with the hierarchy. Examples include artificially low prices for public water, mineral, and energy resources, and subsidies for wasteful overproduction in agriculture. In contrast, various incentives tip the scale to the other side. Because oftentimes the technology that is more benign to the environment is also more expensive, tax laws, market incentives (i.e., premium for "green" products, consumer support, and shareholder support), and stricter liability laws are normally needed to create positive forces for the cleaner option.

CONCLUSION

This paper brings together current and developing environmental management practices to define clearly the scope of each concept, using current literature for background, varied perspectives, and the measurement issues surrounding each one; thus, by developing clear definitions, we have sought to understand possible strategies to achieving a "clean revolution" better. Each concept is in some way linked to other environmental concepts, and emerging management practices are constantly changing the nature of these relationships. We are not, therefore, suggesting that our presentation of the relationships among the concepts is carved in stone. Instead, we hope it will spark a dialogue among policymakers, industry, academia, and the public on strategies for moving toward the ultimate goal of a sustainable environment through a "clean revolution."

This chapter also briefly discusses the desired movement to the top of the hierarchical pyramid, a flexible conceptual structure that only provides a rule of thumb. In addition, the hierarchy does not create an either-or test in which a specific clean technology or source reduction plan is the only acceptable strategy for environmental protection. Rather, it is a framework for continuous improvement in strategies to environmental protection.

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Endnotes

1 V. Daniel Hunt (1992), pp. 127–31.
2 Weissman and Sekutowski (1994), p. 275.
3 Ahearn, Fatkin, and Schwalm (1991), p. 257.
4 Azar (1993), p. 15.
5 Freeman (1989), p. 4.16.
6 Hoffman (1995), p. 4.
7 Cross (1995), p. 6.
8 V. Daniel Hunt (1992), pp. 127–31.
9 Weissman and Sekutowski (1994), p. 275.
10 Ahearn, Fatkin, and Schwalm (1991), p. 257.
11 Azar (1993), p. 15.
12 Freeman (1989), p. 4.16.
13 Hoffman (1995), p. 4.
14 Schmidt and Finnigan (1993), inside cover and p. 21.
15 The link between TQM and environmental management is discussed in greater detail in the following chapter.
16 Schmidt and Finnigan (1993), p. 31.
17 U.S. Navy psychologist Nancy Warren is credited with first suggesting the name Total Quality Management as the label for this new strategy for organizing and managing (Schmidt and Finnigan [1993], p. 31).
18 U.S. General Accounting Office (1991), p. 2.
19 Doraiswamy (N.d.).
20 Bennett, Freierman, and George (1993), p. 32.
21 The Federal Quality Institute was established in 1988 to introduce senior officials in the federal government to TQM and to serve as the primary source of information, training, and consulting services for federal agencies.
22 Hunt, D. (1992), p. 194.
23 Schmidt and Finnigan (1993), p. 7.
24 Hunt, D. (1992), p. 139.
25 Hunt, D. (1992), p. 143.
26 Shetty (1994), p. 47.
27 Schmidt and Finnigan (1993), pp. 17–18.
28 This example is drawn from information from V. D. Hunt (1992), pp. 127–31.
29 TQEM is also known as Total Environmental Quality Management (TEQM), Sustainable Quality Management, and Quality Environmental Management (QEM). See James (1994), pp. 5–6.
30 Bennett, Freierman, and George (1993), p. 21.
31 See Willig (1994) and Fischer and Schot (1993). ISO 14000 is briefly discussed in the appendix of this chapter.
32 Monty (1991), p. 3; Lent and Wells (1994), p. 9.
33 Luken (1990), pp. 8–21.
34 Lent and Wells (1994), p. 9.
35 Monty (1991).
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119 Ember (1991), p. 7.
120 Browner (1993), p.7.
121 Palmer and Simpson (1993), p. 128.
122 This office was renamed the Office of Pollution Prevention, Pesticides, and Toxic Substances.
123 The environmental hierarchy is discussed in greater detail in chapter 11.
124 TRI as amended by the PPA now requires 28,000 industrial facilities to report publicly the amounts of approximately 320 toxic chemicals generated as waste or released to the environment (Browner [1993], p. 3).
125 Joseph T. Ling, vice president for environmental affairs at 3M, is sometimes called the father of pollution prevention (Ember [1991], p. 11).
126 TQEM is discussed fully in chapter 3.
127 EPA (1990).
128 Lent and Wells (1994), p. 12.
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130 Henry (1992). The view of pollution prevention as more than source reduction is incorporated in Executive Order 12856 on Pollution Prevention and the Right-to-Know in Government.
131 Hirschhorn and Oldenburg (1991), pp. 37–53.
132 Becker and Ashford (1995), p. 220A.
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134 Becker and Ashford (1995), p. 222A.
135 Scrubbers also generate sludge, which is landfilled or recycled.
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137 Ahearn, Fatkin, and Schwalm (1991).
138 See editorial in EPA Journal, July/September, 1993.
139 Hunt and Auster (1990), p. 7.
140 Cross (1995), p. 3.
141 Byers (1991); Pfahl (1994).
142 EPA (1994c), p. 2.
143 Weissman and Sekutowski (1994), p. 275.
144 Ferraro (1994).
145 Bhushan and MacKenzie (1994), pp. 89–90.
146 Bresnan (1994).
147 Bennett, Freierman, and George (1993), pp. 156–57.
148 Neidert (1993), p. 41.
149 Vajda (1992), p. 36.
150 OTA (1986), pp. 8–9.
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159 Greiner (1992), pp. 4–5.
160 Huang and Fan (1993), p. 117.
161 Information for above techniques taken from Freeman (1989), pp. 5.5–5.16.
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163 Ahlert, pp.13–16.
164 Ahearn, Fatkin, and Schwalm (1991), p. 262.
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167 EPA (1994b), p. 4.
168 Hirschhorn and Oldenburg (1991), p. 46.
169 EPA (1989), p. 8.
170 EPA (1994), p. 4.
171 Helfand (1992), pp. 6–7.
172 Helfand (1992), pp. 44–45.
173 Federal Register (1985), p. 51264.
174 Freeman 1989, pp. 5.13–5.15.
175 EPA (1994), p. 31.
176 Allenby and Richards (1994), p. 165.
177 Graedel and others (1995), p. 260.
178 Hirschhorn and Oldenburg (1991), p. 45.
179 Freeman (1989), p. 5.24.
180 Hirschhorn and Oldenburg (1991), p. 48.
181 Federal Register (1995), p. 21371.
182 Hirschhorn and Oldenburg (1991), pp. 48–49.
183 Information for postconsumer recycling and design for recycling taken from Azar (1993), pp. 15–16.
184 The meaning of the term pollution control has evolved since the early days of environmental management. Whereas in the past it included all efforts to reduce or eliminate pollution, current usage focuses only on curtailment of the release of pollutants into the environment.
185 See also chapter 5 of this paper for a discussion of the prevention versus control debate.
186 Hunt and Schecter (1989), p. 5.3.
187 Hirschhorn and Oldenburg (1991), p. 38.
188 Powers (1995b), p. 36.
189 Information in this section is drawn from Soast (1995), pp. 36–38.
190 Freeman (1989), p. 8.175.
191 RCRA §260.10.

192 RCRA §260.10.
193 EPA (1994b), pp. 40, 12–13.
194 Freeman (1989), p. 14.3.
195 Information on physical and chemical treatment drawn from Freeman (1989), pp. 7.21–7.85.
196 Information for above three thermal processes drawn from EPA (1994c), pp. 17, 23, 35.
197 Freeman (1989), p. 8.57.
198 EPA (1994), p. 2.
199 Freeman 1989, p. 9.19.
200 EPA (1994), p. 9.
201 EPA (1994), p. 39.
202 Incineration or thermal processes can be included as a type of disposal process, if nearly complete destruction of contaminants occurs; in addition, the act of allowing emissions to escape into the air is considered disposal.
203 Freeman (1989), p. 10.3.
204 Information for deep well injection and surface impoundments/ lagoons drawn from EPA (1994c), p. 39.
205 Freeman (1989), pp. 14.4, 14.9.
206 Freeman (1989), p. 4.13.
207 Freeman (1989), p. 4.18.
208 Kovalick and Kingscott (1993), p. 10.
209 Hoffman (1995), p. 6.
210 Hoffman (1995), p. 10.
211 Hoffman (1995), p. 10.
212 Office of Science and Technology, p. 43.
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215 EPA (1991).
216 Freeman 1989, p. 12.51.
217 EPA (1990).
218 Following information on Love Canal drawn from Hoffman (1995), pp. 6, 7, 9, 25.
219 Cross (1995), p. 6.
220 Hirchhorn and Oldenburg (1991), p. 39.
221 Personal communication from Burt Hamner, ASEAN Environmental Improvement Project.
222 "Blueprint for National Pollution Prevention Strategy" (1991).