Opportunities for Innovation: Pollution Prevention

Edited by

David E. Edgerly
National Institute of Standards and Technology
Gaithersburg, MD 20899

Prepared for

U.S. Department of Commerce
National Institute of Standards and Technology
Gaithersburg, MD 20899

Grant 5OSBNB3C7626

August 1994
CONTENTS

PAGE

Preface..................................................
   Steven T. Ostheim, Pittsburgh, PA

The Challenges & Opportunities for Pollution Prevention...
   Robert B. Pojasek, Winchester, MA

Pollution Prevention in the Chemical Industry............
   Thomas W. Zosel, St. Paul, MN

Pollution Prevention in the Electronic and Office Equipment Industry
   Patricia A. Calkins, Jack C. Azar, Webster, NY

Pollution Prevention in the Metals Coating Industry.....
   Marvin M. Floer, Auburn Hills, MI

Pollution Prevention in the Metal Degreasing Industry...
   Stephen Evanoff, Ft. Worth, TX

Pollution Prevention in the Metal Finishing Industry.....
   Kevin P. Vidmar, East Greenwich, RI

Pollution Prevention in the Pulp and Paper Industry.....
   David H. Critchfield, Jay, ME

Pollution Prevention in the Printing Industry............
   C. Nelson Ho, Pittsburgh, PA

Pollution Prevention in the Textile Industry............
   Brent Smith, Raleigh, NC
PREFACE

The objective of NET's Opportunities for Innovative (OFI) is to encourage the industrial competitiveness of small- to medium-sized businesses. U.S. businesses, small as well as large, face continuing competitive and financial challenges, including the growing cost to comply with increasing environmental regulations, including the costs associated with the generation and disposal of wastes. Pollution prevention (P2), reducing pollution at the source, is a sound way for businesses to reduce their environmental compliance costs, while simultaneously helping the environment and increasing their production efficiencies (by lowering their waste generation rates and inefficient use of energy resources).

The objective in preparing this monograph was to identify technological opportunities within a number of selected industries and/or manufacturing/finishing processes, to reduce pollution. These industries/processes were selected as representative of and applicable to the broad range of U.S. manufacturing businesses. These include: metals coating (i.e., painting) which is widely done in a number of major industries, including the automotive industry; metals degreasing; recyclability of office equipment; chemical manufacturing; printing; textiles dye and dyeing; and the pulp and paper industry. Solutions developed for these industries should be broadly applicable across a number of industrial sectors. Additionally, the promulgation of new regulations, requiring companies to change their historical manufacturing and waste generating/disposal practices, will continue to create technological needs and opportunities for savvy businesses to develop solutions.

To identify these technology opportunities and solutions, experts within these industries were chosen to author various chapters. They were asked to identify problems and needs, and possible areas of solutions, if possible. We believe the authors have been successful in identifying a number of technology development and/or process modification needs which could represent collaborative opportunities between large and smaller industry and solution providers.

In completing this monograph, I am indebted to Paula Comella and Mary Rose Glaser for their technical editing expertise, and especially grateful to Audra Ometz, for the many hours she spent typing the draft and final edited chapters.

Finally, in addition to the authors and reviewers, Jarda Ulbrecht from the National Institute of Standards and Technology played a key role in the preparation of this Monograph. This Monograph is a testament to his vision for the OFI program, and for recognizing the integral role of environmental issues in the competitiveness of U.S. industry. We are honored to have been able to participate in this Monograph.

Steven T. Ostheim
Volume Editor and Director
Center for Hazardous Materials Research
Subsidiary of the University of Pittsburgh Trust
Pittsburgh, PA
Pollution prevention is not just about producing less waste; it involves conserving the use of hazardous materials and other resources such as air, water, and energy. It also involves the most efficient use of all of these resources in the manufacturing process. To properly audit a manufacturing process to identify pollution prevention opportunities, a team should be assembled to prepare detailed process flow documentation of the facilities’ operations and processes (the Descriptive Approach). While there are impediments to implementing pollution prevention recommendations, facilities should accept and learn to operate with the impediments. The best way to overcome these impediments is to foster the notion of continuous improvement in manufacturing firms through ongoing programs rather than discrete technological solutions. Government can support pollution prevention by encouraging firms to use the “Descriptive Method” which encourages firms to understand process functionality, rather than its prescriptive checklists, etc.

Key Words

Benchmarking; biotechnology-based processes; coating removal; descriptive approach; impediments to pollution prevention; improved materials; process monitoring systems; separations technology; surface preparation; surfact treatment; technology avoidance.
1. Introduction

Unfortunately, changing a manufacturing process to accommodate a new technology that encourages pollution prevention is never an easy decision for a company to make. Built-in resistance to change, as typified by the “not invented here syndrome,” is difficult to overcome, even in facilities with pollution prevention programs that serve as “best in class” examples for others to benchmark against. However, many firms simply fail to either realize the opportunities for pollution prevention which potentially include new technologies or to recognize the ability of these “clean” technologies to provide a reasonable return on investment taking into account activity-based costs.

There is a growing awareness of areas where the potential for invention would greatly improve pollution prevention efforts. R&D-based firms involved in meeting these technological needs must understand how to best present their equipment or materials. They must keep in mind both the cultural element of how the facility operates and the proper means of justifying the costs, taking environmental activity-based costs typically allocated to the facilities overhead structure. Realizing savings will help lower the facility’s overhead rate. This will be looked upon in a favorable light by any facility manager. Hopefully, by understanding the concepts presented in this chapter, no matter how sobering they may be, development and acceptance of new pollution prevention technologies can help advance the competitiveness of both parties in a global market.

2. Current Perspectives on Pollution Prevention

Many practitioners perceive pollution prevention as a well-defined practice complete with its own literature of case histories and its protocols of checklists, questionnaires, and worksheets. The U.S. Environmental Protection Agency (EPA) and a number of states have sought to standardize the practice within their jurisdictions by publishing guides for companies to follow. Such a prescriptive approach to pollution prevention often leads to opportunistic fixes. Companies are encouraged to look in places where others have looked before and only try solutions that others have written about. Emulation of case histories leads to an overreliance on good operating practices and, to some extent, materials substitution. This does not create a demand for new technologies.

Another problem with the way pollution prevention is practiced is that it has been conducted largely by the environmental personnel. Pollution prevention is not just about producing less waste; it involves the conservation of the use of hazardous materials and other resources such as air, water, and energy. It also involves the most efficient use of all these resources in the manufacturing process. These are not areas where the environmental specialists have a lot of experience. Only through a thorough knowledge of the process can a cross-functional team catalog all losses of resources from the process. By using the principles of continuous improvement, the firm can sequentially address the opportunities while moving towards the use of new technologies. Process vendors will want to exploit efficiency. A strong theme in most manufacturer’s drive is to remain competitive in a global economy.

Pollution prevention literature does not adequately address the function of a manufacturing process. Each operation or process in industry consists of a functional sequence of events. One action initiates another, which in turn initiates still another, until the process is completed with some type of product or result. By understanding functionality, both the company and the technology vendor can better understand the need for new technologies in the process. The “Descriptive Approach” to pollution prevention is specifically designed to meet this need. This approach is briefly presented below.

To gain a proper appreciation of functionality, each firm should prepare detailed process flow documentation of all its operations and processes. This is the starting point of
most quality improvement programs. It is best to assemble a team for this task, which includes the senior managers of the different functional groups at the facility (i.e., production, scheduling, purchasing, accounting, environmental, health and safety, quality improvement, labor, maintenance, facilities engineering, etc.) Using a trained facilitator to move the process along, this team will prepare preliminary process flow diagrams. Without an unbiased third party to guide assembly of the process flow documentation, the different perceptions individual team members have of the work process can prevent the agreement necessary to construct the diagram. The group will note the following items for each unit: the materials used, other resources used, activity-based costs, process losses, and the functionality of each unit.

It is important to identify the boundaries of the process. This is often easier said than done because the work often begins earlier than people realize and ends later. Easily overlooked are preparatory stages at the start and service, repair and other steps after work is thought to be complete. The group must be on the lookout for intermittent and ancillary operations.

This group should work on one segment of the process flow diagram at a time. When the overall process has been depicted, they must go back and provide the detail that may be involved in some of the steps. This detail is necessary to properly depict functionality. A storyboard format is good to use for this exercise. It can be left in place for a period of time to allow the group to observe the operations and then return to make changes or additions. Each of the team members will see the process differently. This is necessary to get a complete picture that none of the team members can provide alone.

When the initial exercise is complete, the process flow diagram will be cleaned up and reviewed by many others in the organization. They will likely offer worthwhile additions and corrections. The most important output from this activity is the list of losses from the operation. As shown in Fig. 1, these losses must include those to the air, water, solid wastes, as well as spills/leaks and accidents. These losses will be cataloged by the individual units in the process responsible for generating them.

Every loss from the operation is an opportunity for pollution prevention. It becomes readily apparent that every manufacturing operation has many process losses—perhaps more than are worth considering in a pollution prevention program. Pareto analysis can be used to rank these losses. This analysis demonstrates that 80 percent of the environmental activity-based costs are caused by 20 percent of the opportunities. Hence, the 80/20 rule.

Just as quality improvement teams operate in a total quality management program, separate teams can take on each of the primary opportunities. Groups dedicated to primary opportunities must be trained in group dynamics and creative thought to be successful in identifying all the alternatives for addressing losses. Pollution prevention programs show that there are many categories that can be considered (see Fig. 2). Some alternatives should be examined from each such category. A prize should be given to the group member who comes up with the “most outrageous idea that might just work” as voted by the other members in the group. The group will then look at a set of criteria to screen the large number of alternatives to a smaller number for the feasibility study.

It might be that one of the alternatives is an easy-to-implement operating practice. The group can recommend that this be done and observe the process before and after the change. If the loss was not eliminated or shifted to other media, it must be added back to the list of opportunities kept by the pollution prevention steering committee along with the information collected to date. In this manner, there will always be new opportunities to consider. Continuous improvement will be noticed as the progress proceeds to materials substitution and technology implementation. Technology will be used both in the recycle and pollution prevention modes.

It is important to say a word about the feasibility study at this point. In the world of pollution control, a feasibility study has traditionally meant choosing the best available control technology and implementing it. There was little choice because of short time frames and the
difficulty of getting regulatory agencies to approve alternative technologies. Facilities have gotten a little “rusty” when it comes to conducting a valid feasibility study [2]. For pollution prevention, all the alternatives for each opportunity must be considered. Included in this range of alternatives are the operating practices, materials substitution, product changes, technology changes, and recycle/reuse. If an improved operating practice can be implemented in the name of continuous improvement with little impact on the operation, it should be done in an expedient fashion. However, new technologies may require bench- and pilot-testing and more detailed analysis before they can be utilized.

It is easy to see that attention to operating practices in the early implementation of pollution prevention is the first order of business. Often, significant reduction in the amount of waste generated will be realized by firms that use chemicals. Cleaning of batch processes and coating of materials are major consumers of chemicals. Technologies which make these operations more efficient or allow the recycling and reuse of spent materials should be in great demand.

Many companies seek substitute chemicals which do not appear on any government lists. Use of regulated materials adds substantial costs to an operation. However, when many firms switch to the same substitute, there may be unintended consequences [3]. Allergies and reproductive effects have played havoc with some commonly used substitutes. There may be a need for technology that allows the use of a chemical in a closed system. This allows much less exposure to the chemical and optimizes its recycling. Technologies which can clean surfaces without chemicals (e.g., laser, electron beam, CO, pellets, etc.) should also see increased demand.

It is easy to understand how the Descriptive Approach helps both the company and the technology developer appreciate the need and the benefit of a given technological alternative. Of course, the greater the level of understanding, the better the chance to make a match. It should be noted that this approach is not industry-specific. Opportunities to service many diverse industries with a similar problem can be determined.

Before discussing some general areas where matches may currently exist, it is important to examine the historic trend to avoid new technologies followed by the current regulatory impediments to the use of pollution prevention technology.

3. Historic Technology Avoidance

During the industrial revolution in the middle of the last century, industry produced a series of significant innovations in process and product technologies. In the early part of this century, manufacturers increasingly refined proven technology rather than developing and implementing new and diverse technologies to accomplish, or even eliminate, traditional tasks. This apparent trend toward a more stable, conservative approach to process technology in a broad range of industries caused a shift towards more modest improvements in productivity. There were some notable exceptions to this trend, including electronics, chemicals, and biotechnology. In these industries, most of the product breakthroughs depend on breakthroughs in process capabilities. However, in most other manufacturing industries, there was a demand on short-term profits rather than long-term development of product and process technologies [4].

Because of the feeling that new technology did not seem to offer great potential, manufacturing focused instead on product engineering at the expense of process engineering. Since manufacturers had their hands full simply adding capacity of a known type, they saw no pressing need to add new process technologies at the same time. Consequently, many firms
Figure 1. Closed-Loop Vision
Figure 2. Typical Remanufacturing Process
spent incremental dollars on product technology and very little on new process technology. Process development was left to the equipment suppliers. Most firms allowed their own skills at such development to decline. The operative word was, “Make the product with no surprises.”

By operating processes more efficiently, manufacturing managers increased productivity. This mode of operation, is dramatically upset when significant improvement or new technology is implemented by a competitor. Management’s view of manufacturing was based on the premise that smart people should be able to determine the optimal solution for handling the tasks of the manufacturing function and then control the process and organization for maximum stability and efficiency until some external event forces change. This is a reactive view that overlooks the potential contributions of the manufacturing function to overall competitiveness. Advances in production planning, project evaluation, and operations research offered new tools for maintaining stability and increasing productivity. Computers were able to take detailed measurements and exhibit sophisticated control. They became another impediment to process changes.

These manufacturing trends have led to increased tuning and relining of a set of resources that were, in many cases, outdated and increasingly inappropriate. Some firms slipped into a debilitating spiral: additional investment was withheld because the current investment was not performing as expected; those operating the current investment simply tried to minimize the problem in the near term rather than looking for long-term solutions they knew would not be approved and supported. These conditions still linger in today’s manufacturing industry.

It is interesting to note the attitudes towards technology in a benchmarking study of the facilities with the “best-in-class” pollution prevention performance. In a survey conducted by the Business Roundtable [5] of companies with pollution prevention programs, eight questions were asked regarding the use of new technologies.

How do you find and evaluate new technology or pollution prevention ideas?
What are your sources of information for new technology?
(Internal technology transfer, external technology transfer, etc.)

Please describe your technology transfer process (facility to facility transfer, corporate to facility transfer, external to the corporation [university, industry], etc.)
What unique or innovative approach or technology have you used to produce significant results?
How do you evaluate new technologies and lessons learned across processes?
How are new technologies and lessons learned incorporated into your program?
Are the gains you’ve experienced incremental or step changes or a combination of both? Please explain.

What could be done to enhance technology transfer in the future?

Six benchmarked firms responded to these questions on the use of technology to achieve significant improvement as follows:

3M - Sources of new technology included corporate research group, other 3M plants, in-house development, other 3M divisions, and outside vendors and consultants.
DuPont - Sources of new technology included corporate engineering, company R&D, Texas Chemical Council, and company communication sources.
Intel - Sources of new technology were primarily internal R&D and process engineers and collaborative efforts with vendors.
Martin Marietta - Sources of new technology included seminars, trade journals, professional associations, and internal technology transfer meetings.
Monsanto - Sources of new technology included directed university research, intra-company technology transfer, and alliances with other companies.
Procter & Gamble - Sources of new technology came primarily from facility employees. Other sources included other company facilities, suppliers, and waste brokers.

None of these firms emphasized working with firms included in developing new technologies to help with their pollution prevention programs. There may be a number of regulatory impediments that might explain this finding.

4. Impediments to Pollution Prevention

The benefits of implementing pollution prevention have been widely promoted by EPA and the state governments. However, several impediments help create business risks for those who would seek to implement pollution prevention programs. It is beyond the scope of this chapter to examine all of the impediments because they vary greatly from industry to industry and from facility to facility within the same industry. However, it is worthwhile to explore some of the regulatory and nonregulatory impediments to see what impact they may have on the use of new pollution prevention technologies in industry.

It is important to point out that companies learn to operate with the impediments. In some cases, impediments may even be created to discourage change. Changing the way products are made or processes are operated is what pollution prevention is all about.

In order for pollution prevention to drive the development of new technologies, there must be predictability in the direction of the environmental regulations. There must be strong enforcement of the existing regulations and a demonstrable drive to pollution prevention as the highest level on the waste management hierarchy. None of these conditions are presently encouraging.

Environmental regulations have sunset provisions that provide for re-authorization within a fixed time period. Legislation is passed through extensive compromise thus making the outcome uncertain to all who follow the torturous path that these Congressional bills must follow. Once environmental legislation is passed, it is relegated to the EPA. The agency must then write new regulations or modify old ones. State governments, that can be more stringent than the new federal regulations, must scramble to be authorized to implement the new rules. All of this takes place in agencies with tremendous strains on personnel resources as exacerbated by Congressionally mandated time frames. Industries and environmental organizations then bring legal suits against the EPA in order to have the courts help provide an even different interpretation of these regulations.

Despite this climate of uncertainty, many public officials are strongly committed to pollution prevention. Speeches, Executive Orders, and other pronouncements have created a sense of anticipation that there is a priority for pollution prevention. However, these people must “walk the talk” to ensure that there is adequate follow through. One past EPA Regional Administrator made every department commit 15 percent of its budget to efforts to encourage pollution prevention. One state environmental agency took all the media-specific (e.g., air, water, hazardous waste, solid waste, etc.) programs and placed them into a Bureau of Waste Prevention. These moves were far more than symbolic gestures and demonstrate the support for pollution prevention at the highest levels.
There is still an approach to regulate industry one-pipe-at-a-time and to do this with end-of-the-pipe technologies. Some states have started to look at a multimedia approach giving the companies an opportunity to meet the requirements with prevention. However, federal regulations often simply prevent this. There is a growing trend to incorporate pollution prevention requirements separately in all media regulations. RCRA requires companies to have a waste minimization plan. In the stormwater program, a firm must have a stormwater pollution prevention plan. The TSCA program is developing a pollution prevention plan. Some sewage treatment plants require a pollution prevention plan for discharging wastewater under the pretreatment regulations. Oil storage often requires an SPCC Plan. Firms meeting the Clean Air Act requirements can file for an early emissions reduction plan to delay implementation of the regulations. Finally, many states are requiring plans. It is very difficult for firms to combine these disparate plans for fear that a regulator will be unable to determine compliance with the regulations.

Many companies have signed up with EPA’s voluntary pollution prevention effort, the 33/50 Program. However, in most cases these firms have only exercised opportunistic changes in operating practices and materials substitution to attain their goals but lack a formal program to seek continuous improvement. There are often large variations in pollution prevention effectiveness in a multi-facility company. Most of this is attributable to the facility managers responsible for implementing these programs. Too often, the changes required are too great for them to be comfortable with.

A coatings manufacturing firm responds to its customers by developing new, “compliant” coatings. It is not unrealistic to assume that they will spend $2 million to $4 million to develop and test a new coating. It is likely that the cost of the new coating will be higher than that of the coating that it is designed to replace. In addition, the cost of the R&D has to be recouped in a reasonable period of time. Companies will pay more to remain in compliance with the regulations. However, there is not a great driving force to go to no-VOC coatings at a slightly higher cost if no one requires it. No one has gone to jail yet for not practicing pollution prevention. Thus, there is a greater risk for a coatings supplier seeking to fill the needs only of the firms who are seeking to stay out in front of the regulations.

As alluded to above, perhaps the greatest nonregulatory impediment is the resistance to change that exists in manufacturing. Many facility managers believe that processes are already being optimally operated. There is no perceived need to change technology. There is a lack of commitment to make this change even in today’s competitive market. Often there is no written policy encouraging pollution prevention and no person is in charge of seeking prevention at the facility level.

When prevention programs are mandated by state and trade association initiatives, as well as EPA voluntary programs, there is a lack of personnel and resources assigned to the program. The environmental department’s primary responsibility is to keep people out of jail for serious noncompliance. This is also a reactive situation like the historical perspective for manufacturing described above.

There is inadequate cost accounting for process losses. All environmental expenses are often placed in overhead and applied equally to all operations in the facility. However, some operations have greater environmental costs than others. Many facilities are turning to activity-based costing to remedy this problem.

In most firms there is no incentive system in place to reward pollution prevention efforts. Yet there are plenty of disincentives to punish noncompliant behavior. Finally, there are intense production pressures that do not allow a lot of experimentation with the process. There is also a great concern regarding product quality. Other competitive pressures may also fuel a reluctance for companies to exchange information when technology changes lead to an increase in market share.

The best way to overcome these impediments and the reactive historical perspective is to foster the notion of continuous improvement in manufacturing firms. To some extent, many
of these firms are already familiar with the concept of continuous improvement from their quality improvement initiatives. Instead of trying to focus on opportunistic targets in a pollution prevention program, a firm must identify opportunities for pollution prevention and have a program to move in the direction of new technologies that may bring breakthrough progress in the quest to minimize waste in the operation.

5. Opportunities for New Technologies

The focus on the difficulties involved in using new technologies for pollution prevention should not convince one that there is no need for process changes in a sustainable facility pollution prevention program. If the determination of alternatives for each pollution prevention opportunity is conducted properly, there will be a number of technological fixes for each case. However, if there is no generally applicable technology that can be developed to serve a particular functional need, it is likely that the facility will continue to modify and fine tune the process internally.

As more information becomes available in the Descriptive Approach format, a wide variety of technology needs will rise. However, some needs are universally needed at the present.

1. Surface Preparation and Coating Removal. This is a major consumptive use of chemicals. Halogenated solvents have been widely used for this application. Of course, many different surfaces and materials need to be removed from these surfaces. Many physical removal techniques may have wide applicability here. Industry has experimented with blasting with synthetic and natural materials (e.g., plastic beads or walnut shells); and use of Maxwellian light, hot and cold blasting media; and other energy-transforming means.

2. Surface Treatment. Companies are looking for less polluting technology for painting, plating, etching and cleaning. Substitute chemicals alone will not provide the complete answer. A means of using these materials effectively and efficiently in a closed system will be needed.

3. Improved Materials. This represents a very fruitful area for R&D and inventions. Corrosion-resistant materials would not need to be coated. Metal-free material substitutes are needed for inks, biocides, corrosion inhibitors, and paint. Substitutes for halogenated solvents are always in high demand along with alternatives to other toxic materials. Nonstick coatings would facilitate the cleaning of process equipment and other surfaces.

4. Improved Separations Technology. By using advanced membrane technologies, materials can be recovered and reused within the process. Advancements in this technology will even allow the recovery of dilute contaminants in high-volume waste streams.

5. Biotechnology-based Processes. Materials can be converted using microorganisms in lieu of chemicals. This often leads to lower energy use and reduces the use of toxic materials.

6. Process Monitoring Systems. Advances in the development of sensors will enable processes to be controlled in a manner so as to increase the efficiency of the operation.

These items pertain to a wide cross-section of industries. More examples will be provided in the industry-specific chapters in this book. It is important to understand where ideas that work in one industry can be applied to another. Increased demand for new technologies will go a long way to faster, further developments in this area.
6. Conclusions

A reluctance to change is firmly entrenched in manufacturing industrial facilities. Some of this is due to a historical perspective and some has been brought about by an uncertain regulatory and economic climate. However, this reactive stance is not conducive to remaining competitive in a global marketplace. Information on opportunities to apply technology to make manufacturing processes more efficient is needed for both the potential users and the suppliers of the technology to review. Whenever a process or operation is made more efficient, there will be fewer losses to the workplace and the environment as shown in the equation below:

\[
\frac{\text{Materials Used} - \text{Materials Lost}}{\text{Materials Used}} \times 100\% = \text{Unit Process Efficiency}
\]

This gain in efficiency is an important measure in the field of pollution prevention. Government must stop using its prescriptive checklists, questionnaires, and worksheets to get companies to conduct pollution prevention programs. Instead, the “Descriptive Method” which encourages firms to understand process functionality will be needed. There are few detailed process flow diagrams in the pollution prevention literature. If more information was available in this format, individual firms could utilize these maps to make refinements for the way they operate in their facilities. Technology vendors could utilize this basic information to identify industries where their inventions would be of use. In many cases, a number of different manufacturing industries have the same opportunity. Since the EPA often looks only at one industry at a time, these important cross-industry opportunities are often missed.

By holding focus groups with people from different industries that may have need for a given technology, vendors can get important ideas on how to position technologies for market entry. Vendors can also get some idea of the cultural issues that may be faced in certain industries and how impediments have been overcome in others.

By initiating partnerships between vendors and different industry groups, perhaps through a university, a particular pollution prevention technology can be piloted in a volunteer facility. This information can then be made available to others participating in the program. Because the firms are from different industries and not competing directly, this program can be quite effective. The competitors will find out about the change when the participants’ market share begins to rise. Some forward-thinking trade associations may convince their members to share a particular pollution prevention technology that would benefit all members equally.

Information on pollution control technology has been freely shared in the past within trade associations. There are ways to share pollution prevention technologies without antitrust violations. More efforts are required in this area.

Finally, there must be a push to continuously improve the maintenance of industry pollution prevention programs. The prescriptive approaches do not make this possible. By using the approaches described in this chapter, a firm can move steadily to the point where a technological approach will help increase the level of pollution prevention for a particular opportunity. By successfully easing into this technological alternative, the facility can overcome the resistance to change that has persisted for so long.
7. References


About the Author: Dr. Robert B. Pojasek directs a national pollution prevention engineering practice with GEI Consultants, Inc., Winchester, Massachusetts. He helps industrial facilities plan and implement programs using quality improvement tools. He is also involved in reviewing pollution prevention technologies for venture capital groups. In addition to this work, Dr. Pojasek teaches a graduate-level course in pollution prevention at Tufts University, Medford, Massachusetts, and currently serves as Past President of the American Institute for Pollution Prevention.