POLLUTION PREVENTION:

METHODOLOGY, TECHNOLOGIES AND PRACTICES

by

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To our wives
Cathy and Yvette

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Foreword

For better or worse, engineers rarely make the headlines. When we do, it is a fair bet that it is the result of something gone wrong. Technology, when it works well, is (and should be) invisible. And as often is the case, so are the people who create it.

Consider an oil refinery. Few people, driving past it on their way to work, pause to wonder about the engineering feat of turning crude into the plastics that comprise much of their car, the gasoline that powers it, and the asphalt beneath the tires (which, incidentally, also had their origins in that same refinery, or one remarkably like it). In fact, it is likely that the majority of people driving past don't give the refinery a second thought at all.

Which, perhaps, is as it should be. But, on surprisingly rare occasion, something will happen to bring the inner workings of technology into the public spotlight.

One of the most interesting recent examples of this phenomenon is the so-called Year 2000 ("Y2K") problem. The problem stems from the way that early computer programmers recorded date information. Faced with the need to keep both code and data as compact as possible, programmers often truncated dates to record only the last two digits of the year. In other words, the year 1998 (the year that this book was originally published) would be recorded as "98." Obviously, this poses a potential problem for software that must track dates past the year 2000. Does a date entry of "02" stand for the year 2002, or 1902?

Public reaction to this rather arcane issue of software programming has been surprising. Reactions range from mild concern to dire predictions of the imminent demise of civilization. In the worst-case scenarios, banks will fail, the government will come grinding to a halt, and airplanes will fall from the sky. Of course, this assumes that they are still flying — as of this writing several airlines have announced that, as a precautionary measure, they will suspend all flights when the final hour arrives.

The truncation that seemed an expedient solution thirty years ago has "suddenly" introduced the one thing that computer programmer's try so hard to avoid — ambiguity.

Like many engineering problems, the Y2K problem was well understood by the people who created it. But (again, like many engineering problems) the decision that led to the problem was part of a conscious trade-off. Faced with the challenge of getting software to function within constraints of available memory and processor speed, it was an expedient solution to a problem whose ultimate solution was assumed to lie in the future — when improved technology would make it possible to implement a more complete solution.

The problem, of course, is that the future is now.

In ways that are strikingly similar, the process industries are facing their own version of the Y2K problem, in the form of environmental wastes. Like the Y2K problem, process waste is often the result of engineering trade-offs that were made between efficiency and capital cost, and between the state of existing technology and the need to get product to market. One result of these trade-offs is waste, which in many cases can no longer be tolerated either economically or environmentally.

Think of a chemical plant as a computer program for turning raw materials into products, with the instructions (code) written in steel, rather than bytes. Like the software engineers who must examine every line of code to find a persistent bug, we are faced with the challenge of methodically "opening up" each process, and eliminating the sources of waste and pollution that threaten the environment, and threaten the viability of the industry.

This book is an instruction manual for debugging the chemical process industries.

This book will help the chemical engineer recognize pollution prevention as nothing more than a reformulation of traditional chemical engineering problem solving, and in the process provide new applications for your skills. The same reaction engineering skills that optimized processes for maximum throughput and minimum capital investment can also be applied to the challenge of re-optimizing for high selectivity and maximum efficiency. Sometimes, for example, when dealing with persistent and bioaccumulative materials, the questions may need to be rephrased in somewhat different ways — "can we live without this intermediate in our product or process?" but ultimately, it still becomes a problem amenable to a mixture of creative problem solving and fundamental technical skills learned in school and on the job.

For the non-chemical engineer, the book demonstrates in understandable terms the application of the chemical engineer's toolkit — reaction engineering, transport phenomena, equipment design, and engineering economics

— to the challenges of preventing waste in the process industries.

Finally, for all readers, the generous use of case studies and examples from process plants will help you gain an understanding of how pollution prevention techniques can be used to reduce or eliminate plant bottlenecks, improve product quality and yield, and improve overall profitability of today's process plant.

Scott Butner
Senior Research Scientist,
Environmental Technology Division
Pacific Northwest National Laboratory
Seattle, WA

Preface

In 1994, the DuPont Company established "The DuPont Commitment" for Safety, Health, and the Environment. As part of this Commitment, the company resolved to drive toward zero waste generation at the source and zero emissions. Having spent the previous 5 years delivering on corporate goals to reduce air toxic and air carcinogen emissions, we realized the value that pollution prevention could play in improving the environment and the manufacturing process, while also making money for the business. What a concept! As a result of our work on end-of-pipe treatment of waste streams, we were also armed with valuable information on the cost of abating emissions at the tail end of the process. We quickly realized that the cost of end-of-pipe treatment could be a catalyst to help drive pollution prevention in the businesses. What was missing, however, was the ability to quickly identify feasible pollution-prevention technologies and practices that applied across multiple manufacturing processes and industries. Being chemical engineers, we envisioned a "unit operations" approach to pollution prevention.

Since 1994, we have responded to DuPont's corporate commitment to drive toward "zero waste and emissions." With the help and support of many colleagues at DuPont, particularly Robert W. Sylvester, we invented a structured methodology to identify the best pollution-prevention solutions for any manufacturing process, as well as a unique set of pollution technologies and practices that are based on chemical engineering know-how. In addition, we took full advantage of the important end-of-pipe treatment and economic evaluation skills and knowledge that were available to us at DuPont. We did not waste any time in leveraging this knowledge across the globe. By being proactive rather than reactive, we have helped DuPont reduce total waste generated by 300 million pounds per year, and have helped position the corporation to meet its goal of "zero waste and emissions," while also gaining competitive advantage through faster, more effective, revenue-producing pollution-prevention programs.

The novel methodology described in this book uses a structured brainstorming process that requires minimum resources to identify chemistry and engineering changes that can be made to existing and new processes. These process improvement ideas not only reduce the amount of waste being generated, but they also make money for the business. We have participated in or led over two dozen brainstorming sessions to identify the best waste reduction. In this sense, the methodology is proven and of practical use to engineers responsible for reducing waste generation in both new and existing processes.

To support the brainstorming of ideas, we transformed an extensive database of process-specific pollution-prevention case histories within DuPont and the open literature into fundamental pollution-prevention knowledge that is applicable to all businesses around the world. Examples of this pollution-prevention knowledge include equipment and parts cleaning, optimizing the use of water, pollution prevention in batch operations, pollution prevention through reactor design and operation, pH control as a pollution-prevention tool, high-value wastes, organic solvent selection, minimizing equipment leaks, and greener separations.

This extensive knowledge was then further simplified to a set of pollution-prevention "wisdoms" that are easily understood and broadly applicable. This fundamental knowledge allows plant operations personnel to have just as important a role in pollution prevention as do the engineers and chemists.

In the process, we developed a course based on the pollution-prevention methodology, technologies, and practices described in this book, and taught it to over 250 DuPont professionals in the United States and Europe. The course was also given in Poland as part of a World Environment Center initiative, and was taught at the University of Delaware as part of their Environmental Certificate Program and Chemical Engineering Graduate Program. In addition, we helped design and participated in three pollution-prevention workshops—two sponsored by the American Institute of Chemical Engineers' Center for Waste Reduction Technology and one organized by the Delaware Chamber of Commerce. Lastly, the work was recognized with a DuPont Safety, Health, and Environmental Excellence Award, one of only 13 achievements chosen to receive this award in 1998 by a corporate selection committee comprising DuPont professionals and external representatives from leading environmental organizations.

In summary, this book offers many practical tools and methodologies for establishing and implementing a pollution-prevention program at your site, whether large or small. Our approach combines a proven, well-structured methodology with simplified tools and techniques to speed your journey through the process. If nothing else, we hope that we have dispelled the myth that pollution prevention is process-specific.

Kenneth L. Mulholland
James A. Dyer

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"If you always do
What you always did,
You will always get
What you always got."

Joe Juran

"It is not the answer that illuminates,
it is the question."

Playwright Eugene Ionesco

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