Identification of Cleaner Production Improvement Opportunities

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A joint publication of the American Institute of Chemical Engineers and John Wiley & Sons, Inc.

Published by John Wiley & Sons, Inc., Hoboken, New Jersey.
Published simultaneously in Canada.

Library of Congress Cataloging-in-Publication Data:

Mulholland, Kenneth L., 1939–
Identification of cleaner production improvement opportunities / Kenneth L. Mulholland.
p. cm.
ISBN-13 978-0-471-79440-0 (alk. paper)
ISBN-10 0-471-79440-6 (alk. paper)
1. Chemical industry—Waste minimization. 2. Manufacturing processes—Production control. 3. Green technology. 4. Pollution prevention.
I. Title.
TD899.C5M85 2006
658.5'67—dc22 2005030393

Printed in the United States of America.

10 9 8 7 6 5 4 3 2 1

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Acknowledgments

The author wishes to acknowledge the valuable contribution of a number of colleagues at The Dow Chemical Company, Korean Institute of Industrial Technology and Hanwha Chemical. Specifically:

Duane Koch of The Dow Chemical Company for providing me with the opportunity to develop the manual.

Ray L. Schuette of The Dow Chemical Company for helping me with the initial development and implementation of the manual.

Dr. Kwiho Lee of the Korea Institute of Industrial Technology for working with me to further prove the effectiveness and value of the manual.

Mr. K. H. Hyun of the Hanwha Chemical Corporation for providing the resources and guidance while implementing the cleaner production technologies at the Ulsan vinyl chloride monomer plant.

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Foreword

One of the very first-pollution prevention projects I recall was such a "no-brainer" that any first year chemical engineering student would have spotted it in a heart beat. in this case, a Fortune 100 company was taking a concentrated waste stream, mixing it with a largely aqueous stream and sending it off for treatment. In other words, a low-volume, highly-contaminated stream had been transformed into a large volume waste stream with low contaminant concentration. It doesn't take much of an imagination to realize that the treatment cost of the latter scheme would be enormously higher than the cost of treating the more concentrated, low-volume stream.

Why did the above happen? I like the story that the author of this manual, Dr. Ken Mulholland tells in a June, 2003 paper that he published in Chemical Engineering progress entitled "Think Outside the Box to Reduce Wastes." To quote Ken, "Consider the person who walks along a circular path in the same direction every day. The first time Every thing is new. By the 30th time, the walker only notices the unusual. The slow deterioration of the walkway or cumulative minor changes in the landscape are not evident. However, if on the thirty-first walk, the person walks in the opposite direction, all of a sudden everything is new, It is the same scenery, but now it is seen from a different perspective."

"The same holds true for a manufacturing process," according to Ken. "Instead of starting from the front of the process, if you start with the waste streams and move backward through the process, and ask different questions of the same process information, your views change completely."

All well and good you say, but so what? Why should I be bothered to spend money in this manner to identify process improvements that might reduce my wastes? Dr. Paul Tebo of DuPont said it best several years ago: if we use pollution prevention as a weapon, we can increase yield, eliminate the need for some of our expansion projects, lower our treatment costs, reduce permitting requirements and thereby gain a competitive edge on our competition. In other worlds, it is all about money. Many would argue (I amongst them) that such thinking leads one on a pathway to sustainability and improved community relations.

The example I cited above is clearly, in the vernacular, low hanging fruit. How does one get at the more intractable problems that are more process driven? As an example, how did the waste in that original low flow highly contaminated waste stream get there in the first place? And how do I eliminate them?

In this era where we 'talk the talk" about sustainability, Ken provides the tools one needs to actually "walk the walk" to "meet the needs of the present without compromising the ability of future generations to meet their own needs." *

* Atkisson, Alan. 1999. *Believing Cassandra, An Optimist Looks at a Pessimist's World.* White River Junction: Chelsea Green Publishing Company.

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Preface

Processes that produce waste reduce profitability. Pollution prevention, waste minimization, and cleaner production programs can reduce waste generation by 40–50% with a 200% internal rate of return. Unfortunately the education and training of chemical engineers have resulted into a thought framework or "box of thought" leading to process designs that produce excessive waste and thus have higher investment and operating costs. The engineer needs to be shown how to think outside the "box" and discover process improvements that traditional engineering problem-solving techniques do not find.

Consider the person who walks along a circular path in the same direction every day. The first time everything is new. By the 30th time, the walker notices only the unusual. The slow deterioration of the walkway or cumulative minor changes in the landscape are not evident. However, if on the 31st walk the person walks in the opposite direction, all of a sudden everything is new. It is still the same scenery, but now it is seen from a different perspective.

The same holds true for a manufacturing process. Instead of starting from the front of the process, if you start with the waste streams and move backward through the process, and ask different questions of the same process information, your view changes completely.

The basic skills and knowledge of the engineers, operators, mechanics, scientists and business people are available to solve waste generation problems. The information is available. All that is needed is a different approach to looking at the information

The cleaner production/pollution prevention technologies were described in the book *Pollution Prevention Methodology, Technologies and Practices* that was published by AIChE in 1999. Using the book's information and technology, I worked with The Dow Chemical Company to develop this manual. I further refined the manual while working with the Korean Institute of Industrial Technology.

To accelerate the introduction of cleaner production technologies to various industries throughout South Korea, in 1999 the Ministry of Commerce, Industry and Energy formed the Korea National Cleaner Production Center (KNCPC) as a division of the Korea Institute of Industrial Technology. In 2001 I worked with KNCPC to develop cleaner production technology for complex processes. Hanwha Chemical Corp. volunteered to provide a process and resources to demonstrate the technology.

Hanwha Chemical manufactures polyvinyl chloride (PVC), low-density polyethylene (LDPE), linear low-density polyethylene (LLDPE), and chloralkali. It is headquartered in Seoul, has a research and development center in Daejeon, and operates two manufacturing plants — Yosu and Ulsan. Hanwha's policy is to follow stricter environmental management guidelines than required by regulation, and it has adopted the ISO 14001 Environment Management System. Even though Hanwha had just completed a massive energy conservation program, the company's leadership understood the value of cleaner production technologies and volunteered to work with KNCPC to develop such technologies for complex processes.

The project focused on the Ulsan vinyl chloride monomer plant, since it had a higher manufacturing cost and environmental load. Plant personnel were trained on how to view their process by focusing on the waste streams instead of the product streams. A brainstorming team, consisting of experts in chemistry, engineering, environmental control, electricity, piping and equipment, and operations, met and generated more than a hundred process improvement ideas. The top ideas underwent further technical and economic analyses, and an implementation plan was formulated for the best ideas. The process improvements required no new technology, only better use and understanding of existing technologies, and ranged from revised operating procedures to major process modifications that can be patented. The improvements, which are expected to be completed by the end of 2003, involve a capital investment of $2,600,000 and will achieve:

- a 35.7%, or 5,232-m.t., waste reduction
- a cost reduction of $3,200,000
- additional revenue generation of $6,000,000.

Hanwha Chemical is expanding the program to all of its processes at the Ulsan site. KNCPC is actively implementing and promoting cleaner production technologies for all industries. It is working to: develop metrics by industry type; disseminate technology through collaborations with universities, institutes and research teams, as well as via forums such as roundtables; and provide support for businesses developing and implementing cleaner production technologies.

In summary this book contains a tested technology that will lead your business personnel to discover process improvements that will reduce your waste generation, reduce the resources requirements to manufacture your product and increase the revenue to your business.

Section I

Cleaner Production and Waste

Introduction

Processes that produce waste reduce profitability. Pollution prevention, waste minimization, and cleaner production programs can reduce waste generation by 40–50% with a 200% internal rate of return. [1,2] Unfortunately the education and training of chemical engineers have resulted in a thought framework, or "box of thought", that leads to process designs that produce excessive waste and thus have higher investment and operating costs. The engineer needs to be shown how to think outside the "box" and discover process improvements that traditional engineering problem-solving techniques do not find. (Figure I-1)

Consider the person who walks along a circular path in the same direction every day. The first time everything is new. By the thirtieth time, the walker only notices the unusual. The slow deterioration of the walkway or cumulative minor changes in the landscape are not evident. However, if on the thirty-first walk the person walks in the opposite direction, all of a sudden everything is new. It is still the same scenery, but now it is seen from a different perspective.

The same holds true for a manufacturing process. Instead of starting from the front of the process, if you start with the waste streams and move backward through the process, and ask different questions of the same process information, then your view changes completely.

The basic skills and knowledge of the engineers, operators, mechanics, scientists and business people are available to solve waste generation problems. The information is available. All that is needed is a different approach to looking at the information.

The book *Pollution Prevention Methodology, Technologies and Practices* [3] contains more detail on the cleaner production/pollution prevention technologies described in this manual. This manual's information and technology were tested at The Dow Chemical Company and further refined with the Korean Institute of Industrial Technology.

In summary, this manual contains a tested technology that will lead business and design personnel to discover process improvements that will reduce waste generation, reduce resource requirements to manufacture product(s) and increase revenues to the business.

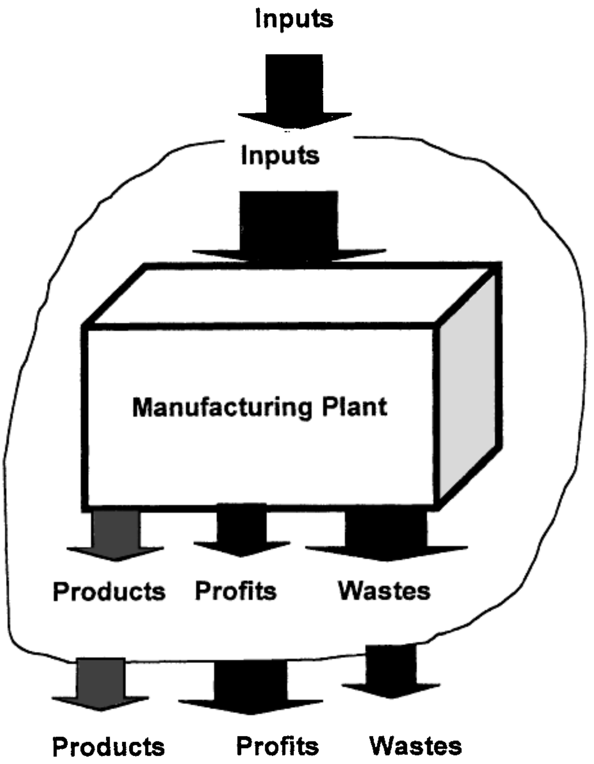

Fig. I-1. Think outside the "box", reduce inputs and wastes and increase profits

Manual

The manual consists of five (5) sections:

- Section I discusses the relationship between cleaner production, waste, cleaner production analyses and the business value derived by using a cleaner production methodology to identify process improvement opportunities.
- Section II covers how to develop a cleaner production program and to identify which businesses and waste streams to attack first.
- Section III discusses the data requirements and data analyses to prepare for the opportunity identification step.

- Section IV is the opportunity identification step.
- Section V covers how to assess and rank the best ideas.
- Appendix A contains copies of the forms and handouts needed to accomplish different steps in the methodology.
- Appendix B describes a chemical process case study to illustrate the methodology.

Cleaner Production and Sustainable Manufacturing

The traditional approach to process design is to first engineer the process and then to engineer the treatment and disposal of waste streams. However, with increasing regulatory and societal pressures to eliminate emissions to the environment, disposal and treatment costs have escalated exponentially. As a result, capital investment and operating costs for disposal and treatment have become a larger fraction of the total cost of any manufacturing process. For this reason, the total system must now be analyzed simultaneously (process plus treatment) to find the minimum economic option.

Experience in all industries teaches that processes that minimize waste generation at the source are the most economical. For existing plants, the problem is even more acute. Even so, experience has shown that waste generation in existing facilities can be significantly reduced (greater than 30% on average), while at the same time reducing operating costs and new capital investment. Also, experience has shown that processes, which generate waste, require 10% to 35% more investment. The higher investment is required to store, heat, move and separate the waste streams from the product(s) and recyclable feed materials, solvents, catalysts, and so on.

Cleaner production technology provides tools, which address the problems of negative environmental impact, loss of materials to waste, and increased process investment to deal with wastes. The application of these tools will result in a manufacturing process evolving from a typical process shown in Figure I-2 to the desired process shown in Figure I-3.

The most common definition for sustainable development is development that "meets the needs of the present without compromising the ability of future generations to meet their own needs."[4] For a manufacturing facility the definition translates to a process that requires the minimum amount of resources and produces no waste, that is, Figure I-3.

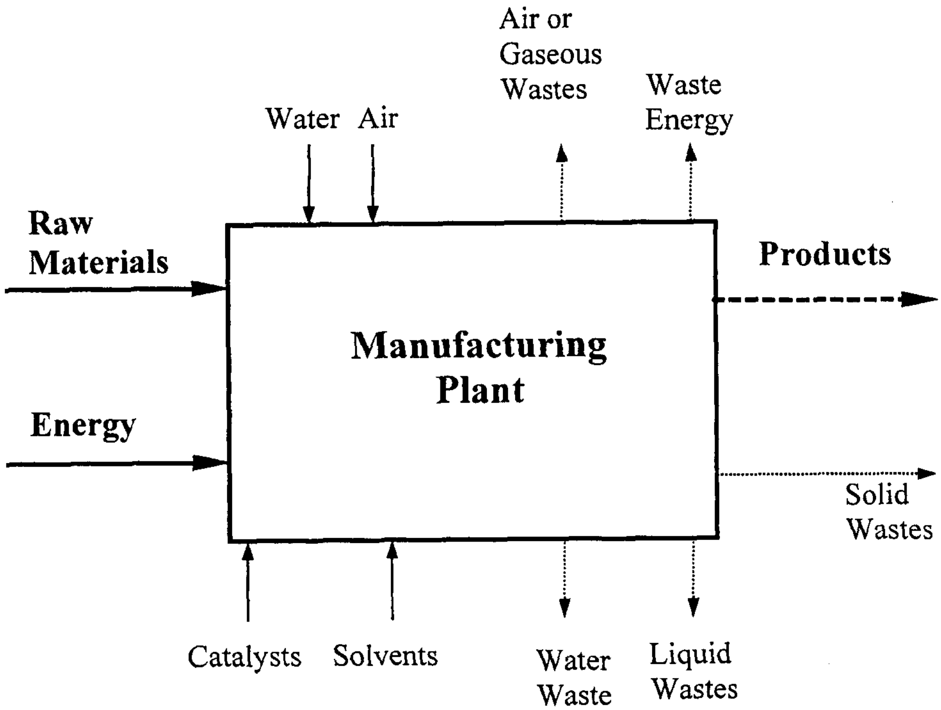

Figure I-2. Plant with Pollution.

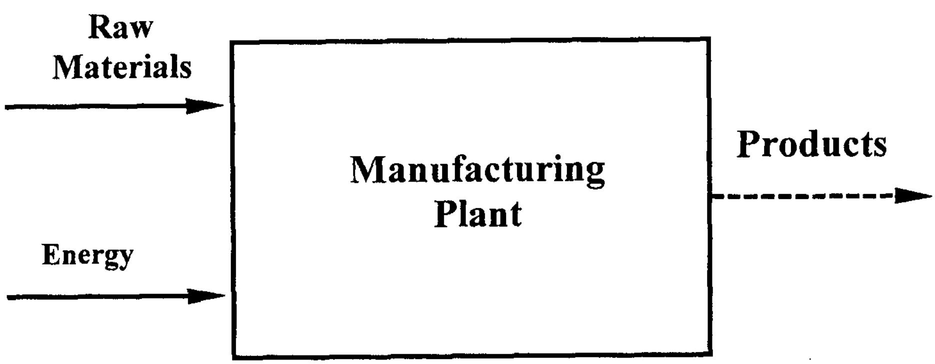

Figure I-3. "ZERO" Waste Generation Facility

The concepts behind the methodologies presented in this manual are described in the book "Pollution Prevention: Methodologies, Technologies and Practices." The last chapters of that book describe technologies and practices to reduce the waste from processes ranging from ventilation problems to reactors to pH control.[3]

Why Waste?

The standard college education, normal process design procedures and on-the-job training are three contributing factors as to why manufacturing processes produce excessive waste (Figure I-2). The education, design and training focus has been on the product.

College Education

Until recently, for the last 5 to 10 years, when the vast majority of plants now operating within the U.S. were designed, the teaching of process design focused on:

1) Lowest possible investment,

2) Lowest operating cost, and

3) Highest throughput possible, especially first pass yield.

These three major objectives of process design were developed in an environment which now seems both innocent and naïve because of the beliefs that:

1) Air was an infinite sink - that is the gases disappeared and were not even considered as harmful or at worst were easy to treat,

2) The lines that left the flow-sheet for treatment were someone else's problem, and

3) Energy costs were not significant.

Further exacerbating the problem was the fact that society was not aware of the problems being caused by waste. Jobs were more important than any harm to the environment or discomfort to the workers, for example, coal miners and coal dust, mill workers and ergonomics, smelter workers and fumes, farm workers and pesticides and so on.

Process Design

The normal design process has the following steps.

1) Researchers develop a new product.

2) Engineers synthesize a design using their previous experiences around the criteria of minimum investment, minimum operating cost and maximum throughput.

3) The design is further refined to make maximum profit.

4) Just before final design any necessary treatment facilities to meet regulatory requirements is then considered, almost as an afterthought.

5) Construction and finally startup.

Once the plant is running the businessperson directs the plant manager to run the process to offset startup costs and generate revenue. The plant manager cannot take time to optimize the process - the business needs the cash.

Training of New Engineers

Now comes the training of the engineers to solve process problems. An experienced engineer mentors an engineer new to the process. The mentor starts with the feed system and discusses the problems associated with the feed system, safety etc. The mentor explains how the reactor operates, temperatures, pressures, catalysts, hazards, etc. Then the mentor describes the separation systems, packaging and shipping. Finally the mentor states that the process does generate some waste and this or that is the waste treatment system. This system is described almost as an afterthought.

The "new" engineer is asked to solve some problem to see how well he/she will handle the challenge. Having no preconceived ideas the engineer uses his/her full range of skills and does a good job. Now it is 10 years down the road. The now "experienced" engineer solves the problems tomorrow the same way as the problems were solved yesterday. Over time while solving problems the engineer acquires blinders on all other happenings, almost as if they were at the Colorado River of the Grand Canyon instead of being on the upper plateau and being able to have a greater view of everything.

Result

The engineer's education, the design process and engineer's training at their job result in a thought framework or "box of thought" that result in process that produce excessive waste, thus require higher operating costs (Figure I-1). The need is to show the engineer how to think outside the "box" and discover process improvements that standard problem solving techniques do not find.

Cleaner Production Analysis Defines Improvement Opportunities U.S. EPA and DuPont Chambers Works Waste Minimization Project[1]

In May 1993, the U.S. EPA and DuPont completed a joint two-year project to identify waste reduction options at the DuPont Chambers Works site in Deepwater, New Jersey.[1] The project had three primary goals as conceived:

1. Identify methods for the actual reduction or prevention of pollution for specific chemical processes at the Chambers Works site.

2. Generate useful technical information about methodologies and technologies for reducing pollution which could help the U.S. EPA assist other companies implementing pollution prevention/waste minimization programs.

3. Evaluate and identify potentially useful refinements to the U.S. EPA and DuPont methodologies for analyzing and reducing pollution and/or waste generating activities.

The business leadership was initially reluctant to undertake the program, and was skeptical of the return to be gained when compared against the resources required. After completing a few of the projects, however, the business leadership realized that the methodology identified revenue-producing improvements with a minimum use of people resources and time, both of which were in short supply.

The pollution prevention program assessed 15 manufacturing processes and attained the following results:

- A 52% reduction in waste generation.
- Total capital investment of $6,335,000.
- Savings and earnings amounting to $14,900,000 per year.

— Reduced treatment costs	11%
— Recovered product	15%
— ***Process Improvements***	***74%***

11 of the 15 manufacturing processes identified waste reduction opportunities that would require less than $50,000 capital investment and could be completed within 6 months.

The key to the site's success was following a structured methodology throughout the project and allowing the process engineers' creative talents to shine through in a disciplined way.