Cleaner Production : Basic Principles And Development

*Michael Overcash**

**Pollution Prevention Research Center*

Chemical Engineering Department

Raleigh, North Carolina, 27695-7905

Tel :919-515-2325, Fax : 919-515-3465, E-mail :overcash@che.ncsu.edu

ABSTRACT : Cleaner production is of substantial importance in changing the environmental approach within advanced industrialized countries. The critical principles involve fundamental understanding of diverse industrial processes, adherence to the earliest techniques of a hierarchy for reducing wastes, and utilization of an underlying thought process to achieve pollution prevention successes that are both technically feasible and cost-effective. Chemical engineering has played a major and unique role in this environmental field. Improving the sustainability of cleaner production will rest on including this subject in the curriculum of university engineering.

1. INTRODUCTION

No single dimension of environmental solutions has captured the imagination of engineers, scientists, policy -makers, and the public like pollution prevention. In the space of 10 years (1980-1990), the philosophical shift and the record of accomplishment have made cleaner production a fundamental means for environmental management. This decade began with pollution prevent ion origins in 1976-1979 when the 3M Corporation initiated the 3P program and North Carolina adopted waste minimization as a state-wide priority for managi ng emissions from industry. By 1990, virtually all of the Fortune 1000 United States corporations had pollut ion prevention as the first emphasis in describing their approach to the environment. The shift from 20-50 years of conventional pollution control to a preventative approach was dramatic because of this reversal in priorities.

The adoption of pollution prevention as a clearly differentiated approach to environmental improvement began in U.S. industry and policy during the late 1970's. While examples of improved efficiency and hence less waste had existed since the start of the Industrial Revolution, the distinct explosion of successes in pollution prevention did not occur until the 1980's. Fig. 1 is an approximate time line of this period [1,2]. The early creation at the 3M Corporation of money saving innovations that reduced chemical losses to air, water, or land was widely publicized [3]. However, propagation into other large corporations was almost non-existent. The efforts through university research, state programs (beginning in North Carolina) to illustrate the benefits of pollution prevention, led to a steady presentation of principles extending over the early to mid-1980's. In 1986-1988, the improved information regarding chemical losses to the environment as a part of the U.S. EPA Toxic Release Inventory(TRI) program precipitated action [4].

A number of CEOs in large corporations challenged their companies, in a very public fashion, to reduce these chemical losses.

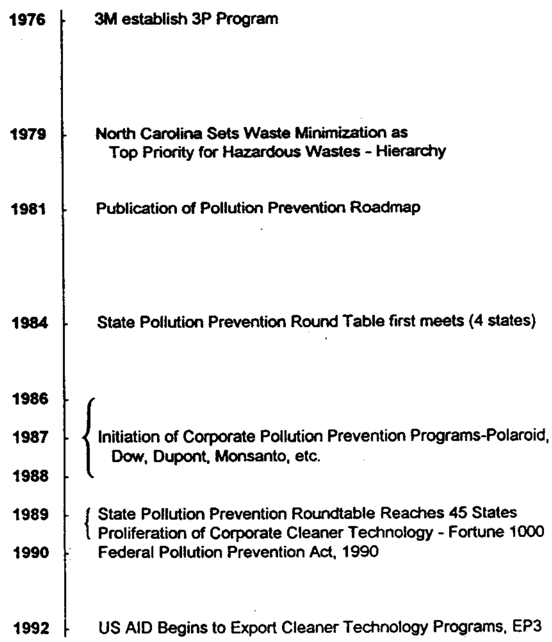

Fig. 1. General historical sequence for growth of cleaner technology in the U.S.

As the autocatalytic effect spread to other companies and whole industry associations or sectors, the policy of priority for pollution prevention took shape in the U.S. The outcome has been impress- ive, not necessarily uniform, by achieving a philosophical shift to cleaner manufacturing. These events were even more impressive when it is recognized that virtually all of the individual changes to manufacturing have been cost-effective (a generally held rule of a two year payback on capital investment).

Use of the term pollution prevention is common in the United States, but is actually one of many synonyms. These include

-waste minimization
-cleaner production
-waste reduction
-clean technology
-source reduction
-environmentally benign synthesis
-environmentally-conscious manufacturing
-industrial ecology
-sustainability

Use of a particular terminology is usually linked to the forum in which the debate is occurring and hence these terms have subtle differences, but share the major emphasis on prevention. That is, all of these descriptors refer to the intuitive perspective that it is advantageous to manage chemical losses or wastes generated from the top of a hierarchy for waste management, Fig. 2.

2. POLLUTION PREVENTION PRINCIPLES

The hierarchy for waste management has been reconstructed numerous times by authors in the cleaner production field, but still retains the same basic fundamental principles. The first point in time and potentially the most thermodynamically or economically effective opportunity for reducing impact on the environment is to prevent or reuse wastes. These wastes are chemical losses from the vast diversity of industrial conversions that occur between chemicals in the natural state found around the world and the state of those chemicals in the products or services which reflect the gross domestic product of the all countries. Preventing chemical and material losses reduces waste and the magnitude of the remainder of the waste management hierarchy, Fig. 2.

However, wastes can never be reduced to zero in conjunction with the industrial conversions described above. Thus, the next level of the waste management hierarchy is aimed at converting to less- or non-hazardous constituents, Fig. 2. This is pollution control and was the predominant means of environmental protection prior to the shift to cleaner technologies. It may in fact still be the predominant technologies for environmental protection, but is no longer viewed as preferable. Unfortunately these treatment techniques, as with other conversions in chemical states, also produce wastes, or residues, Fig. 2. Landfills and underground injection are the dominant approaches for residue management in the United States. The increased costs of pollution control and residue management levels of this hierarchy can stimulate pollution prevention. Conceptual development of the hierarchy and the need to focus on the preventative and reuse elements was not sufficient to achieve progress and general understanding of the pollution prevention field.

total quality management (TQM), continuous process improvement (CPI), and safety. However, with a formal set of procedures, the transferability of pollution prevention occurred across all types of industry and countries.

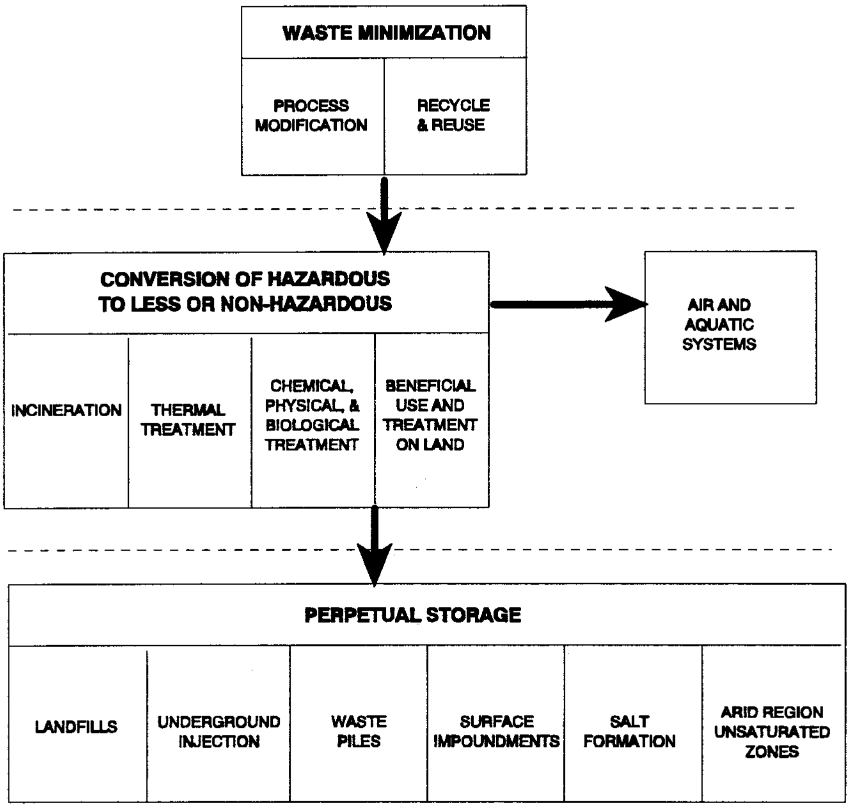

Fig. 2. Overview of pollution prevention and industrial manufacturing (Cleaner production) Hierarchy concept (Overcash and Miller 1981)

A methodology for achieving cleaner technology was needed. This roadmap, Fig. 3 [5], was first developed in 1981 from studies of the small literature of pollution prevention successes. In essence, the roadmap identified the generic concepts in cleaner production.

Following the logic or thought process in Fig. 3 has repeatedly lead firms to discover pollution prevention alternatives that are technically and economically feasible. In retrospect, this roadmap is very similar to the solutions in manufacturing of other goals such as

The driving forces for adoption of cleaner technology also include major economic factors. These are related to both the rapidly increasing cost of compliance with the regulations for managing wastes that are generated by industry and the economics of significant process improvement. Fig. 4 illustrates the national annual expenditures by U.S. industry to comply with the environmental laws governing air, water, and land [6].

In 1987, when pollution prevention was beginning to grow rapidly, these costs were about $75 billion per year. In 1990, the amendments to the Clean Air Act alone added an estimated $32 billion per year. Current estimates are in the range of 4%-6% of total sales are spent on environmental compliance.

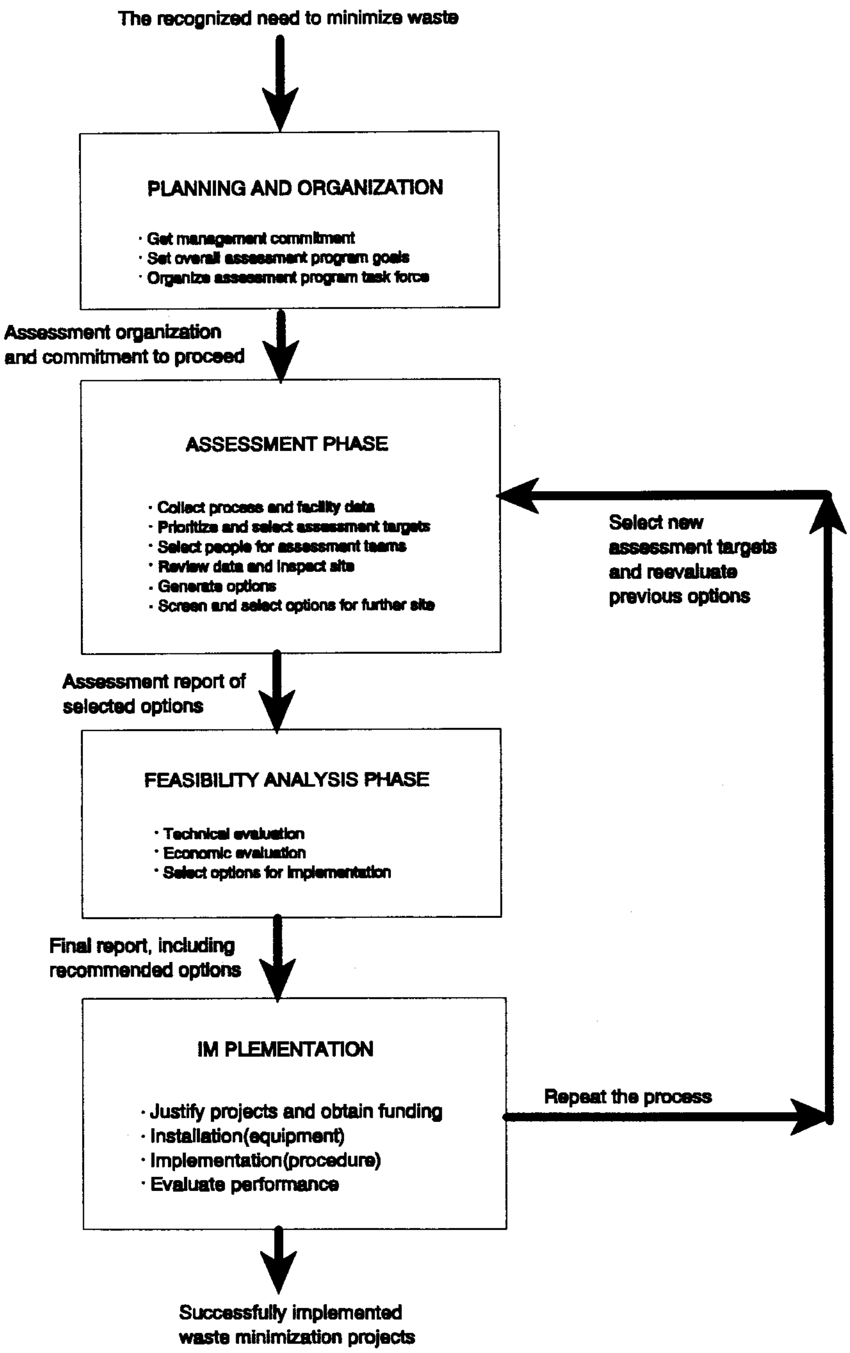

Fig. 3. Roadmap for implementing cleaner production

These are large costs and the trend was for escalating expenditures as successive waves of environmental law amendments were developed. Within companies, costs of 20% of the total manufacturing expenditures for environmental compliance occurred.

Pollution prevention is aimed at avoiding these costs and the escalating trends through future decades. However, the experience with the cost benefits of pollution prevention has shown that regulatory cost avoidance is often exceeded substantially by the cost improvement through greater process efficiency.

From ten randomly selected pollution prevention economic studies with sufficient information to differentiate the origin of savings, a study was done [7], Table 1. In a significant number of cases the dominant fraction of the cost savings occurred from process improvement, rather than avoidance of environmental compliance costs. Thus, the driving forces for pollution prevention may often originate in opportunities to improve manufacturing through a new framework for analysis, namely the environmental emissions.

3. CONCLUSIONS

Chemical engineering plays a major role in the innovative new environmental field of pollution prevention or cleaner technology, particularly as executed in industrial organizations.

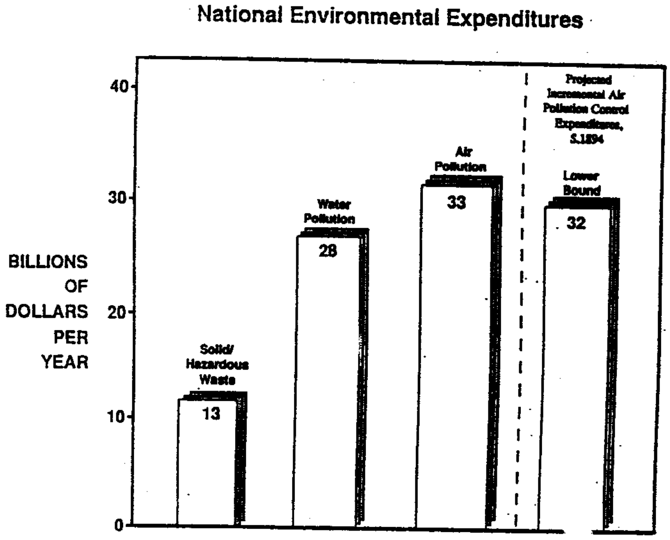

Fig. 4. U.S. Department of comerce, pollution abatement costs and expenditures, 1987)

Table 1. Summary of nine U.S. industrial case studies in pollution prevention
Source: Michael Overcash, original research for this project paper, november, 1991.

Industry Category of the plant	Process Change	Capital Cost (to nearest $500)	Annual Savings (to nearest $500)	% of Savings from Improved Efficiency
Fine Chemicals	Heat recovery	$7,500	$5,000	50%
Chemical Mfg.	Vapor loss reduction	$5,000	$275,000	100%
Food Canning	Stream recapture	$15,000	$45,000	100%
Brewing	Waste as fertilizer	$88,000	$88,000	0%
Textile Mfg.	Effluent heat reduction	$100,000	$50,000	100%
Furniture Mfg.	Hazardous waste reuse	$1,500,500	$905,000	0%
Textile Printing	Solvent recovery	$7,500	$90,000	100%
Metal Finishing	Spray paint loss reduction	$874,000	$642,000	33%
Small Appliance Mfg.	Solvent recycling & substitution	$3,000	$20,500	85%

The principle of a waste management hierarchy and the procedures for achieving cleaner production are generic across industrial boundaries. The economic incentives for pollution prevention remain strong. Undergraduate educational focus on pollution prevention is largely non-existent in 1995, despite the major priority given this field by industry.

The techniques for increasing the awareness by undergraduates of cleaner production are diverse. The greater the commitment and interest by the faculty in pollution prevention, the more progress appears likely in undergraduate education in this field.

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