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Hazardous waste source reduction : an analysis of hazardous waste minimization efforts and source control methodologies

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ABSTRACT

HAZARDOUS WASTE SOURCE REDUCTION:
AN ANALYSIS OF HAZARDOUS WASTE MINIMIZATION EFFORTS AND SOURCE CONTROL METHODOLOGIES

by Donna Smith DiNunzio

The practice and regulation of hazardous waste management have traditionally focused on treatment and long-term storage. Today, these approaches are too costly and industry needs to shift to the prevention of hazardous waste at the source. Despite the many benefits associated with this approach to both government and industry, industry appears reluctant to adopt new measures.

This thesis surveyed businesses in Santa Clara County, California, to determine the previously undocumented status of countywide hazardous waste minimization practices. Those same businesses were surveyed and a review of the safety profession literature was also conducted to identify, analyze, and document barriers and specific source control methods available for hazardous waste minimization efforts.

As access to these methods increases, it will facilitate industry's transition from current treatment to more economical minimization methods. Such a transition will ultimately benefit the environment by reducing the production, storage, treatment of hazardous waste and its associated release of pollutants.

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

ACRONYMS

ARB	Air Resources Board
BAAQMD	Bay Area Air Quality Management District
CAA	Clean Air Act
Cal/EPA	California Environmental Protection Agency
Cal/OSHA	California Occupational Safety and Health Administration
CAS#	Chemical Abstract Registry Service Number
CCR	California Code of Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFC	Chlorofluorocarbon
CFR	Code of Federal Regulations
CPC	California Penal Code
CWA	Clean Water Act
CWC	California Waste Code
DI	Deionized Water
DOT	Department of Transportation
DTSC	Department of Toxic Substances Control
EH&S	Environmental, Health, and Safety
EPA	Federal Environmental Protection Agency

ACRONYMS (Continued)

FDA	Food and Drug Administration
GMP	Good Manufacturing Practices
H&SC	Health and Safety Code
HMBP	Hazardous Materials Business Plan
HMMP	Hazardous Materials Management Plan
HSWA	Hazardous and Solid Waste Act
HWCA	Hazardous Waste Control Act
ISO	Organization for International Standards
LMMS	Lockheed Martin Missiles and Space
MSDS	Material Safety Data Sheet
NPDES	National Pollution Discharge Elimination System
ODS	Ozone Depleting Substance
OPPTD	Office of Pollution Prevention and Technology Development
OSHA	Federal Occupational Safety and Health Administration
P2	Pollution Prevention
PM	Preventative Maintenance
POTW	Publicly Owned Treatment Works
PPE	Personal Protective Equipment

ACRONYMS (Continued)

PRCC	Periodic Report of Continued Compliance
R&D	Research and Development
RCRA	Resource Conservation and Recovery Act
RQ	Reportable Quantity
SARA	Superfund Amendments and Reauthorization Act
SB 14	Senate Bill 14: California Hazardous Waste Source Reduction and Management Review Act of 1989
SOP	Standard Operating Procedure
SWRCB	State Water Resources Control Board
SWPP	Storm Water Pollution Prevention
TRI	Toxic Release Inventory
TSCA	Toxic Substances Control Act
UFC	Uniform Fire Code
U.S.	United States
U.S.C.	United States Code

CHAPTER 1

INTRODUCTION

Statement of the Problem

Importance

Corporations in the United States (U.S.) generate hazardous waste in large quantities. These materials have traditionally been disposed of at landfills, chemical treatment facilities, or by incineration. Today's hazardous waste generators are incurring higher costs for proper storage, treatment, and disposal of hazardous wastes due to a reduction in available disposal space and increased liability of long-term hazardous waste storage facilities.

As these costs continue to rise, companies producing hazardous waste will experience ever increasing negative impacts upon corporate profitability. If companies are to remain competitive, they must adopt and practice another means of hazardous waste management: hazardous waste source reduction.

For multinational or large domestic corporations with vast resources, investing in hazardous waste source reduction is a viable, and often profitable, alternative to traditional disposal methods. This is not the case for small businesses[1] or those with limited resources. For these companies,

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[1] See Glossary for definition of small business as stated in Government Code, Article 2, Section 11342.

establishing a hazardous waste source reduction program has become an almost insurmountable task.

Generality

Although implementation of pollution prevention (P2) strategies for hazardous waste has been widely recognized as resulting in cost savings (Cal/EPA Reporter 1994; Ember 1992; Kerns 1992; Breen 1992; Keane 1992), P2 is not widely practiced yet in the U.S. industrial community (Underwood 1994; Thayer 1992; Rittmeyer 1991; Thomas 1992). Underwood discovered that few source reduction measures were being implemented nationwide.

In California, state regulations mandate that each business consider facility-specific hazardous waste minimization options. These requirements were legislated in the California Hazardous Waste Source Reduction and Management Review Act of 1989[2] and subsequently associated with Senate Bill 14 regulations,[3] hereafter collectively referred to as "SB 14." SB 14 regulations mandate that beginning in 1990, businesses that annually generate more than the threshold amounts of 13.2 tons of hazardous waste or 26.4 pounds of extremely hazardous waste,[4] complete a Hazardous Waste

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[2] Article 11.9 of Chapter 6.5 of Division 20 of the Health and Safety Code (H&SC), commencing with section 25244.12.

[3] Title 22, Chapter 31, Article 1 of the California Code of Regulations (CCR) commencing with section 67100.1.

[4] A third criteria for waste generation was adopted in 1992 under section 25179.7 of the H&SC. This criteria specifies businesses producing more than 5,000 kilograms per year of a listed hazardous waste are also captured under the SB 14 plan requirements.

Source Reduction Plan (hereafter referred to as a "SB 14 plan"). The first SB 14 plans, which were due September 1, 1991, were based on 1990 hazardous waste generation quantities. Subsequent SB 14 plan revisions are due every four years, for example, on September 1, 1995.

With these regulations in mind, what is being done at the locally in California to attain compliance? Santa Clara County, California, was selected to further gain further insight into that question. Isao Kabashu, Program Manager of the Santa Clara County Environmental Management Agency, Pollution Prevention Office, believes many Santa Clara County businesses are implementing SB 14 plans, but has no data to confirm this. One reason county regulators do not know the extent of compliance is they have not yet required the submission of the plans for regulatory review. At the state level, the situation is not much better. The state lead regulatory agency for SB 14 compliance is the Department of Toxic Substances Control (DTSC). Dave Hartley, Chief of Technology Clearing House of the DTSC Pollution Prevention and Technology Department, states the DTSC has only requested copies of SB 14 plans from companies representing one of the following four groups: 1) the semi-conductor industry, 2) the petroleum industry, 3) businesses that use paints, polymers, and resins, or 4) ones that use 1,1,1-trichloroethane. He states that, to date, no enforcement action has been taken for noncompliance with respect to SB 14 mandates. Although all California businesses generating hazardous waste quantities over threshold amounts are required by law to complete a SB 14 plan whether they have complied is unclear. If they have not, what barriers have impeded compliance? For those companies in compliance, have SB 14 plans been a useful tool for finding opportunities to minimize hazardous waste generation and a cost-effective alternative for hazardous waste management? The DTSC conducted a poll in Spring 1995, and 52 percent of those surveyed felt the SB 14 program is a worthwhile exercise for their companies to complete.

This thesis addresses the above questions, but in doing so recognizes that implementation of SB 14 plans is merely one approach to a complex area of business practice. If a business wants to implement hazardous waste minimization strategies effectively, it must develop a comprehensive and systematic plan that considers all aspects of business operations. SB 14 plans are not the solution to hazardous waste generation; rather they are part of a comprehensive change in the way hazardous waste is managed and business is conducted.

Focus

A literature review and a telephone survey were conducted to gather information and data for this thesis. In an effort to better understand how Santa Clara County businesses are complying with SB 14, a telephone survey was conducted, contacting businesses that generated hazardous waste in quantities greater than the SB 14 threshold of 13.2 tons. The purpose of the telephone survey was threefold: 1) to determine what percentage of Santa Clara County businesses are considering hazardous waste minimization through compliance with SB 14 plan requirements, 2) to identify barriers that prevent companies from complying with SB 14 regulations, and 3) to obtain completed SB 14 plans[5] and information about hazardous waste source control methodologies used.

A literature review was also conducted to collect background information about hazardous waste methodologies. This thesis presents various source control methods for hazardous waste minimization available to businesses from the literature and SB 14 plans. This document provides examples of how the implementation of hazardous waste minimization methods and analysis of the benefits and drawbacks associated with these methods.

Purpose, Scope, and Limitations of Thesis

This thesis has three objectives: 1) to determine the status of SB 14 compliance in Santa Clara County, 2) to identify barriers to implementing hazardous waste minimization plans, and 3) to identify methods of pollution prevention through hazardous waste source control that can be implemented

[5] SB 14 plans are deemed public documents in the SB 14 regulations (CCR, Title 22, Section 67100.3 [b]), and must therefore be made available to members of the public upon request.

by companies with limited resources. One of the primary barriers identified in the literature was lack of information on methods for implementing hazardous waste minimization plans. This thesis presents information on source control methods for hazardous waste source reduction, their benefits and drawbacks. Data was collected from a review of the literature and source control methods used in SB 14 plans received from Santa Clara County businesses. The resulting information focuses on aiding local businesses in implementing effective SB 14 plans for hazardous waste minimization and complying SB 14 regulations.

The scope of the thesis is limited to Santa Clara County and source control methods of hazardous waste minimization. The Santa Clara County telephone survey of SB 14 compliance status targeted businesses that in 1993 exceeded the hazardous waste generation thresholds (i.e., greater than 13.2 tons). Santa Clara County was selected to study because of the author's local contacts in the health and safety profession, and because of the substantial industrial base regulated by SB 14 (e.g., the semiconductor industry). Large businesses, not specifically targeted, tended to have well-established plans and to provide higher quality information and are therefore strongly represented in this study.

This study is limited in that not all businesses on the telephone survey list were available for comment. Additionally, the survey list includes only a portion of generators that must comply with SB 14 regulations: those annually generating more than 13.2 tons of waste for off-site disposal. This criterion was considered to be the most important of the SB 14 applicability criteria because it represents the largest amount of waste being tracked by uniform hazardous waste manifest and disposed of off-site.

Lastly, this study focuses on source control, which is only one of the many methods of hazardous waste management.

Methodology

Four types of information were gathered to address the objectives of this study: 1) a literature review, 2) a review of sixteen SB 14 plans submitted by businesses in Santa Clara County for use in this thesis, 3) information presented at a professional conference,[6] and 4) telephone surveys with local professionals and regulatory agencies, for example, the DTSC and the Santa Clara County Office of Pollution Prevention.

The Tanner 1 report and a telephone survey were used as the primary sources of information to address the first topic, the status of Santa Clara County's SB 14 regulatory compliance. The Tanner 1 report for 1993 was obtained from the California Environmental Protection Agency (Cal/EPA),

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[6] Environmental Assistance for Local Businesses, "A Conference for Industry by Industry, Pollution Prevention." Conference presented to Alameda County businesses sponsored by the Union Sanitary District, Fremont, California, 21 March 1995.

DTSC. It identifies California businesses, sorted by county, that generated hazardous waste during 1993. Calendar year 1993 was selected because it is the most current year for which data is available. This report, which is a public document, is a computer print-out from the DTSC database of hazardous waste generation. It provides information about hazardous waste producing businesses including facility name, address, county, EPA identification number, and annual quantity of hazardous waste generated.[7] Using this report, Santa Clara County businesses generating greater than 13.2 tons of hazardous waste were identified for a telephone survey.[8] Of the 3509 businesses generating hazardous waste in Santa Clara County in 1993, 327 generated more than 13.2 tons of hazardous waste. Each of these 327 businesses is required to complete a SB 14 plan. All 327 of these businesses were contacted regarding the telephone survey, but only 113 business representatives consented to participate. Interviews were conducted with the company representative who has primary responsibility for environmental

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[7] For the purposes of this report, hazardous waste includes all hazardous waste shipped off-site with a uniform hazardous waste manifest. This could be hazardous waste, extremely hazardous waste, or listed hazardous waste. The Tanner 1 report does not differentiate the types of hazardous waste being generated.

[8] SB 14 requires the following categories of hazardous waste generators to complete SB 14 plans: 1) generators of greater than 13.2 tons per year of hazardous waste, 2) generators of more than 26.4 pounds per year of extremely hazardous waste, 3) generators of listed hazardous waste, and 4) generators that treat hazardous waste on-site (e.g., wastewater neutralization systems). Unfortunately, the Tanner 1 report does not distinguish between categories one through three. Category four is not tracked by the Tanner 1 report. Regardless of the type of waste generated, if the quantity exceeds 13.2 tons annually, SB 14 compliance is required.

compliance. In large companies, this individual was often the environmental, health, and safety manager. In smaller companies, the range of representatives included mechanic, maintenance manager or supervisor, production supervisor, operations manager, plant superintendent, safety officer, off-site consultant, lab scientist, and shop supervisor. The telephone survey consisted of five questions (see Appendix One for a copy of the survey form). The DTSC also conducted a similar survey and presented me with the unpublished data. The telephone survey results are presented and discussed in chapter 5.

The telephone survey was also used, in conjunction with a literature review, to identify obstacles businesses face in minimizing hazardous waste generation and implementing a SB 14 plans. If a business representative indicated during the telephone survey that it had not prepared a SB 14 plan, information was gathered about the reasons for noncompliance. Chapter 4 presents the barriers businesses face when implementing SB 14 plans in Santa Clara County, as determined in the telephone survey, as well as other barriers drawn from the literature review.

The types of source control methods used by businesses for SB 14 plan implementation were identified through review of the current hazardous waste minimization literature and review and analysis of sixteen SB 14 plans voluntarily submitted by Santa Clara County businesses.[9] The current literature was surveyed for source control methods and categorized into the various subtypes of those methods. Examples of source control methods were drawn from the review of SB 14 plans and used to support or supplement those methods identified by the literature review. Analysis of each method, including benefits and drawbacks, is presented in chapters 6 through 9.

The survey provided supporting data on what companies in Santa Clara County are doing to reduce hazardous waste at the source through implementation of the SB 14 regulations. It also provided information about was able to gather information about why people, required by law to complete the SB 14 plans, did not. Additionally, specific source control methodological data from the existing SB 14 plans were collected, and a detailed literature review was conducted.

Research Questions

This thesis addresses the following research questions regarding SB 14 compliance and types of hazardous waste source control methods available to industry:

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[9] Although 40 businesses indicated that they had SB 14 plans, only sixteen were willing to provide a copy of this public document. Businesses were generally reluctant to share this type of information with the author, which may indicate that the extent of compliance is actually lower than that indicated by respondents.

A. What is the status of SB 14 plan compliance in Santa Clara County by the portion of the industrial community regulated under 1993 generation quantities?

1) Of those Santa Clara County companies required to comply with SB 14 regulations based on their 1993 hazardous waste generation, what percentage have a documented program in place?

2) What barriers do businesses face in implementing hazardous waste minimization plans?

B. What hazardous waste source control methods are available, and of those, which are currently in use in Santa Clara County?

1) Of the methods identified, what are the associated benefits and drawbacks?

C. How can the information from A. and B. be used to implement more effective SB 14 plans at businesses with limited resources in Santa Clara County?

1) How is information on source control methods best presented to small businesses to facilitate SB 14 plan preparation and method implementation?

CHAPTER 2

HISTORICAL PERSPECTIVE OF HAZARDOUS WASTE MANAGEMENT

Introduction

To appreciate the history of hazardous waste management in the U.S., one must understand the evolution of the concept of controlled waste and the economics of managing that waste. This chapter describes the evolution of several regulatory and economic aspects of hazardous waste management: 1) changes in legal limits for discharge of waste materials to the environment, 2) increased costs associated with a higher level of waste control, 3) how a more comprehensive system of cost incentives[10] is forcing industry to re-examine its waste generation practices, and 4) how the development of more stringent environmental, health, and safety regulations (e.g., Comprehensive Environmental Responsibility, Compensation, and Liability Act liability) adds to the cost of disposal and management. The combined effect of the above-listed elements and others has increased the cost incentives for industry to reduce and prevent hazardous waste generation. This growing trend is the basis for industry's reconsideration of pollution prevention (P2).

[10] See chapter 3, tables 1 through 5, for a list of the types of costs incurred in managing hazardous waste.

Traditional Approaches to Hazardous Waste Management: World War II Through the Early 1970's

Between 1945 and the early 1970's, little thought was given to management and disposal of industrial hazardous waste (Josephson 1993; Underwood 1994). In hindsight, most businesses disposed of hazardous materials irresponsibly by simply discharging their industrial by-products in land or water, without regard to potential consequences. This practice was partly due to ignorance and partly because releases to the environment imposed no direct cost to the disposer.

In the early 1970's, state and federal regulators began to appreciate the tremendous costs to society of loosely-regulated discharges of hazardous materials (Underwood 1994). As a result, new federal regulations, such as the Clean Air Act (CAA)[11] of 1970 and the Clean Water Act (CWA)[12] of 1972, began to control pollution discharges, marking a dramatic change from earlier federal approaches to environmental regulations. Although the CAA and the CWA were positive steps towards reducing the amount of waste discharged into society's air and waterways, other, stricter federal

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[11] The Federal Clean Air Act of 1970, Code of Federal Regulations Section 70, consisted of amendments to previous legislation dealing with air pollution standards. The act was further amended in 1977 and allow for the more realistic attainment of deadlines.

[12] Federal Water Pollution Control Act (the "Clean Water Act"), 33 U.S.C. Sections 1251-1387.

environmental regulations that were adopted later caused companies, for the first time, to bear the costs of environmentally-responsible waste management.

These later federal regulations, including the Resource Conservation and Recovery Act (RCRA) of 1976,[13] its 1984 amendments under the Hazardous and Solid Waste Act (HSWA), and the associated with the federal Comprehensive Environmental Compensation and Liability Act (CERCLA) of 1980 imposed on business, for the first time, the financial responsibility of managing hazardous wastes from its creation to destruction, or "cradle to grave" (Cheremisinoff 1992; Cohen 1992; Keane 1992).[14]

Shifts in Hazardous Waste Management Approaches

Institutionalization of "End-of-Pipe" Technologies

Although the new legislation significantly increased control of releases of pollution to the environment, it failed to address the root cause of the problem, pollution itself. Legislation under the CWA and CERCLA focused on pollution control only after the pollution had been created. This

[13] RCRA was enacted in 1976 as an amendment to the Resource Recovery Act, which was a 1970 amendment to the Solid Waste Disposal Act of 1965 (Keane 1992). Under RCRA hazardous waste was defined into four categories (ignitable, reactive, corrosive and toxic).

[14] It should be noted that California was a front runner with environmental legislation regarding hazardous waste. In 1972 the Hazardous Waste Control Law (H&SC, Chapter 6.5, Sections 25100-25250) was enacted. This is the major law dealing with hazardous waste management in California.

legislation sought to control pollution at the point it was being discharged (e.g., the end of pipe). This is defined as point-source pollution control. As a result, limits for pollution discharge were set and controlled at the point of discharge. Once a control measure was set, industry was forced to comply with those standards by limiting the amount of waste released from the facility accordingly. Industry was responsible for quantifying and controlling waste discharged from the facility to air, water, and soil. Industry accomplished this objective primarily by investing in end-of-pipe pollution control equipment and methods, such as, installing precipitators, scrubbers, and waste neutralization systems.

These end-of-pipe control techniques served two purposes. First, they addressed larger quantities of waste than had been regulated under the traditional system of uncontrolled discharge to the environment. Secondly, companies had a defined standard of pollution control to achieve, and therefore they knew whether or not they were in compliance with regulations. These processes and methods for pollution control were institutionalized and industry gained expertise in this type of regulatory compliance. Additionally, those responsible for enforcing the control standards, the regulators, became familiar with end-of-pipe regulations and their associated enforcement action.

It is this institutionalization and investment in pollution control methodology that currently impedes innovations Freeman 1992).[15] To give an example of the gravity of the situation, Freeman et al. (1992) state that over 99 percent of all federal and state funding is devoted to controlling pollution after waste is generated, and less than 1 percent is spent on P2.

Traditional Approaches No Longer Feasible

Over the past decade, the long-term financial liabilities associated with hazardous waste treatment, storage, and disposal and the scarcity of disposal sites have made hazardous waste generators and regulators alike more conscious of the need to reduce or eliminate the quantity of wastes leaving industrial facilities for disposal (Cohen 1992; Ember 1992). As a result of this new awareness, regulatory agencies reacted with a new regulatory approach: one that shifted from the traditional "end-of-pipe" pollution control to P2 (Thayer 1992). In doing so, legislation was enacted to reduce hazardous waste production, leading to a new form of legislation. Instead of the traditional and prescriptive command-and-control form, the new compliance mandates were more voluntary in nature. Instead of setting limits which companies must comply with, the new structure of legislation mandated industry to "consider" source reduction as the preferred method for managing hazardous

[15] See chapter 4 for discussion of the institutional barriers associated with P2.

waste (Cal/EPA Reporter 1994; Cal/EPA, DTSC, Office of Pollution Prevention 1993).

In California, the resulting environmental legislation was the Hazardous Waste Source Reduction Management Review Act of 1989 (SB 14). SB 14 requires companies generating certain quantities of hazardous wastes to evaluate hazardous waste source reduction measures and promotes hazardous waste reduction at the source. At the federal level, additional RCRA legislation enhanced the P2 approach by requiring companies to report the ultimate fate of 300 chemicals and to publicly report on waste management efforts (e.g., biennial reports,[16] SARA Title III Toxic Release Inventory reports,[17] etc.) (Thayer 1992). To further promote the pollution prevention approach, the EPA established a national hierarchy for waste management in the Pollution Prevention Act of 1990.[18] This act focuses on

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[16] The biennial report is required in H&SC Division 20, Chapter 6.5 of the Hazardous Waste Control Act. It is also required in CCR Title 22, Division 4.5, Chapter 30. This report is required from the Cal/EPA DTSC if the business generates greater than five tons of hazardous waste per year.

[17] SARA Title III, Section 313, Toxic Release Inventory (TRI) requires the annual reporting of releases to the environment of listed toxic chemicals being used under 40 CFR Section 372. The report, which is entitled "Form R." must be filed by qualifying businesses annually.

[18] The Federal Pollution Prevention Act of 1990 established a national hierarchy for hazardous waste disposal by declaring it national policy that pollution should be prevented or reduced at the source whenever feasible. Pollution that can't be prevented should be recycling in an environmentally-safe manner whenever feasible. Pollution that can't be prevented or recycled, should be treated in an environmentally-safe manner. Disposal or other releases to the environment should be employed only as a last resort, and should be conducted in an environmentally-safe manner (Clayton 1994).

preventing or reducing waste at the source or source reduction in place of treatment, disposal, or releases to the environment (Thayer 1992; Cal/EPA, DTSC 1993; Mizsey 1994). Finally, President Clinton mandated that federal agencies shift towards P2 methods.[19] Regulatory tools became available to encourage businesses to voluntarily shift their hazardous waste management perspectives from control to prevention.

Current Hazardous Waste Management: the 1990's

Whether today's management plan is termed "zero discharge," "hazardous waste minimization," "emission reduction," "source reduction," or "waste reduction," it falls under the concept of P2. The environmental and economic imperative to achieve P2 has been heralded as "the environmental theme of the 1990's" (Breen 1992; Underwood 1994; Cohen 1991). Support for these preventative approaches is broad-based and includes environmentalists, industrialists, law-makers, academics, regulators, policy-makers, and economists (Breen 1992). The common sense of the P2 concept seems obvious to all parties. With a large pool of professionals and industries involved, the potential for creative preventive solutions seems great.

Despite the broad-based support, there is some question whether P2 can

[19] Executive Order 12873-Federal Acquisition, Recycling and Waste Prevention, October 20, 1993, states that "...whereas, the Nation's interest is served when the Federal Government can make more efficient use of natural resources by maximizing recycling and preventing waste whenever possible...." In Section 208, "waste prevention" is defined as source reduction to reduce the volume or toxicity of waste.

enjoy wide-spread implementation in today's competitive market-based economy: can businesses within the same industry cooperate with each other? Can industry and government work together effectively? Reisch (1993) found that industry can do more to cut chemical waste production through cooperation than by confrontation. He found that EPA's and Du Pont's combined effort to minimize hazardous waste yielded cost savings by improving production efficiency and lowering waste disposal costs.

Does this mean we are entering a new era of cooperation between EPA and industry or a new era of corporate P2? Alm (1992) believes companies need to see their products in the light of their environmental impact and by doing so will more effectively achieve P2 goals. He believes the U.S. is not yet there, and a new paradigm will be developed. To achieve P2 goals would require a strong commitment and decentralization of operations. Does our current corporate hierarchical structure impede this progress? This question and the barriers currently facing businesses in achieving P2 objectives will be discussed in the next chapter.

The major questions raised in the literature about P2 are "What are the effects of this new regulatory structure?" and "How effective are P2 regulations at the local level?" These questions also will be discussed in the following chapters. Remember that new waste minimization objectives and regulations come without authority or, generally, the expertise to regulate production activities. At the national level, P2 objectives are established essentially because there are no national reporting requirements by the EPA (Breen 1992; Underwood 1994; Clayton Environmental Consulting Inc. 1994). For example, under the Federal requirements for National Pollution Discharge Elimination System (NPDES),[20] all facilities must complete a Storm Water Pollution Prevention Plan (SWPP), but submission of the plan to the EPA or local implementing regulatory agency is not required (Clayton Environmental Consulting Inc. 1994). Similarly, there are no federal reporting requirements under the Pollution Prevention Act of 1990. Instead, the EPA has relied on voluntary efforts by industry to achieve P2.

At the state level in California, reporting requirements are similar. Although there are stiff penalties for not preparing and maintaining SB 14 plans,[21] the DTSC has not used penalties to enforce compliance. To date, DTSC has requested only a few SB 14 plans and has yet to aggressively enforce compliance with P2 regulations.[22]

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[20] In 1987, the Federal Water pollution Control Act (known as the Clean Water Act) was amended to include Section 402 (p), which established the framework for regulating municipal and industrial storm water discharges under the NPDES program. In 1990, a NPDES permit was required which requires the development of a SWPP plan. Although SWPP plans are considered public documents under Section 308 (b) of the CWA, they are not required for submission to U.S. EPA. The California State Water Resources Control Board adopted the federal recommendations and required permit compliance by 1992 (State Water Board, Water Quality Order No. 91-13-DWQ, NPDES).

[21] The plan must first be requested by the Cal/EPA or other governing agency either during an inspection or by a written request. If a plan is not submitted within 5 days of an on-site inspection or 30 days of a written request, the penalty is $1,000 per day late (Cal/EPA, DTSC 1994c).

[22] The telephone survey of Santa Clara County, California, revealed that the majority of businesses have not yet submitted plans to the state.

Industries have spent two decades investing in "end-of-pipe" technologies, and have complied with discharge-based regulations. If businesses are to shift business practices to P2, they need help in effectively achieving those goals (Breen 1992). Dissemination of waste minimization methods, other than those previously developed and proven through end-of pipe pollution technologies, will help demonstrate the economic and environmental benefits of a source reduction technologies (Cal/EPA Reporter 1994).

Because P2 is relatively new to both industry and regulators, implementation will take time. Most businesses have been slow to adopt proven methods of reducing hazardous waste production, and have yet to enjoy the associated source reduction and resulting increased profitability. P2 strategies have been underused throughout much of the industrial U.S. (Underwood 1994; Cheremisinoff 1992). Hazardous waste production needs to be viewed as a sign of inefficient business practices. If viewed in this manner, waste managers expand their concept of efficient and competitive business practices to include P2. Until this fundamental shift occurs, P2 will likely continue to be underused in the U.S.

Although hazardous waste is an inevitable by-product of most manufacturing facilities, the cost of managing it acts as an incentive for industry to practice hazardous waste source reduction (Underwood 1994). When industry does so, it increases productivity while simultaneously protecting human health and the environment (Wentz 1995; Thomas 1992).

CHAPTER 3

HAZARDOUS WASTE MANAGEMENT PRACTICES--COSTS AND BENEFITS

Costs of Managing Hazardous Waste

There are several reasons why companies should be interested in developing a P2 program to minimize hazardous waste production. One of the most persuasive reasons is economic. There are three major cost incentives associated with hazardous waste generation: 1) storage, handling, and disposal costs, 2) regulatory compliance costs, and 3) liability for contaminated hazardous waste site clean-ups.

There is limited hazardous waste storage capacity, and as that capacity becomes filled, costs rise (Cheremisinoff 1992). For example, land disposal, which once cost ten dollars per ton of waste, now costs at least $240 per ton (U.S. EPA, Risk Reduction and Engineering Lab 1990). In accounting for the operating costs associated with hazardous waste management (regulatory reporting, penalties for violations, employee training, etc.), the profitability of preventing pollution rather than managing it has been well documented (Cal/EPA Reporter 1994; Ember 1992; Kerns 1992; Breen 1992; Keane 1992; Sun 1982; Cheremisinoff 1992; Kobashi 1994). The most compelling cost incentive associated with hazardous waste minimization is the potential reduction in corporate potential liability under CERCLA. This potential cost alone has made many companies re-evaluate their waste production processes (McClintock 1987; Cal/EPA, DTSC 1988).

Hazardous Waste Storage, Handling, and Disposal Costs

Hazardous waste is expensive to treat and dispose of properly. Federal, state, and local regulations require that hazardous waste be managed from the time of its generation to its ultimate disposal or from "cradle to grave."[23] Required management practices include tracking capabilities at all levels of the waste management cycle. This typically starts with proper storage of waste while it is being generated: labeling materials, proper storage, spill containment, and control. From there, employees must be trained to understand and abide by the storage and clean-up rules. Eventually, a licensed waste hauler, whether maintained as an in-house capability or retained as a contractor, will be required to package, manifest,[24] and haul the waste for proper disposal. Although hazardous waste handling and treatment costs vary with the type, volume, and degree of toxicity, it is always an additional business expense. For example, bulk disposal of one 55-gallon drum of flammable liquid waste can typically cost $1,000 for handling, transportation, and disposal. Nonbulk disposal through lab packs (drums or boxes of several distinct, but compatible,

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[23] For example: 40 Code of Federal Regulations, parts 260-270; California H&SC, Division 20, Chapter 6.5 of the Hazardous Waste Control Act; CCR Title 22; and Santa Clara County Hazardous Materials Storage Ordinance.

[24] A uniform hazardous waste manifest is used to document the location and transfer of hazardous waste from the point of generation to the final disposal location.

waste containers) can be even more costly per unit volume. Current prices can be hundreds of dollars for small volumes of waste, including the costs to profile, handle, transport, and dispose of the waste.[25]

Certain wastes are restricted from land disposal until acceptable treatment is developed. In this case, companies must store these wastes on site until alternatives are developed. Prior to even incurring the storage costs, many companies must contract with waste haulers to package and handle the waste; labor rates are usually over $100 per hour.[26] When hazardous waste is stored at a facility, a variety of regulatory reports are required by local, state, and federal agencies. These compliance burdens for hazardous waste management and associated costs are only going to increase as landfills reach maximum capacities and emissions limitations become more restrictive (U.S. EPA, Risk Reduction and Engineering Laboratory 1990).

Hazardous Waste Regulatory Compliance Costs

When a company begins to generate hazardous waste, a complex set of regulatory reporting and compliance activities are required by local, state, and federal government agencies. If the regulations are not followed, penalties can be incurred. (See table 1 for examples of environmental, health, and safety violations, and associated penalties, pertaining to hazardous waste. See

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[25] Costs from disposal invoices received by Collagen Corporation, Palo Alto, California.

[26] Costs from invoices received by Collagen Corporation Palo Alto, California.

tables 2, 3, and 4 for examples of rules companies must comply with on the federal, state, and local levels, respectively, regarding hazardous waste management.) As demonstrated in these tables, the compliance obligations are substantial. Environmental, health, and safety regulations mandates are numerous and complex and are ultimately costly for businesses to comply with.

For example, local fire departments require companies who handle hazardous materials to prepare Hazardous Materials Business or Management Plans (HMBP and HMMP respectively), inventory all hazardous materials, as well as have emergency response capabilities. It costs Collagen Corporation of Palo Alto, California, thousands of dollars for report preparation and maintenance of response capabilities to comply with this agency's regulations alone. The larger the quantity of hazardous materials kept on-site, the greater is the commitment to cost of materials maintenance and regulatory compliance. Regulatory compliance is expensive, and as rules and regulations become more sophisticated, the cost of compliance will increase.

In summary, the economic incentives to reduce regulatory compliance costs are great. One method to reduce regulatory compliance costs is to reduce the amount and toxicity of the materials that are being regulated, particularly materials with complicated and expensive management requirements, such as hazardous wastes.

Table 1.--Environmental Regulatory Compliance Costs Associated with Hazardous Waste Management

Violation	Potential Penalty	Legal Citation*
Criminal act (e.g., nonpayment of taxes and fees regarding hazardous materials, falsifying documents, unlawful hazardous waste disposal. See tables 2, 3, and 4 for some regulations these rules apply to)	$25,000/day/violation of regulations, 3 years of prison or both for managers	California Corporate Criminal Liability Act, CPC 387 (a)
Failure to submit Toxic Release Inventory	$25,000/day	40 CFR Section 372
Failure to submit chemical inventories or HMMP	$10,000 or $25,000/day and civil action	H&SC 25503.5-25505
Failure to keep hazardous waste manifests filed properly for 3 years	$25,000/day	22 CCR 66262.20
Failure to report chemical releases to air, water (groundwater, storm drains, and POTW), soil when over specific reportable quantities (RQ) (landfill leachate and spill to soil, underground storage tanks)	Between $5,000-$25,000/day, plus 1-2 years prison, or both	CWC 13271(c); H&SC 25359.4(d), 25189.2(c), 25507, 25501(k); CCR Title 22 66264.56(d); 42 U.S.C. 9609(a)-(b); 40 CFR, 302.7, 355.5, 6928(a), and (e); CCR Title 23 2251
Noncompliance with Bay Area Air Quality Management District permit	$25,000/day/violation	42 U.S.C. 7413 (b)
Noncompliance with National Pollutant Discharge Elimination System (NPDES) Permit (i.e., stormwater discharge)	Civil penalty of $25,000/day/ violation and potential prison, criminal penalty of $25,000/day, 1 year in prison or both	40 CFR 122.41 (a), CWC 13370 et. seq.)
Superfund (CERCLA) sites and hazardous waste disposal	Liability	40 CFR, 302.6 (a)
Improper handling of hazardous waste	$250-$25,000 per drum	40 CFR and Title 22 CCR
Failure to submit plans and procedures (e.g., Hazardous Materials Management Plan; SB 14 Plan)	$2,000/day/agency; $1,000/day	CCR T22, 67100.3 (a)
Environmental monitoring costs	For example, lab fees associated with wastewater monitoring as required by local POTW for Periodic Reports of Continued Compliance	Chapter 16.09 of the Sewer Use Ordinance (Palo Alto Municipal Code)

* Legal citations obtained from Landels, Ripley, and Diamond Law Firm.

Table 2.--Examples of Federal Environmental, Health, and Safety (EH&S) Regulations Associated with Hazardous Waste Management

Federal Agencies*	Regulations/ Statutes*	Some Examples of Action Required*
Environmental Protection Agency (EPA): Office of Solid Waste and Emergency Response	40 CFR CERCLA (Section 280) CWA (Section 117) TSCA (Section 761) CAA (Section 70) RCRA (Sections 260-70) SARA (Section 372)	SWPP Training, Taxes, NPDES Permits, Biennial Generator Reports, Notification, Records, EPA Id. #, Manifest management, Inspections by agencies (fines, penalties, and time), Toxic Chemical Release Report (TRI -Form R) See State: Cal/EPA (state rules comply with federal rules)
Occupational Safety and Health Administration (OSHA)	29 CFR	See State: Cal/OSHA (state rules comply with federal rules)
Department of Transportation (DOT)	49 CFR Section 171 (Hazardous Materials Transportation)	Reporting, Biannual Training, Bill of Lading
Nuclear Regulatory Commission (Radioactive Hazardous Waste)	10 CFR	See State: Health and Welfare Department Permits, Training, Inspections by agencies (fines, penalties, and time), proper storage, disposal, and monitoring
Department of Fish and Game	Water Quality	Spill Reporting
Coast Guard	Water Quality	Spill Reporting

* See Acronyms list for definitions.

Table 3.--Examples of California EH&S Regulations Associated with Hazardous Waste Management

State Agencies	Regulations/ Statutes	Some Examples of Action Required
Cal/EPA Department of Toxic Substances Control State Water Resources Control Board Air Resources Board Office of Environmental Health Hazard Assessment	HWCA, H&SC, Division 20, Chapter 6.5, CCR Title 22, Division 4 , Chapter 30 CCR Title 23 (Water, Underground Storage Tanks), Porter-Cologne Water Quality Control Act, CWC, 13000 et. seq.	SARA Title III Toxic Release Inventory Report (Form R) 40 CFR 372 Hazardous Waste Minimization Plans-written plan and reporting (H&SC 25244.12) Hazardous Waste Manifest Fees (H&SC 25205.15) EPA Id # Verification Fees (H&SC 25205.16) Inspections by agencies (penalties and time) Proposition 65 Postings (Title 22, Division 215, Section 12000) SB 14 Plans (Title 22, Section 67100) SWPP Plan and Monitoring (CWC 13000)
Cal/OSHA	CCR Title 8	Inspections by agencies (fines, penalties, and time) Written plans, procedures, and training (i.e., Hazard Communication (Section 5194), IIPP (Section 3203), PPE (Section 3203), Respiratory Protection (Section 5144), Chemical Hygiene (Section 5191), Hazardous Waste Operations and Emergency Response [Section 5192]) Industrial Hygiene Sampling (Section 5144, 5209)
California Highway Patrol (Transportation)		Reporting of hazardous materials incidents on the highway.
California State Health and Welfare Agency-Radiological Health Branch (Radiation Safety)	CCR Title 17 Radioactive Hazardous Waste	Taxes and fees Inspections by agencies (fines, penalties, and time), training permits, proper storage, disposal, and monitoring.

Table 4.--Examples of Local EH&S Regulations Associated with Hazardous Waste Management

Local Implementing Agencies	Regulations/ Statutes	Some Examples of Action Required
Publicly Owned Treatment Works (POTW)- Water Quality and Pollution Control Plants	Municipal Codes Local Sanitation District regulations	Permits, taxes, and fees Inspections by agencies (fines, penalties, and time). Cease and desist for illegal hazardous waste discharges.
Bay Area Air Quality Management District (BAAQMD)	Municipal Codes	Permit to operate, taxes, and fees Inspections by agencies (fines, penalties, and time)
Fire Department - Hazardous Materials Division/Unit	Uniform Fire Code	Taxes and fees Inspections by agencies (fines, penalties, and time) HMMP or HMBP (25506[b]) Risk Management Prevention Plan (H&SC 25534 (h) Acutely Hazardous Materials Permit (H&SC 25533-25541)
County Health Department (Hazardous Materials & Waste)	Municipal Codes (i.e., Santa Clara County Hazardous Materials Ordinance, Hazardous Materials Division)	Taxes and fees Inspections by agencies (fines, penalties, and time) Hazardous Waste Generator Permits
Santa Clara Valley Nonpoint Source Control Program	Local ordinances	
Regional Water Quality Control (all point source discharge to waters including POTW discharge)	Local ordinances	

Hazardous Waste Liability Costs for Clean-Up at Disposal Site (CERCLA)

As illustrated in tables 1 through 4, there are numerous EH&S regulations, and compliance and liability concerns at the federal, state, and local levels that are activated when hazardous waste is generated at a facility. One federal regulation, CERCLA, has broad ramifications for corporate liability and warrants additional discussion. Although there are financial liabilities and costs associated with all EH&S regulations, CERCLA provides for far-reaching liability and potential costs for hazardous waste management.

CERCLA introduced a previously unknown and a more significant form of hazardous waste liability. Under CERCLA, hazardous waste that is shipped off site for disposal now poses a long-term liability for all companies generating it, almost without exception. Under CERCLA, or "Superfund" regulations, companies potentially bear a costly liability associated with unconfined or leaking hazardous waste disposal sites (Sell 1992). For example, the federal EPA has identified some 27,000 hazardous waste sites with an estimated clean-up cost of $25 million per site (Newell et al. 1990). Newell also indicates that even property that is only mildly contaminated or suspected of being contaminated has only a limited marketability or impaired future collateral value and therefore carries with it potentially significant indirect costs. Hazardous waste disposal sites are determined to threaten the general public; liability for hazardous waste clean-up costs is strict and severe. This is because a generator can be held liable for clean-up costs of the entire site, even if the generator only disposed of a small portion of waste at that site (Cal/EPA, DTSC 1988). Additionally, CERCLA liabilities are retroactive. Generators can be held liable for pollution resulting from practices that, although illegal today, were legal at the time of release. Finally, there is no need to show that generators were negligent, only that they contributed wastes to the site.

Sun (1982) states that the cost of CERCLA is enormous because such a large percentage of businesses are covered under the regulations. With at least 10,000 transporters of waste and as many as 20,000 facilities in 1982 that store, treat, or dispose of chemicals, the number of potentially-responsible parties under this legislation is enormous. This demonstrates that the financial implications of CERCLA liability can be staggering. Cleanups commonly can cost several million dollars (McClintock 1987; Cal/EPA, DTSC 1988).

To cover such immense liability, generators prefer to rely on insurance coverage. However, insurance covering the liabilities for gradual environmental release of hazardous waste is essentially unavailable (Newell et al. 1990). Insurance policies currently offered usually only cover sudden and accidental pollution. To manage business risks associated with hazardous waste, companies are either self-insured, form risk-retention groups, or remain uninsured (Cal/EPA, DTSC 1988).

If one considers the total cost of hazardous waste management, including compliance with EH&S regulations, RCRA requirements, and CERCLA liability, minimizing hazardous waste generation has excellent potential to save companies money. However, economic benefits are not the only virtue of P2: there are also intangible benefits from more efficiently using natural resources and protecting the environment and public health from the associated hazards. Kobashi (1994) and Cheremisinoff (1992) agree that if a business is to remain competitive and succeed in the 1990's and beyond, it must fundamentally change its approach to hazardous waste management. They both recommend a shift from post-generation treatment and disposal methods to P2 strategies that maximize production efficiency and minimize waste generation. Economic analysis of hazardous waste management clearly indicates that reducing hazardous waste generation can greatly reduce the cost of conducting business under the traditional post-generation treatment and disposal approach.

Benefits of Hazardous Waste Source Reduction

The high cost of business expenses, liability, and compliance responsibilities associated with hazardous waste management is only one reason to reduce hazardous waste generation. There are other, often unquantifiable, benefits of hazardous waste reduction. The benefits of hazardous waste P2 can help an industry increase productivity through increased efficiencies, while simultaneously providing environmental protection (Thomas 1992). The benefits derived from implementing hazardous waste minimization measures through evaluation of processes from a new perspective numerous: reduced regulatory burden and long term liability, improved environmental, health, and safety impact, as well as improved public image and operating efficiency. Some examples of each type of benefit are presented:

1) Reduced Regulatory Burden

- off-site waste transportation, treatment, and disposal costs are reduced
- hazardous waste generator permits, taxes, and fees are reduced
- compliance with current environmental regulations is attained and often easier to maintain
- regulatory agencies and companies can work together to attain common P2 goals

2) Reduced Long Term Liability

- reduces fines and compliance costs
- facilitates acquisitions, mergers, and international activities
- reduces future civil and criminal prosecutions and liability
- future problems, such as, those experienced under CERCLA, are avoided
- reduced need for pollution liability insurance

3) Improved Environmental Impact

- more efficient use and protection of energy supplies and natural resources
- reduced need for emergency spill response planning and associated equipment and training
- less need for waste treatment and landfill capacity
- more effective management of waste streams
- less pollution released to environment, resulting in lower remediation costs
- minimize uncertainty and impact to the environmental quality and public health if releases occur

4) Improved Workplace Safety and Health for Employees

- safer work conditions and fewer occupational exposures, hazards, and associated on-the-job injuries or illnesses will benefit employees and the community at large
- employee accident and exposure costs, compensation, and insurance premiums could be reduced
- improved employee relations can result from increased attention to health and safety issues

5) Improved Public Image

- enhanced public image and improved public attitude towards relations with company

- efforts to protect the local environment may result in potential marketing advantages through positive media coverage
- may attract top professionals
- improves financial analysis (50 percent of Fortune 200 companies report P2 progress in annual financial reports)

6) Increased Operating Efficiency and Reduced Capital Expenses

- increased product yield, quality and productivity with a reduction in scrap, rework, and defects
- reduced expenses and operating costs (increased operating profits)
- improved process control
- low cost of achieving waste reduction with documented return on investment
- reduced total cost of raw materials through maximum use of these materials
- expanded market share with "green" products
- incentive to invest in R&D that improve business operations, such as, new processes for manufacturing new or existing products
- reduced laboratory analytical costs (for compliance with treatment and disposal standards)

(Cheremisinoff 1992; Kerns 1992; Breen 1992; Benforado 1991; Kobashi 1994; Ember 1992; Huff 1995; Hirschhorn 1991; Lurker 1995, Underwood 1994).

As illustrated in this chapter, the benefits of hazardous waste source reduction are numerous. Companies implementing source reduction will derive economic benefits, such as, reduced operating and compliance costs and liability, as well as intangible benefits, including reduced environmental impact, improved worker health and safety, enhanced public image, and increased operating efficiency. The tangible and intangible benefits of adopting a source reduction approach to hazardous waste are compelling and create strong incentives for industry to replace the traditional, post-generation management strategy with P2.

CHAPTER 4

BARRIERS TO IMPLEMENTING HAZARDOUS WASTE MINIMIZATION PLANS

Introduction

Despite strong evidence of cost savings and other benefits associated with hazardous waste reduction, U.S. industry has begun to utilize the potential of P2 (Underwood 1994). Industry has been slow to incorporate P2 into business practice and to reap the economic and intangible benefits of P2 because of several obstacles (Thomas 1992). These obstacles are both external to industry, for example, the scarcity of information, and internal to industry, including institutionalization of pollution control approach and fragmented management and limited resources (both financial and time) that prevents the total cost of pollution from being recognized and addressed by business operations. These numerous barriers are discussed in detail in this chapter.

Any change in business practice leaves industry, especially in businesses with limited resources, with a lack of financial resources to implement changes. Some businesses cannot afford to undertake initial P2 evaluations, to say nothing about gathering technical data and implementing projects resulting from these evaluations (Forester 1992). The challenge, therefore, is to address these barriers. Hazardous waste reduction potential must be brought to the attention those involved through education about the benefits and successes that are attainable through effective P2 planning (Hirschhorn 1991).

Institutional Business Practices

Some of the predominant barriers to practicing P2 are institutional. There are three major types of institutional barriers identified in existing literature: 1) most companies assume their processes are efficient and are reluctant to change established business practices, 2) current hazardous waste disposal processes are in accordance with the law, and 3) the department-alization of businesses and jurisdictional character of regulatory agencies create barriers to informational flow (Underwood 1994). The combined effort of these three institutional barriers hampers industry's efforts to minimize hazardous waste generation.

To effectively change hazardous waste management efforts, there must be a shift in business practices from "end-of-pipe" waste management and control to waste minimization and prevention. To change existing systems may not be a smooth transitionary process. It means familiar procedures and equipment that are already in compliance must be re-engineered from a new perspective, and less tangible alternatives but invested in. There is a wide-spread sentiment within industry of "if it's not broken, don't fix it" (Freeman et al. 1992).

Most importantly, there is psychological resistance to change or interference with practices across departments in businesses. Rittmeyer (1991) claims that smaller companies, or those with limited resources, will find launching a P2 program difficult to achieve without help from outside experts. Those experts can be from outside the company (e.g., consultants), or outside of the production departments (e.g., environmental compliance specialists). However, business management and employees are often reluctant to use outside resources. This reluctance arises because business employees and management often have a sense of ownership of both their existing production processes and the modifications of these processes. If inefficiencies or other areas for improvement are identified by outside experts rather than those directly responsible for the processes, internal strife can result (Hirschhorn 1991). Unfortunately, this is a common situation for P2 modifications. This is because most business employees and management believe their manufacturing processes to be well run and are unwilling to see hazardous waste generation as a shortcoming of these existing processes (Hirschhorn 1991; Underwood 1994).

Another institutional barrier lies within the regulatory framework under which businesses operate and the incentives created by that framework. From a regulatory perspective, generating hazardous waste is not illegal, except for a limited number of chemicals banned by the government. Hirschhorn (1991) believes this aspect alone is a major institutional barrier to the implementation of P2 programs. Because hazardous waste generation per se is not illegal, business representatives see no fundamental distinction between pollution control and P2 approaches to hazardous waste. Businesses fail to recognize that all forms of waste management and pollution control are inferior to P2 because of the hidden risks and liabilities associated with them. The financial incentives that result from regulations and other sources to avoid generating hazardous waste are not yet strong enough to push the majority of businesses into fully using the P2 approach.

One disincentive to investing in P2 is that there is ample incineration capacity at present. When incineration was the preferred method of hazardous waste control, many businesses invested thousands of dollars in on-site incinerators. Industry is inclined to continue using the installed base of incinerators to continue to realize benefits from the past capital investments and avoid incurring new capital expenditures. These financial choices are further reinforced by minimal government restriction on hazardous waste generation and increased corporate operating budgets available for commercial off-site incineration (Hirschhorn 1991). Because waste generation is not illegal, companies are less inclined to be proactive and devote attention to assessing their operations for P2 opportunities because they are putting so much energy, money, and time into complying with existing regulations (Cal/EPA Reporter 1994). Other companies are strapped for resources and simply cannot invest in proactive solutions when existing solutions are in compliance with the laws.

Another institutional barrier that often impedes P2 change to operating practices is jurisdictional boundaries. These barriers occur both within a single company, between different industries, and between regulatory agencies. From an intracompany jurisdictional perspective, many companies are departmentalized. This is largely due to the fragmented operations and responsibilities at most companies. Departments are run with different agendas and objectives, and interdepartmental communications within the facility are often ineffective. Often those who manage hazardous waste are not aware of the plant processes generating that waste and are therefore not in a position to recognize P2 opportunities (Underwood 1994; Cal/EPA Reporter 1994). Being unfamiliar with the process, they are unable to evaluate potential P2 measures; they do not know if a different raw material will adversely impact the existing process or product.

Ironically, those who manage the process flow of production materials often do not have an environmental compliance background and are therefore unaware of what they could do to enhance P2. This was found to be the case from the telephone surveys conducted in Santa Clara County. Those individuals surveyed who were maintenance supervisors or lab chemists usually did not have the regulatory background to understand that the waste they were generating fell under SB 14 compliance mandates.[27]

The second type of jurisdictional boundary that hampers P2 plan implementation occurs between competing businesses. Many businesses that have invested in P2 and have realized cost savings simply do not want to share their technological advantages with their competitors or other institutions. One business representative, who wished to remain anonymous, stated categorically that his company would not share their information with the public because it had spent thousands of dollars researching alternatives and would not give that proprietary information away. This person believed that a competitive edge was more important than the greater benefit to society through shared methodological data to prevent pollution and he did not acknowledge the fact that SB 14 regulations require that work in this area be made public information upon request.

The telephone survey revealed widespread resistance on the part of companies to sharing their P2 data. Though the philosophy of SB 14 is one of information transfer and open sharing of methodological data, the imperatives of corporate competitiveness and absence of regulatory enforcement for plan communication seem to undercut the SB 14 objective of transferring information to benefit society. This is supported by the surprisingly-high 62 percent of businesses surveyed that indicated they had a

[27] Other findings from the telephone survey are discussed in Chapter 5.

SB 14 plan but refused to make the plan available to the author. Reasons stated for not providing a copy included a) proprietary content, b) fear of the information being used against them (e.g., being noted as out of compliance, or use of old, outdated versions of plans[28]), c) fear that disseminating proprietary information would spoil a competitive edge, and waste the underlying investment in technology, and d) unwillingness to cooperate with the general public, environmental activists, etc. Though all representatives were informed that the regulations explicitly state that SB 14 plans are public documents, even in the case of proprietary information those surveyed generally refused to share this information.[29] However, several of the larger corporations (e.g., Hewlett-Packard and IBM), readily shared plan information and insights into P2 practice.

The third jurisdictional barrier to P2 implementation occurs because of regulatory agencies. Often federal, state, and local agencies are not coordinated with each other. Regulations promulgated at different levels of government can mandate compliance requirements that have conflicting priorities and standards. What is acceptable to one agency may be illegal to another. For example, a local Publicly Owned Treatment Works (POTW), the Union Sanitary District of Fremont in Alameda County, permits the

[28] The first plans were due in 1993 and required to be updated in 1996. Some businesses, although completing the initial plans, failed to subsequently update those plans.

[29] The regulations state that two versions must be made in the case of proprietary information, one to remain confidential, and one to be made available to the public.

discharge of particular pollutants into the sewer system because the treatment facility renders this type of discharge innocuous. Additionally, federal law (RCRA) allows for the discharge of federal hazardous waste to sanitary sewers. Yet the Alameda County Department of Health Services, which has jurisdiction over hazardous waste management, prohibits the discharge of any hazardous waste into any waters, regardless of whether they go to a POTW. Freeman (1992) confirms this finding, stating that it is easy to go afoul of one regulation while trying to comply with another. Industry and government experts agree that conflicting regulations can occasionally inhibit hazardous waste minimization efforts (Freeman 1992).

To make matters more complex, regulatory agencies outside the environmental compliance arena can also inhibit changes towards P2. For example, if a business operates a manufacturing process certified by the Federal Food and Drug Administration (FDA), proposed changes to that process must undergo a lengthy approval process. This approval process alone can deter implementation of P2 changes to operations.

Regulators seeking to encourage P2 send a conflicting message to hazardous waste generators by emphasizing control of hazardous waste after it is produced (Wentz 1995). Regulators seem most familiar and comfortable working in the traditional arena of regulating waste that has already been generated.

The numerous changes in procedures and processes required to implement P2 programs are often impeded by jurisdictional boundaries both at the corporate level and within the regulatory structure. As a result P2 implementation and progress is not occurring fast enough.

Informational and Technological Barriers

Informational and technological factors also impede businesses from implementing hazardous waste source reduction solutions. Many companies do not have access to hazardous waste minimization methods or the regulatory requirements mandating that minimization be implemented. Although information on specific source reduction methods is not interchangeable from company to company, general information about P2 is transferable. But, as discussed earlier, most companies are unwilling to share their information (e.g., their methods, successes, and failures) with other companies because they gain a competitive advantage by keeping such information proprietary.

Because of this, businesses of limited resources that generate hazardous waste do not have access to minimization methods and the expertise to institute them (Cal/EPA Reporter 1994; U.S. EPA 1990). It is not the technology itself that limits businesses from implementing some P2 strategies, especially low technology solutions, but the access to that information and the time it takes to implement the available knowledge.

The hazardous waste minimization literature does not appear to be providing companies with the information required to implement their waste reduction efforts (Noyes 1993; Cal/EPA Reporter 1994; Hirschhorn 1991).

There are numerous explanations for the shortcomings of the existing hazardous waste minimization literature. Noyes (1993) illustrates where the literature is falling short.

> "First, few accounts go into enough detail to give a thorough understanding of why and how waste reduction was carried out. Often it is not clear what waste has been reduced, how much it was reduced, by what method it was reduced, or what the costs and benefits were. Second, the number and cases reported in the literature is limited; the same examples appear over and over again" (Noyes 1993).

Because there is no standardized and accepted definition of hazardous waste reduction, information regarding P2 methods given in one published source may not easily be compared to another method referred to in a different source (Noyes 1993). Without standardized vocabulary and accepted similar terms, comparisons and analysis are not easily attained. Additionally, case studies of source reduction methods implemented at one company are often not recognized as applicable to manufacturing processes at another company. Overcash (1986) states that the idea of information being highly proprietary or unique, and therefore not transferable, is a popular misconception. He states that the "lack of access to information about [P2 methods]" is the problem, not the transferability of the information. He sees dissemination of information about successful waste reduction projects as the essential first step to widespread, economical implementation of P2 projects. Overcash does not identify the types of technical categories or provide detail; nor does he define what the exact commonalities of the types of method are. Noyes (1993) agrees with Overcash and believes that if the source reduction examples were presented as general technologies applicable to a broad range of manufacturing processes, it might be easier to use waste reduction methods across industries. Several references note that companies generating pollutants do not have access to pollution prevention methods or knowledge of regulatory requirements, and they lack the technical expertise to institute pollution prevention strategies (U.S. EPA 1990; Cal/EPA Reporter 1994; Noyes 1993; Breen 1992).

Griffin (1995d) believes the problem is even more fundamental. She states that, in general, business representatives "fail to leave the initial state of ignorance" that is, they never seriously think about P2. In the Santa Clara County telephone survey, 28 percent of the business representatives surveyed did not even know that they were required to complete a SB 14 plan.

The combination of several informational barriers impedes the development and implementation of P2 objectives. Business representatives need to become informed of P2 objectives and then find out what P2 methods are available for their applications. This search for information combined with the reluctance of businesses to share information for competitive reasons creates the difficulties that are encountered when organizations try to determine which methods apply to specific business practices.

Incentives and the Resources to Implement Change

In order for a business to want to change hazardous waste management practices, it must be motivated by strong incentives. Some of the major incentives guiding business decisions are bottom-line profits, resources available to achieve directives, regulatory penalties associated with non-compliance, and motivating employee attitudes to implement changes.

Businesses need to view hazardous waste minimization as a cost savings measure if they are going to invest scarce financial capital to implement P2. Hirschhorn (1991) conducted an analysis of hazardous waste minimization projects prioritization and stated that when businesses are doing well, profits are high, and if the waste quantities are also high, waste management costs seem relatively low in comparison to profit margins. Therefore, to change what is already perceived of as a successful operation to implement P2 may seem to be of little immediate value to the company. Conversely, Hirschhorn notes that when business is poor and profits are relatively low, if the waste quantities produced are small, companies may not be able to devote financial resources to waste reduction projects, even if long-term cost savings will result. Hirschhorn's (1991) studies seem to indicate that a majority of businesses fall into one of these two categories, high profits-high waste or low profits-low waste, and these businesses do not perceive incentives or cannot afford to change their practices even if benefits are perceived. Concluding that business will make hazardous waste minimization a priority if profits are marginal and waste volumes are high seems reasonable. Otherwise, other incentives are required to drive a change in the existing practices.

The next incentive driving business decisions regarding hazardous waste management addresses is the allocation of resources to achieve minimization objectives. In order for hazardous waste minimization projects to be successful, upper management must be involved at the start of the project and allocate adequate resources to project managers. The resources of primary importance are adequate time to conduct a thorough waste stream analysis, and ample inter- and intradepartmental resources granted from other departments that might be affected by resulting changes.

Simply stated, managers do not have time to take on new projects, like SB 14 plans, in addition to their existing work loads. To conduct a thorough SB 14 plan analysis, people implementing the waste reduction measures must have ample extra time. This involves time to familiarize themselves with the manufacturing and production practices as well as to understand fully the waste generating sources. This is much more complex than finding appropriate treatment methods for the end-product waste.

If the manager assigned to the waste minimization project is the environmental compliance manager, the literature reveals some interesting challenges regarding the allocation of resources. Kratch (1995) and Wentz (1995) both describe a major problem facing most environmental compliance managers today. Although these managers typically understand, to varying degrees, the benefits associated with hazardous waste source reduction, they are often left without resources to explore that potential. This is the paradox. Managers are so busy trying to stay in compliance with existing regulations that they are left without the time to take on proven prevention activities. Because these managers are typically stretched thin with current compliance needs, they have no extra resources to put up front to devote to prevention programs that would reduce their compliance requirements. Additionally, if the company has a devoted environmental compliance department, one might assume there would be ample resources. To the contrary, typically, those departments are usually understaffed such that they are only able to achieve the minimum regulatory compliance objectives. Twenty percent of businesses in Santa Clara County without SB 14 plans stated that they did not have adequate resources to take on SB 14 projects. Additionally, that figure is conservative. Lack of resources may contribute to the 45 percent of businesses that were unaware of the SB 14 regulations and the 25 percent who believe that they did not need to do a SB 14 plan.

Whether a dedicated environmental consultant, or people who assume environmental compliance issues in addition to their existing job responsibilities, these professionals usually have no extra time or expertise to allocate to prevention efforts. The DTSC representative,[30] found this is especially true with small companies and those with limited resources. Rittmeyer (1991) claims that starting an effective P2 program can be difficult, if not impossible, without help from outside experts. Because hazardous waste managers have other primary job functions, waste minimization projects are often delegated to a person not qualified to perform a good job. This was demonstrated at Xerox Corporation in Palo Alto. Xerox has a full staff of EH&S professionals, yet a recent waste minimization project was delegated to a summer intern with presumably no experience except that gained on the project.

Once a company decides that a plan will be developed, time being provided for the completion of the project is the first step. Next, adequate capital and interdepartmental resources to implement the sometimes costly changes (e.g., equipment changes and process modifications) must be allocated. When projects are being assigned, management must recognize that most professionals implementing the programs are in charge of hazardous waste disposal, not hazardous waste generating practices. As a

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[30] Dave Hartley, Chief of Technology Clearinghouse, Office of Pollution Prevention and Technology, DTSC in Sacramento, California. Interview was conducted on 7/12/96.

result, often times they have authority and/or capital to make procedural and equipment changes to production activities generating the waste.

The next challenge, the implementation phase of the waste minimization project, begins when identified changes for research or experimentation involve other departments. While P2 projects may be a priority for one group or department within a business, other affected groups may not have the extra time and the resources to devote to a project that is not their primary job function (Cal/EPA Reporter 1994). The issue of resource allocation is a complicated and often a political one within the business structure.

The problems associated with resource allocation all seem to point to corporate priorities and resource availability. Because the recognition of hazards, liabilities, and costs associated with hazardous waste is relatively new to the business community and rarely communicated effectively to high level decision makers, it is typically not incorporated in the corporate planning process and department budget allocations. As a result of this poor planning and lack of recognition, often there is a lack of capital to implement new processes or contract services (Cal/EPA Reporter 1994). For other businesses just trying to stay competitive, they simply do not have extra money to invest in the research, development, and implementation of costly equipment changes and process modifications.

The third major incentive guiding business decisions regarding implementing waste minimization projects is the threat of regulatory penalties. Many environmental compliance professionals with their limited resources must prioritize compliance objectives. Deadlines and penalties for noncompliance were often cited by business representatives during the telephone survey as the guiding factors in determining which compliance issues to address first. To-date, the DTSC has assessed no monetary penalties for noncompliance with SB 14 regulations. This is because, for now, the DTSC considers the punitive approach to be counterproductive. Additionally, at the federal level, generators must certify that they are implementing waste minimization measures, yet no quotas have been established for reduction goals (Freeman 1990). The rules governing hazardous waste minimization efforts are governed by a softer structure with softer penalties, if any. Because hazardous waste minimization compliance projects are often presented under a voluntary structure, those projects tend to become lower in priority to those with specific compliance deadlines. Survey results indicated that, although some industries did a thorough hazardous waste minimization evaluation, the majority of the plans were not completed properly because they did not properly identify source reduction measures. If punitive measures were instituted and standards for correctness or completeness were more clearly identified, businesses would have a greater incentive to complete these reports properly.

Although there is pressure from government and the public to reduce hazardous waste generation, that pressure is not as immediate or as compelling as the pressure to meet existing regulations to control waste (Wentz 1995). The regulatory priority of a particular agency should be evaluated when considering enforcement incentives. Are they phasing in enforcement or merely ignoring enforcement provisions? This point is more clearly demonstrated in a case where one SB 14 plan's results determined that there were no feasible waste reduction measures to undertake. The plan identified nine separate hazardous waste streams. For seven of the nine waste streams, source reduction measures were found to be economically impractical to implement. For the remaining two waste streams, treatment was identified as the source reduction measure was implemented. Treatment is not source reduction, and therefore it is an error to included it in the SB 14 report.

Additionally, the SB 14 regulations specify that the SB 14 report "shall consider" source reduction approaches if economically practical. It does not state any guides for the amount of waste reduction to achieve. One quarter of the SB 14 plans from Santa Clara County businesses included in this survey did not identify any waste minimization methods that were practical to be achieved. Due to the lack of punitive measures and clear standards for SB 14 plans, it appears that SB 14 documents, although demonstrating no true improvement in source reduction, will comply with the SB 14 legislation.

DTSC has the authority to request a written copy, and a company that does not submit it within five working days can incur penalties of up to $1,000 per day. To date, these regulations have not been enforced with punitive measures, whereas other regulations, if neglected, impose stiff penalties and disincentives which more readily assure compliance. P2 has gone virtually unchecked by local regulators. The telephone survey demonstrated this point very clearly. One company representative, an EH&S manager from the semiconductor industry who wishes to remain anonymous, stated that because there are no reprisals or submission requirements until requested, the company simply did not have time to do the SB 14 project. The company representative stated, "Frankly, I don't have the resources to get everything done, so I do those projects with strict deadlines first and only if people will check-up on it."

Finally, the attitudes must be evaluated to understand a business's willingness to implement hazardous waste minimization. Several attitudes that impede the implementation of hazardous waste minimization projects have been identified in the literature and in the telephone survey. These include a fear that production will be delayed due to hazardous waste minimization, that prevention is of no value to the company, and that the process is too technical for easy implementation. These attitudes can effectively prevent minimization projects from being implemented.

Regarding the topic of perceived production delays, many company managers perceive that a new procedure will cause a bottleneck or a stall in production for installation or implementation time. Then, once installed or implemented, the new equipment or procedure may not work as expected. Additionally, there are fears that if production operations change that these changes may adversely affect the product. If the product deteriorates and there is a change in quality, the customers may not accept the new product characteristics.

Secondly, many managers and employees believe in the "principle of least work." This is the view that you don't do something unless you absolutely have to.

Thirdly, and most common, is believing that taking on the pollution prevention endeavor is too technical or complicated to implement easily and, therefore, not worth doing. Some business representatives are prematurely reaching these conclusions without conducting the research. Griffin (1995d) recognizes this type of attitudinal barrier as having a debilitating effect. Griffin states three examples of how lack of information can be an obstacle. The first of the three obstacles is "failing to leave the initial state of ignorance." The individual never seriously thinks about pollution prevention options. Unquestionably, this was the most predominant reason stated by 45 percent of the business polled that had not yet started a hazardous waste minimization plan. The second barrier identified by Griffin is arbitrarily coming to the conclusion that pollution prevention efforts would not benefit the company. This reason was also stated a number of times in the telephone survey. The third major barrier identified by Griffin was managers coming to the conclusion, without due research, that none of the available P2 options were worth implementing.

Griffin implies that business managers are giving up before they even get started. Often, the potential for negative feedback and the perceived risk creates a general fear of change. Griffin also states that the risks and uncertainty are perceived as too high to warrant the investment of time or money to investigate the potential solutions. Because the implementation of a waste minimization plan is perceived as a highly technical process and without proper education, there is no reason to believe to the contrary. Griffin states that managers, in general, use a small network of trusted business contacts to obtain information, and that knowledge of government sponsored P2 programs is not commonly found within that group.

The problem is that, right now, government programs have most of the data and educational materials. If these materials are not disseminated effectively, the misconception that waste minimization methodologies are highly technical will continue to be perpetuated. If new terminology associated with the topic of waste minimization is not presented clearly, it can be misinterpreted, misunderstood, or simply ignored (Griffin 1995d).

Calculating Costs to Implement Selected Methods

The success of hazardous waste minimization programs is difficult to determine because when minimization methods are selected and implemented, the true costs of the waste saved are rarely calculated and difficult to quantify decisively. If managers are not sure of the cost of implementing certain methods and of the true savings realized after implementation, then the true success of the programs is not easily measured or documented. Additionally, if true costs are not represented, there is less economic incentive to implement those measures.

When deciding whether or not to implement waste reduction measures, doing some kind of feasibility study to calculate costs is necessary. At this point businesses encounter a major barrier in determining just what to analyze. Many of the analyses fail to reveal the true costs of generating the hazardous waste, i.e., CERCLA liability and hazards costs, and therefore, the benefits of reducing the waste are not factored in as negative costs. If more comprehensive costs associated with hazardous waste management were attributed in the feasibility portion of the waste minimization plan, it would serve as a greater incentive for implementing minimization programs (Cal/EPA Reporter 1994). Without comprehensive cost accounting, hazardous waste minimization projects that would in fact benefit a business are not being selected. Higgins (1989) concluded that economic benefits are not fully being accounted for to realize net benefits by businesses and therefore waste reduction projects are not being fully pursued.

There are a number of reasons why these costs are not accurately calculated: a) the costs of waste production are hidden in general overhead accounts and indirect costs have not been considered, b) the time frame over which profitability is estimated is not long enough and reductions in future liabilities are not factored in the analysis, c) public image improvements are not calculated or included, d) loss of production time resulting from possible environmental accidents is not calculated, and e) other benefits are difficult to quantify or include (Griffin 1995; Hirschhorn 1991). In general, if the analysis process is too complicated and takes too long, analysts are less likely to do a thorough job.

The reasons for inaccurate calculations for SB 14 feasibility can stem back to a lack of resources explaining how to perform this task. With regards to SB 14 compliance, DTSC's Hazardous Waste Source Reduction Guidance Manual (Cal/EPA, DTSC 1994) suggests using seven criterion to evaluation the methods for feasibility for implementation: 1) waste quantity, 2) technical feasibility, 3) capital costs, 4) quality, 5) health and safety, 6) regulatory, and 7) release discharge. However, it does not go on to explain how to identify costs that are noncapital in nature, nor does it provide any type of equations or methods to quantify that type of data. For example, Komag Incorporated and Hewlett-Packard both had very detailed and thorough waste minimization plans, but both analysis sections were really best guesses. For many companies, if completing a detailed analysis takes too long, staff will do what is readily implementable, based on common sense, not analytical data. As a result, the major weaknesses of most SB 14 plans were the economic feasibility documentation.

In SB 14 plans created by Santa Clara County businesses, some general cost-benefit analysis trends were apparent. Instead of full economic feasibility, business decisions regarding hazardous waste minimization projects selection appeared to be based on simple criteria, such as, ease of implementation, low cost, and potential impact to product quality. If those three measures were all present, the project was usually approved for implementation. Another criterion that was important was the capital cost associated with equipment purchases necessary for source reduction. If the costs were too high, regardless of the potential benefits, the project would not be implemented. These criteria seemed to be the true determining factors most businesses are using, not full cost accounting systems. Griffin (1995b) agrees. She states that because profitable projects never realize their true benefits on paper, they often never go beyond the idea stage.

Although the literature recommends repeatedly that a formal cost benefit analysis be conducted, most managers are not economists, and therefore do not have the tools to do this type of analysis. Hirschhorn (1991) recommends a formal analysis project is really needed to capture and identify costs, benefits, uncertainties, risks, schedules, and relationships to other company projects. If this is not done correctly, people may incorrectly conclude that they have exhausted their waste reduction opportunities and that the costs of implementing waste reduction are too high, or they may even pursue projects which are either technically, economically or environmentally ill-advised (Hirschhorn 1991). Lurker (1995) refers to surveys that document that cost analysis methods do not extend for long enough to reflect true savings. He recommends ten years to fully realize cost savings. Currently, many SB 14 plans simply do not calculate long term liability into figures.

Immediately and obvious economic benefits, even though they exist, are not easily documented or presented. So, profits and identified costs savings, the bottom line for much of industry, are not available. Often times the true costs of waste have been externalized at the local level in the company with the EH&S department paying for the waste and on the global level to society as a whole. If industry can not see the short term immediate cost savings, it sees little incentive to invest in P2. The benefits, although there, have not been fully recognized due to incomplete analysis.

Summary

Although business representatives understand that P2 is a good idea, a number of obstacles appear to prevent source reduction from reaching its true potential. The barriers are numerous and include institutional business practices, informational, technological, incentives, resources, and unidentified costs.

In order to implement hazardous waste minimization projects, a manager must gain the proper institutional support, information, resources, money, and time to do a proper job. Many businesses attempting these projects are either unwilling or unsuccessful in their attempts to produce quality source reduction projects. For a project to be successful, it must be thoroughly planned with a guarantee of resources and institutional support at the beginning.

CHAPTER 5

TRENDS OF HAZARDOUS WASTE MINIMIZATION PROGRAM IMPLEMENTATION AND SB 14 COMPLIANCE

United States

In the United States, several federal and state regulations mandate that hazardous waste minimization programs be in place, for example, the hazardous waste manifest certification requirement, biennial hazardous waste reporting requirement, and California's SB 14 requirements (Kobashi 1994). In spite of these regulations, national level research has determined that waste minimization practices are not being fully implemented (Underwood 1994; Forester 1992; Wentz 1995). Forester (1992) states that despite some successes achieved by large corporations, most companies in the U.S. still do not have significant P2 programs in place. Underwood (1994) agrees and states that, although there are many benefits associated with P2, industry has only scratched the surface of its potential. In Underwood's independent research conducted on hazardous waste minimization, she found few source reduction measures are being adopted throughout the U.S. For example, she reviewed SARA Toxic Release Inventory (TRI) statements submitted to the U.S. EPA by hazardous waste generators and they reported that their hazardous waste generation volumes would vary by less than 2 percent from 1991 to 1993. Smaller companies and those with limited resources also appear to be having a most difficult time complying. For them, P2 efforts are difficult, if not impossible, to achieve without help from outside experts (Rittmeyer 1991).

Hirschhorn (1991) has found that not only is waste minimization not being implemented, but, on a national level, hazardous waste levels seem to be increasing. He predicts that hazardous waste generation will increase from 291 million tons in 1988 to 510 million in the year 2000. That's over a 75 percent increase in production.[31] In 1988, the U.S. EPA's own data revealed that 52 percent of industry nationwide was out of compliance with hazardous waste regulations (Hirschhorn 1991). Hirschhorn also presented some alarming statistics regarding the status of hazardous waste minimization efforts at the national level including the following:

• 75 percent of waste reduction methods used in waste minimization projected or referred to in professional papers used, in fact, end-of-pipe methods rather than P2

• In 1985 and 1986 over 50 percent of 275 companies polled in the state of Illinois, and 75 percent of 100 companies polled in California had not yet started waste minimization practices.

Understanding what is being done at the national level is hard because decisively measuring source reduction activities is difficult. Although

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[31] The annual rate of increase is going down, but that is off-set by the fact that more materials are falling under the regulated hazardous waste category.

hazardous waste manifest disposal record an other representative data on how much hazardous waste is being generated is available, reliable data that documents what hazardous wastes are being reduced does not exist (Hirschhorn 1991). For the most part, hazardous waste minimization data is gained from self reporting surveys. Typically, this data is misleading for a number of reasons: 1) people who self report tend to over report. For example, they mistakenly report end-of-pipe treatment, off-site recycling, and incineration as waste minimization, 2) companies who do not have waste minimization in place, typically do not self report,[32] and 3) questions can be raised as to the accountability and reliability of self-claimed accomplishments (Hirschhorn 1991; Breen 1992).

Even though there are difficulties associated with quantification of exactly what is being done to minimize waste at the national level, it is still agreed upon in the literature that waste minimization in not being fully implemented at the national level.

California and Santa Clara County, California

Pollution prevention planning is now mandatory in 15 states (Clayton Environmental Consulting Inc. 1994). But how effective are these state mandates in California? In California, hazardous waste minimization plans

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[32] This skews that data in one direction. Additionally data is compiled irrespective of production rates (therefore, other factors may explain the lower waste outputs like reduced production or plant closings).

are required under SB 14 legislation, yet many plans are incomplete and inaccurate. Moreover, state regulators are extremely busy and thus have little opportunity to review plans for completeness (Clayton Environmental Consulting Inc. 1994).

An interview conducted with Dave Hartley of the California DTSC revealed the DTSC's current efforts with regard to SB 14 compliance measures. The DTSC is not focusing on overall compliance and no enforcement action has been used to date, instead, they are in the process of compiling specific plans from a limited number of specific businesses in industry. Of those plans the DTSC has received, the biggest problem is their inaccuracy and incompleteness. Dave Hartley provided additional data regarding a survey that the DTSC conducted in 1995 about SB 14 related issues.[33] The survey consisted of mailing 9692 questionnaires to California businesses. Nine percent of those surveyed responded. Of the 9 percent, 82 percent of the generators found waste minimization opportunities over the last three years, and 71 percent of that majority had reduced their waste generation by up to 25 tons. Of those returning surveys, 89 percent reported that they had saved money over the last three years: 66 percent of them saved up to $25,000, and five percent, up to $100,000. From the original 9 percent responding to the survey, only 52 percent of those felt SB 14 was a worthwhile

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[33] The survey results were documented on an unpublished inner-office memo dated June 13, 1995 from Phil Loden to OPPTD staff. Dave Hartley of DTSC, OPPTD provided a copy of this memo to the author.

exercise for companies to complete. Unfortunately, these results do not reflect data for the entire state of California, but only the 9 percent that responded back voluntarily. What the survey results do indicate is that savings can be incurred, both in money and quantities of waste being generated with SB 14 plan implementation and that about half the people polled who responded did not think SB 14 plans are a worthwhile exercise.

At a county level in California, the Santa Clara Pollution Prevention Office officials contend that pollution prevention is taking place. The problem is that they too find it extremely difficult to quantify how much pollution is being prevented. They have not surveyed businesses to see who is in compliance with SB 14 regulations and who has implemented SB 14 plans. Additionally, they have not qualified how accurate SB 14 plans are to see if measures identified are true source reduction measures, or if they are merely shifting waste from one environmental medium to another.

In an effort to answer some questions that neither Santa Clara County nor the DTSC could answer, a survey of current business practices regarding SB 14 compliance was conducted for Santa Clara County businesses (see fig. 1 for Santa Clara County, California, map). DTSC compiles data from hazardous waste manifests on the quantity of waste each business generates each year. These data can be sorted in a variety of ways. The most recent (1993) Tanner 1 report, which is a report from the DTSC that lists the names

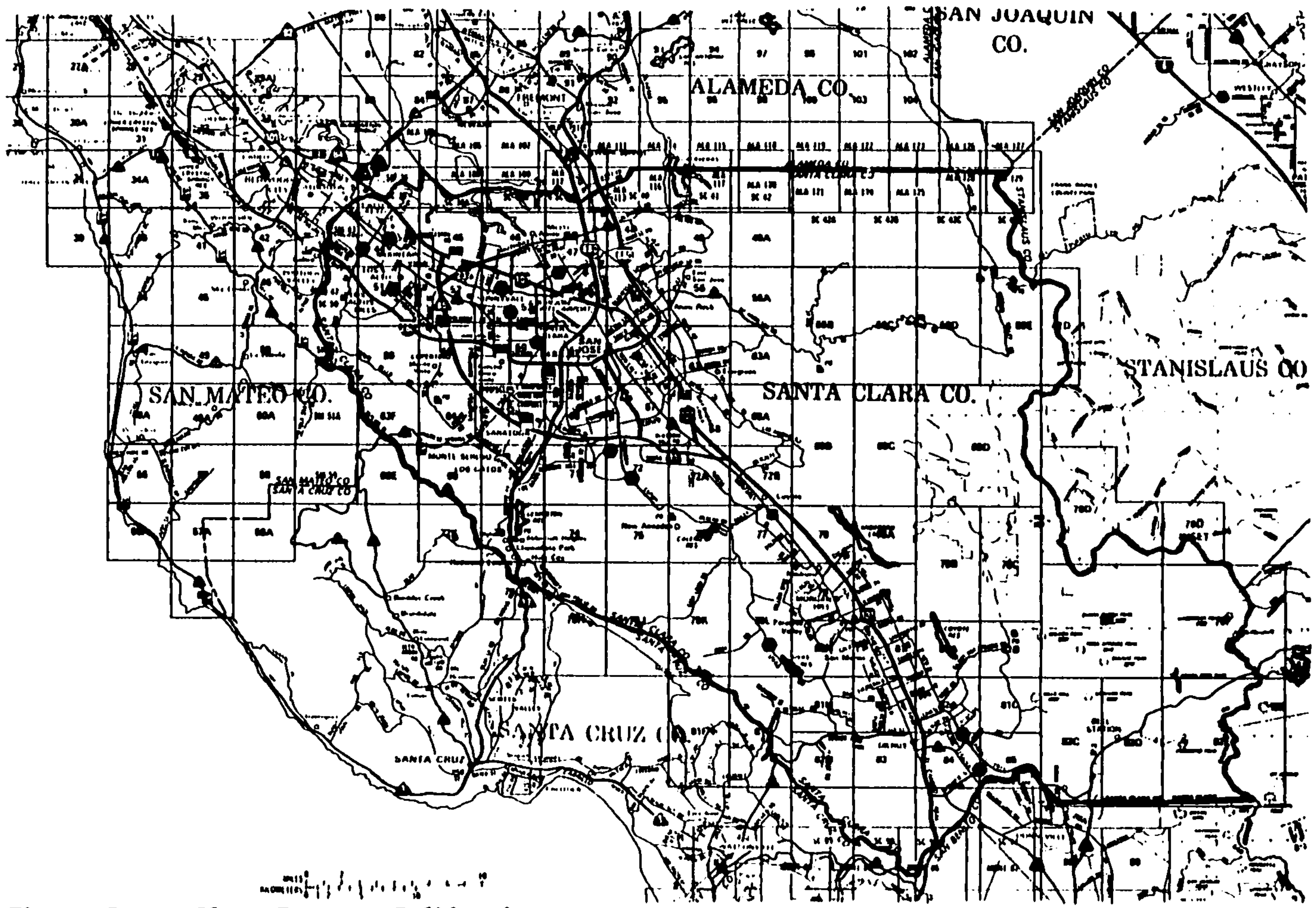

Fig. 1. Santa Clara County, California
(Source: Thomas Brothers Maps)

of generators by county for 1993, was used to determine which businesses in Santa Clara County generate greater than 13.2 tons of hazardous waste in 1993.[34] In 1993, Santa Clara County had 3,510 facilities that generated hazardous waste. Of those hazardous waste generators, there were 327 facilities that generated over the threshold amount of hazardous waste, 13.2 tons, which mandates compliance with SB 14 regulations. Those 327 companies were surveyed to see what they were currently doing with regards to their SB 14 compliance efforts (see table 5 for complete results). The results were startling. Of the 113 businesses in which a representative was available and willing to engage in discussion, nearly 63 percent of these business did not yet have SB 14 measures in place.[35] Of those stating that they did have a SB 14 plan, 62 percent would not provide a copy of the document for review, thus eliminating any way of verifying that the plan in fact existed.

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[34] The Tanner 1 report has the following data: 1) the name of the facility generating hazardous waste, 2) the quantity of waste generated for 1993, and 3) the facility address-sorted by county.

[35] Seventeen percent of those companies felt that they did not need to comply with the regulations because of the type of waste they generate or the types of activities conducted.

Results

Table 5.--Santa Clara County SB 14 Compliance Survey Summary

Status of SB 14 Compliance	Number	Percent Polled
Company Representative Inaccessible[36]	214	x
Plan Was NOT Completed	71	63
Representative Believes the Plan is Not Needed[37]	18	
Due to Lack of Resources	14	
Unaware of SB 14 Regulations	32	
Would not Discuss Why	7	
Plan Was Completed[38]	42	37
Received Copy for Review	16	
Would NOT Send Copy for Review[39]	26	
Total	327	100

[36] Company representatives were inaccessible for the following reasons: a) no phone number, b) business moved, c) phone calls were screened, d) representative did not return numerous messages (each representative was contacted at least once, a majority were called at least twice), and e) representative was unwilling to engage in dialogue about the topic.

[37] Reasons stated for not needing the plan were: a) company out of business, b) type of business conducted exempted them (e.g., hazardous waste disposal facility), and c) they believed their quantities were not high enough and thus they were exempt from SB 14 compliance (even though actual quantities were documented otherwise by the DTSC).

[38] This was based on their verbal statement over the phone. This number is not verifiable because, although it was stated that the plan did exist, some companies were unwilling to provide copies of the plan for review.

[39] The reasons for not sending copies included: a) fear that in giving the document out it would somehow be used against them, b) proprietary content (even though the regulations state that if proprietary information is of concern that two separate documents must be prepared), c) unwilling to send, no reason stated, and d) will allow for review of plan on site.

Although all companies were required by law to already have the plan in place, large companies who generated the greatest volumes of waste typically were in compliance, whereas small companies generating waste typically did not. The results of the interviews indicate that 63 percent of the companies required to comply with SB 14 regulations have not done so yet. The major reason stated for noncompliance was lack of awareness of the SB 14 regulations.

CHAPTER 6

OVERVIEW OF HAZARDOUS WASTE MINIMIZATION METHODS AND SB 14 REQUIREMENTS

This brief chapter introduces the reader to the broad topic of hazardous waste minimization methods. It details the general categories of hazardous waste minimization methods as identified in the literature and described in chapters 7 through 9. This chapter also enables the reader to understand those chapters in relation to the broad topic of hazardous waste minimization and where that information fits into that broad scheme of waste minimization methods.

P2 is the general category for classifying the prevention of pollution releases to all types of environmental media (e.g., air, water, land). Hazardous waste minimization is a sub-category of a P2 activity. Hazardous waste minimization methods are typically divided into two waste management categories, source reduction and recycling, both on-site and off-site (see fig. 2 for a visual depiction of the types of hazardous waste minimization methods). This thesis focuses on hazardous waste minimization methods encompassed under the category of source reduction. Source reduction is identified in California's SB 14 regulations as the preferred waste minimization method. The hazardous waste minimization category of source reduction is further divided into two categories of methods, product changes, and source control.

The category of product changes involves methods, such as: a) product substitution, b) product conservation, and c) changes in product composition. These methods are product specific and are therefore different for each product. This thesis will not cover that specific data.

The category of source control consists of the following methods: a) input changes, b) technology changes, and c) good operating practices. Input changes usually involve raw material substitutions to reduce toxicity. Technology changes consist of improving process controls, and the upgrading and automation of processing equipment. Good operating practices usually involve changes in procedures that involve the handling, storage, or use of hazardous materials that have the potential to become hazardous waste through operator error or inefficient procedures.

One purpose of this thesis is to identify methods of P2 through source control of hazardous waste. SB 14 requires generators that produce over 13.2 tons of hazardous waste or 26 pounds of extremely hazardous waste in 1990 to prepare two documents. The first document, the source reduction plan, identifies all the major hazardous waste streams at the generator's site and evaluates the potential options for reducing waste through source control. The second document, the management performance report, which assesses the effectiveness of hazardous waste procedures previously implemented, will not be addressed under the scope of this thesis.

The intent of SB 14 is to promote hazardous waste reduction at the source, and wherever source reduction is not feasible or practical, to encourage recycling. Source reduction is defined in the SB 14 legislation as:

> "1) Any action which causes a net reduction in the generation of hazardous waste; or 2) any action taken before the hazardous waste is generated that results in lessening of the properties which cause it to be classified as hazardous. [Furthermore, the act clearly states that source reduction does not include any of the following:] 1) actions taken after the hazardous waste is generated, 2) actions that merely concentrate the constituents of the hazardous wastes to reduce its volume or that dilute the hazardous waste to reduce its hazardous characteristics, 3) actions that merely shift hazardous waste from one environmental medium to another, and 4) treatment" (Cal/EPA, DTSC 1994a).

SB 14 mandates that certain methods be considered and documented in the plan. At least all of the following methods must be evaluated in the plan: 1) input changes, 2) operational improvements (technology changes), 3) production process changes, 4) product reformulation, and 5) administrative steps (inventory control, employee award program, employee training, in-house policies, corporate management commitment, and others). Unfortunately, nowhere in the regulations are these methods defined. There is a guidebook issued by the Cal/EPA, DTSC that gives some additional information about each method that is of some help in defining the methods (Cal/EPA, DTSC 1994c). These definitions will be used in the following sections and chapters that outline the various source control methods available to industry. Generally speaking, all the methods identified by Cal/EPA for mandatory consideration fall under the category of source control (see fig. 2 for a depiction of source control measures). The only method, specified in SB 14 regulations for consideration, that will not be covered in this document will be the topic of "product reformulations" because these methods are product specific. This report uses literature surveys and existing SB 14 plans submitted voluntarily by Santa Clara County business representatives to find, compile, and analyze the variety of source control methods available to businesses. This compilation and analysis was created to provide industry with practical information in evaluating and implementing source control measures as required under the SB 14 plans. In theory, businesses would be able to learn from the successes and barriers encountered by their colleagues regarding implementation of source control measures.

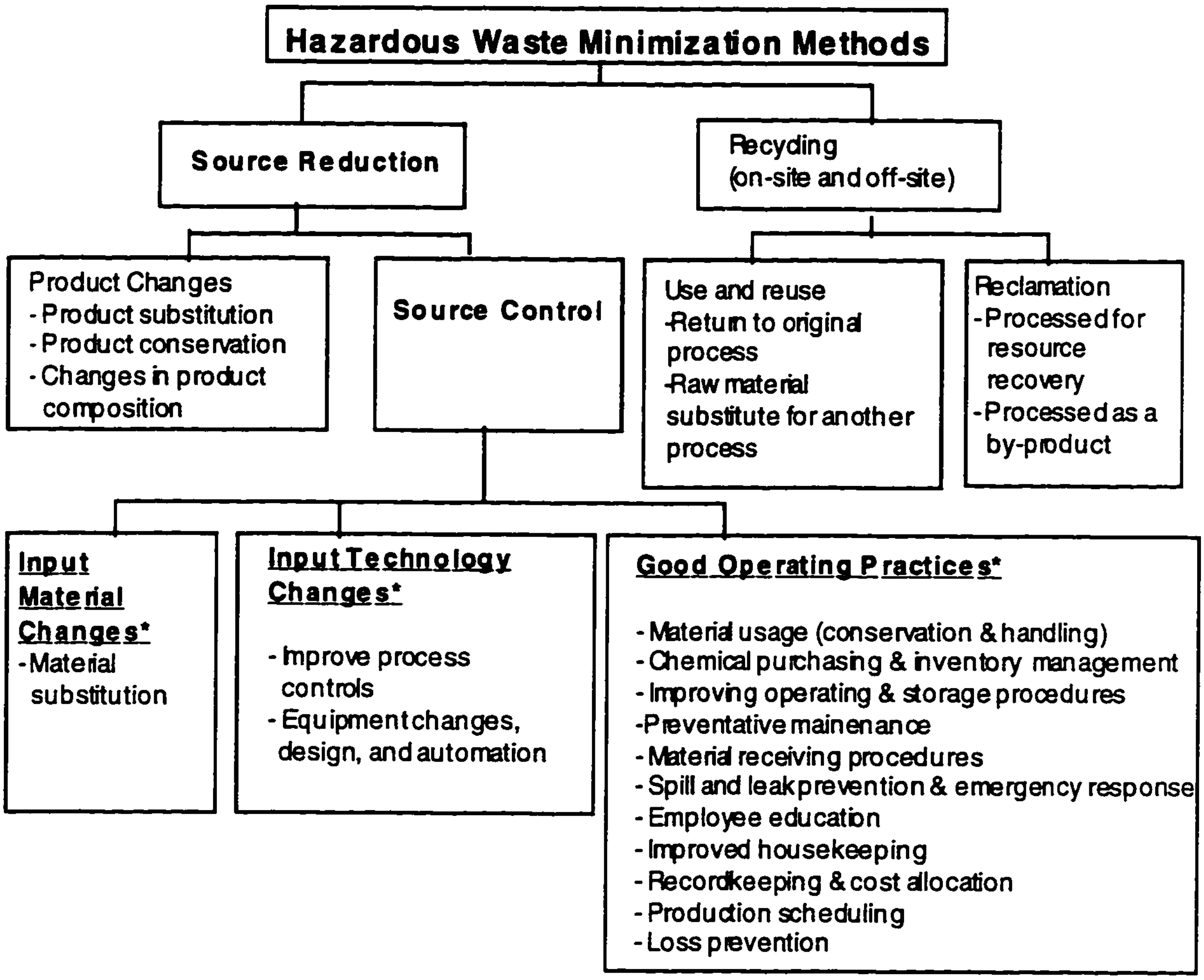

Fig. 2. Categories of Hazardous Waste Minimization Methods

* These categories are methods focused on in chapters 7, 8, and 9 respectively.

CHAPTER 7

HAZARDOUS WASTE SOURCE CONTROL METHODS--INPUT MATERIAL CHANGES

Introduction

Input changes include methods of material substitution intended to reduce, avoid, or eliminate the generation of hazardous waste. Input changes, sometimes referred to as raw material substitutions, are commonly agreed to be changes in one or more of the hazardous raw materials used either in the product's formulation or the production process with a less hazardous or nonhazardous material (Freeman 1989; Huff 1995; U.S. EPA, Office of Research and Development 1991; Cal/EPA, DTSC 1994b, 1994c). The intent of the substitution is to reduce the quantity or toxicity of the hazardous waste being generated both during production and for final use. If intervention occurs in the development of the production process, hazardous waste generation can be controlled at the source. Input changes are identified by SB 14 regulations as one measure that must be considered when performing the waste reduction analysis.

Material substitution is a true source reduction method. It is often the most logical and effective method to eliminate waste because it gets at the root cause of the hazardous waste and simultaneously has the potential to reduce or eliminate associated employee health hazards.

Benefits

The generic benefits of implementing input changes include reduced waste disposal costs and the reduced exposure of workers to toxic materials. These two benefits alone can be enough evidence to substantiate a change (Hill 1995; Higgins 1989). Often times a hazardous or toxic material that goes into production poses threats to the company's, employee's and environment's safety from the time it is produced until the time of ultimate disposal. Because the frequent result of a hazardous material input is a hazardous waste output, nontoxic or nonhazardous input alternatives may eliminate that hazard and its associated problems and costs for waste treatment, storage, and disposal. Input change benefits are more easily and quickly received when changes are made to nonproduct related processes first. Longer term evaluations are required when input changes affect the product being produced.

Drawbacks

For some products and procedures, the internal processes and guidelines of the company are not the only authorities regulating the acceptability of an input change that affects the end-product. If a product is subject to approval by the federal Food and Drug Administration (FDA), such as a medical device, any subsequent changes to the product or product-related procedures are also subject to that agency's approval. Often, gaining change approvals through the FDA is a time consuming, expensive, and difficult process. Sometimes the added cost associated with new approval process and potential lost production time may outweigh any savings identified in hazardous waste disposal and employee safety (Cal/EPA, DTSC, OPPTD 1994a). Another concern which could be a drawback to implementing product-related changes is the potential impact the change has on the final product and customer satisfaction (Lindgren 1989). Once a product has been marketed to the consumer, the new product must have the same therapeutic effect, stability, and purity profiles of the original product; otherwise, sales could be affected (Cal/EPA, DTSC 1994a). In addition, input changes can impact the aesthetic qualities of the final product, which again could impact customer satisfaction and demand. Changes in characteristics, such as, taste, color, or form of dispensing could also result in customer rejection of the product (U.S. EPA, Office of Research and Development, Risk Reduction and Engineering Lab 1991).

Assuming a change passes the scrutiny of both inside management and outside agencies and the end result is desirable to the customer, then an evaluation of the environmental, health, and safety impact of the change must be conducted. Does the substitute pose its own set of potential hazards and issues? Is the substitute more hazardous than the original input material? Are there available disposal options for the resulting waste? Does the change merely shift the pollution from one environmental medium to another? This type of thorough and detailed analysis takes time and money and could be perceived as a drawback. The decision of whether or not a chemical is a reasonable alternative must be made on a case-by-case basis (Katin 1991).

Method Implementation

The first step is to determine what hazardous input materials pose the hazardous waste problem and the next is to determine if there is a less toxic alternative (Hill 1995). This assumes the product is not regulated by an outside agency like the FDA. If that were the case, then extensive analysis would need to be conducted regarding feasibility, implementation time, customer demand, and other factors. For material substitution to be a true source reduction methodology, it must avoid changes which merely replace one form of waste generation or hazardous material with another.

The next step is for a company to prioritize and focus on the one or two of its waste streams that have the largest volume or account for the greatest degree of hazard and have the least impact on product. Waste streams with the highest costs for treatment and disposal should receive priority. Additionally, the largest single waste stream is often the most economical to modify (Katin 1991).

Once the prioritization is completed, one must first find a pool of acceptable alternatives and then select the most effective and least hazardous of those products (see table 6 for a list of alternatives for materials that was identified in the literature and in existing SB 14 plans). Finding alternatives may involve test studies, pilot projects, and numerous other data gathering methods. This analysis can be an expensive long and tedious process, often resulting in dead-end products. Therefore, fully assessing and prioritizing the waste streams effectively up front is imperative. If an acceptable solution is found, the benefits can be numerous and the initial investment will more than pay for itself in the long term.

Case Study Examples

Table 6.--Examples of Hazardous Raw Material Substitutes

Hazardous Material	Substitutes & Alternatives Identified	Some Applications
Solvents		
Aliphatic Hydrocarbons (naphtha, kerosene, diesel)	Aqueous based cleaners & detergents (alkaline salts, surfactants, emulsions, or water based)	Metal parts cleaning and pharmaceutical
Aromatic Hydrocarbons (benzene, toluene, xylene)	Treatment via chemical reaction (reacting chelating agents)	
Halogenated Solvents (trichloroethane, trichloroethylene, perchloroethylene, CFCs, methylene chloride)	Aqueous and semi-aqueous based cleaners and detergents	Cleaning laboratory and process equipment; hand wiping
Specific Trade Name Solvents		
Freon 113 (or CFC-113)	Chlorinated solvents, flammable solvents, combustible solvents (N-methyl-pyrrolidone, dibasic esters), TF-90 (5% potassium hydroxide) Calla 301 (5% potassium hydroxide)	Cleaning and wiping operations to remove oils and pharmaceutical
Freon 12	Freon R-134 (Non-ODS)[40]	Refrigeration
Freon and TCA	Amberclean L12, Duraclean 282, Armakleen E-2001, hot DI water and surfactants	Structural cleaning and small parts cleaning
Phenol Based Solvent Strippers (Microstrip, 712J, J100)	Inorganic acid strippers (EKC 10-W70, SN12)[41]	Stripper baths
N-methyl pyrrolidine (NMP)	Acetone[42]	Photo-lithography
712D Xylene developer, Isopropyl Alcohol (IPA), and Negative Photoresist	EKC 10W-70 [43]positive resist reduces need for xylene and IPA	Photoresist

[40] No economic advantage was achieved, but ozone depleting substances are being phased out of production, so it was a required change. Net result was 1000 pounds for Freon eliminated.

[41] Less toxic substitute.

[42] The acetone was then put into a solvent recycling system.

[43] EKC 10 W-70 positive resist is less toxic than negative resist.

Table 6.--Continued.

Hazardous Material	Substitutes & Alternatives Identified	Some Applications
Toxics		
Chromate	Phosphate based corrosion inhibitors	Cooling tower additives
Chlorine	Hydrogen peroxide or potassium permanganate	Oxidants
Heavy metal based paints (pigments with cadmium, chromium, and lead)	Alternative pigment systems (e.g., soy based)	
Specific Trade Name Toxics		
Diversey 514 (hexavalent chromium)	Deox-It 22L[44]	Metal finishing, aluminum conversion coating process
FPL Etch (hexavalent chromium)	P-2 Etch[45]	Clean, deoxidize, and etch aluminum
TCA	Vapor Clean 161[46]	Metal cleaning and degreasing
Potassium ferricyanide etch	Acid etch	Metals etching
Copper cyanide	Nickel sulfate flash	Copper plating
Corrosives		
Acid or caustic cleaning solutions	Milder alkaline cleaning solutions	
Solvent based inks and paints	Water based inks and paints	

(Katin 1991; Lindgren 1989; Freeman 1990; Cal/EPA 1994b; U.S. EPA, Office of Research and Development, Risk Reduction and Engineering Lab 1991)

[44] The performance of Deox-It 22L (used to replace Diversy 514) tends to decline with age, so it needs to be replaced more frequently than Diversy 514. But there is no chromium, which is a toxic heavy metal.

[45] P-2 Etch (used to replace FPL Etch) was a good alternative.

[46] Vapor Clean 161 is a halogenated solvent, but it is not an ODS.

Results

Both DuPont and Lockheed Martin Missiles and Space (LMMS) spent over three million dollars to replace trichloroethane and Freon 113 with non-ODS. The examples were numerous in the SB 14 plans that some hazardous materials were being substituted with other hazardous materials in an effort to reduce one type of undesired pollution. Because increased negative health effects to employees are not as quantifiable as cost per pound of hazardous waste disposal, those factors may be neglected.

Many successes were identified in the SB 14 reports, with most amounting to thousands of dollars of savings annually, for example, Hewlett-Packard identified two changes that saved $300,000. So if completed properly, the results of implementing SB 14 plans can be profitable.

Some plans failed to give brand names. Instead, they only gave general replacement categories. This lack of information deters someone from benefiting from existing research. Because of the proprietary nature of the product reformulations, specific examples of product substitutions were scarce.

CHAPTER 8 HAZARDOUS WASTE SOURCE CONTROL METHODS--INPUT TECHNOLOGY CHANGES

Introduction

Input technology changes are one set of hazardous waste minimization methods used to control the production of hazardous waste at the source. This chapter defines input technology changes, describes the methods used to achieve those changes, their benefits, and their drawbacks. Specific case study examples obtained from SB 14 plans and the hazardous waste minimization literature are also provided.

Under the topic of input technology changes, the literature identified two major methods: 1) in-process control changes and 2) equipment design and automation changes. During any manufacturing or research and development operations, businesses can produce a number of different waste streams that are generated for a number of different operational procedures. The total waste generated, some of which is considered hazardous, results from a mixture of different of quantities and types of raw materials. The quantity of waste generated is either variable or fixed. A variable quantity of waste is from a source that changes with production rates. A fixed quantity of waste source is a waste that does not change no matter what the production rate is. The source of the waste, be it fixed or variable, is either intrinsic or extrinsic to the process. An intrinsic waste is one which is built into the product and process design. Extrinsic wastes are those wastes that are not dependent on the product's production but rather on general operations, for example, waste resulting from preventative maintenance procedures (Berglund 1991). For technology changes to be effective, they must focus on fixed intrinsic waste. Extrinsic wastes reduction is achieved most effectively through changing operating practices. These changes are the focus of the next chapter.

Using input technology changes to eliminate fixed intrinsic hazardous wastes usually involves equipment and process modifications (Berglund 1991). To achieve this hazardous waste minimization objective in an economically practical way means to reduce concentrations or quantities of hazardous waste generated to the point where further reductions are more expensive that the disposal of the remaining residuals. Berglund (1991) further categorized the most common types of fixed internal waste most likely to be encountered when implementing input technology methods in five ways: a) unreacted raw materials, b) impurities in the reactants, c) undesirable by products, d) spent auxiliary materials, and e) fugitive sources. When trying to implement input technology changes, being able to identify the type of internal waste source and what is contributing to its generation is critical. The reason to select an input technology change method is to alter in-process controls to increase the efficiency of the operating process or equipment. This often means allowing the use of alternative inputs so that the quantity and toxicity of the waste by-products are reduced.

When conducting a hazardous waste stream analysis for a SB 14 plan, considering production process changes is mandatory. Although not specifically defined in the regulations, the DTSC guidance manual defines production process changes as "process changes, changes in production methods or techniques, changes in process operating conditions, such as, temperature, pressure etc., process or plant automation" (Cal/EPA, DTSC 1994c). Consideration and knowledge of input technology change methods will enable compliance with SB 14 regulations. As mentioned previously, there are two major categories of input technology changes: 1) modify in-process controls and 2) modify equipment, design, or automation of procedures. Presented first is modifications to in-process controls.

Modify In-Process Controls

The objective of using in-process control methods is to increase the operating efficiency of a business through changing the operating process to use different process inputs to reduce the quantity and toxicity of the hazardous waste produced (Cal/EPA, DTSC 1994b). When considering true in-process control source reduction methods, one necessary distinction is that there are several places in the operating procedure where improvements may be introduced. Generally speaking, these changes can be divided into two categories: inputs and outputs. The materials and procedures going into production are the inputs, which is where source reduction takes place. Whereas outputs, which are the intended product and the solid, liquid, and gaseous residuals requiring proper management, tend to require end-of-pipe treatment approaches. (This is not source control and therefore will not be addressed in this thesis.) Front-end input approaches are the focus of the in-process source control methods that will aid in the successful completion of SB 14 plans. Waste streams, in general, are due to an unwanted or incomplete reaction by products in chemical synthesis. Focusing on the reacting technologies that have the potential to reduce waste (Cohen 1992). Additionally, many complex chemical reactions do not realize their waste minimization potential is key (Cohen 1992). The challenge is to design or modify processes to maximize and optimize their potential and reduce the resulting hazardous waste that is generated.

When hazardous waste generating production processes are evaluated, significant amounts of hazardous waste can be reduced through improvement in the way a production process is operated and maintained. This approach is one of the most overlooked of all hazardous waste minimization areas. Many wasteful operational practices have gone on so long they have become standard operating procedures (Freeman 1990). Outdated production processes that result in hazardous waste generation can be upgraded or replaced by a more efficient process, thereby minimizing the waste generated (Freeman 1990). If the source and cause of the waste generation is researched, effective measures can be developed to reduce the quantity and toxicity of this waste (Freeman 1990).

Benefits

In-process control changes have the potential to result in significant waste reduction and almost always simultaneously increase process efficiency (Freeman 1989, 1990; Lindgren 1991). Raw materials are used more efficiently, the quantity of waste being treated is reduced, and quality control usually increases. The combination of those factors tends to lower operating costs which should increase profits.

Most of the major input technology changes intended to reduce waste reduction come from installing more efficient process equipment or by modifying existing equipment to optimize production processes (Freeman 1989). Although these types of changes are most often relatively expensive, they usually result in a good pay-back, and therefore are easily justified. They tend to use raw materials more efficiently, run more productively, and therefore produce less hazardous waste to dispose of and use less raw materials. This is typically where most savings are incurred.

Modifying existing process equipment, in lieu of purchasing new equipment, can also be very cost effective (Freeman 1989). Often times the modification is a simple material handling change, or an inexpensive alteration to an existing piece of equipment. These changes typically involve little capital expenditure (Freeman 1990). Again these types of changes, because of the net reduction in raw material use and hazardous waste generation, are often easily justified.

Drawbacks

The input technology change approach is not without its obstacles to implementation. Whenever processes are altered, a number of other questions come into play:

- Is FDA approval required?
- Will the changes cause production down time for installation?
- Is extra capital budgeted to make the investment?
- What extra testing and validation is required?
- What extra training is necessary to operate the new equipment or perform the altered procedures?

(Cal/EPA, DTSC 1994b).

For some managers, just the idea of all those unknowns can be intimidating. Because of that alone, this hazardous waste minimization approach is usually used last after other efforts are exhausted (Berglund 1991). These types of projects almost always require a large amount of time spent on initial analysis.

Method Implementation

Modifying in-process controls to reduce hazardous waste output does not have a simple implementation formula. The method is often dependent on the types of processes being modified. But, there are a few basic steps that need to be done before selecting the appropriate processes for investment. Hazardous waste streams must be identified and quantified in order to target the right processes. Factors like the waste's hazardous constituents, current disposal method, and associated costs must also be considered in the evaluation process. Any waste shipped off-site for land disposal has a long-term CERCLA liability associated with it. Those processes producing the highest quantity and toxicity of waste should be considered first, especially if the waste is shipped off-site for treatment and disposal.

Once the waste stream is determined, the specific chemical or chemicals causing the hazard must be identified. When determining the hazardous constituents of the final process output, those constituents must be traced to their point of input and raw material. When tracing the raw materials through to their final output, efficiency measures usually will be identified (Lindgren 1989; Overcash 1989). Chemical reactions may be taking place during the process that will alter the properties of input materials to render the waste output hazardous. If this trace is done effectively, those variables needing to be explored further will be clearly apparent. This is the point where changes to the process can be identified to reduce the production of that hazardous waste. If waste minimization measures are not effectively identified, then traditional treatment and disposal methods are often relied upon.

The next and often the most difficult step is devising the waste minimization solution. Selecting the right implementation method to produce the desired source control effect can be a tedious, but rewarding process. Therefore, a full economic determination for feasibility is recommended.

Lindgren (1989) recommends the following questions be asked to aid in the company's identification and selection process:

- Do process steps bear a realistic relationship to process need?
- How clean is clean enough?
- How many rinses or how much rinse water is sufficient?
- Do production and process variables have any relationship to the amount of wastes generated per unit of output?
- Are "economies" achieved at high production levels or during continuous (24 hours per day) operation, or is there a linear relationship between production and waste generation?

Case Study Examples

Some of the specific in-process control methods used by industry are in table 7. The general categories being implemented in Santa Clara County for specific process modifications include the following: a) using efficient washing methods, b) extending the useful bath life for process chemicals, c) reducing the concentration of raw materials, for example, by using more dilute concentrations, and d) reducing loss of raw materials, such as residuals on equipment being pulled out of process baths.

If general methods for parts rinsing and cleaning are evaluated, wastewater conservation ideas may be identified. Wastewater is often treated in a wastewater neutralization system and considered hazardous waste. Reducing the demand on the system through water conservation can also reduce the use of raw materials used to operate that system and the volume of hazardous waste being treated. For example, if initial rinse waters contaminated with process bath chemicals are separated from subsequent rinse waters (with presumably little to no chemical contamination), then volumes of hazardous wastewaters can be reduced.

Extending the useful life of process chemicals is accomplished in a number of ways including: a) installing sensors to better regulate the concentration of chemicals, b) lowering the frequency that baths are changed, for example, by changing the definition of what is clean, and c) controlling reaction parameters for increased efficiency, e.g., agitation. Often, baths are replaced, and disposal occurs on a schedule, regardless of actual usage frequency and the need for that change. But in many cases the volume of throughput, not necessarily time, determines the useful life of process bath chemicals.

When evaluating raw material usage, the most dilute form of the material that will still accomplish the job must be determined. Often, the same job can be done with a weaker solution of raw material, and thus fewer raw materials are used.

Table 7.--In-process Control Case Study Methods Used[47]

In-process Control Method	Method Implementation
Control of Rinse Waters	Silicone Wafer Etching Procedures: Wafers are submerged in hydrofluoric acid (HF), then rinsed with large volumes of DI water. The first few rinses may be hazardous waste, but the remaining rinses are merely DI water. If the waters were separated, then wastewater volumes would be reduced.
	Water conserving rinses (counter current spray rinses) in electroplating operations in lieu of rinse baths (Lindgren 1989).
	Multiple stage rinse baths where contaminants are concentrated in initial stages (Lindgren 1989).
	Lockheed was able to reduce rinse water volumes for process tanks. They challenged existing assumptions that a full process tank (500 gallons) of rinsewater is necessary to remove contaminants for a fresh solution. They proved this not to be the case. They instituted a spray rinse and scrubbing with scotch brite pads and final rinse which saved substantial amounts of resulting hazardous rinse water.
Extend Useful Life of Raw Materials	A particle filtration device was installed to extend the useful life of a process bath. If the life of the bath is extended, then it is changed less frequently and less hazardous waste is generated. This method is a combination of treatment and source control.
	One company considered the installation of sensors to extend useful bath life, but determined that it was cost prohibitive for the amount of solvent reduction that would result.
	During a disk plating process at Komag, a glycol re-circulating unit was installed that filtered the glycol so that it could be used three times longer. Costs: $250,000; Savings: $552,000 per year.
	LSI Logic changed cleaning operations and reduced use of sulfuric acid by 60% and phosphoric acid by 80% by lowering the frequency they changed their baths from 4 to 8 hours. They also extended the useful life of HF baths by reusing the raw material 5 times instead of just once as done previously.
	Microchem installed filtration devices to extend the useful life of process baths. Additionally, they installed conductivity meters to regulate the process bath composition more efficiently. Finally, they installed rinse tank agitators (forced air) which help use the entire volume of the rinse tanks more efficiently, thus reducing the amount of material change-outs needed.
	Extending bath replacement period to reflect usage for semiconductor industry. Baths are usually disposed of by time and not by the number of wafers processed.
	Lenthor also installed filtration and monitoring devices to extend useful bath life.

[47] These methods were obtained through review of SB 14 plans submitted to the author. Some companies wish to remain anonymous.

Table 7.--Continued.

In-process Control Method	Method Implementation
Reduce Concentration of Raw Material Used	Wafer Etching Procedures. HF was used as 49% solution to etch wafers and quartz glassware. The concentration was lowered to a 10:1 HF concentration. This used 90% less HF. The drawbacks were longer process times.
	Hewlett-Packard (HP) also reduced the concentration of potassium ferricyanide it its wafer etch by 50%.
Controlling Flow and Dispensing	Lockheed installed a spray mist coolant system to replace the old coolant system (which cooled and lubricated, metal work chips). From the conversion 200,000 lbs. of waste were reduced (mist spray, recycling, in-situ recycling).
Reduce Drag-out of Raw Material From Process Baths	Cyanide waste was reduced by 75% when equipment was allowed to drain for longer periods over the process baths that they were soaking in. Also, raised lip rack supporters were installed to further reduce drag-out wastes.
	Microchem also changed process bath procedures. They practiced slower work piece removal from process baths, this reduced the drag-out volumes. They experienced longer times to complete procedures. They installed drain boards to further capture drag-out and returned to original process baths. Additionally, they shake the racks to further dislodge remaining drips back to the process bath.
	Lenthor changed process bath procedures to reduce drag-out, capture and return drag-out.
Change Definition of Clean	Hewlett-Packard redefined the required cleanliness of a cleaning process and reduced volumes of acetone and isopropyl alcohol by 25%.

Results

Although the case study examples are very diverse and process specific, there were some general trends. First, in order to make any of these changes, a professional must have a thorough understanding of both the production process and waste stream generation. These types of methods should be instituted in the design process, but, often at the time of design, hazardous waste generation was not a high priority. There are specialists, either process engineers or other consultants, who may be of use when identifying available technology and alternative methods.

There were four examples of how rinse water control measures were identified in the literature and in the SB 14 plans. The first example cited in a SB 14 plan used nonspecified separation techniques to isolate contaminated with noncontaminated rinse waters. The costs, benefits, and details of this change were not specified.

The second example obtained from the literature specified that controlled dispensing of rinse waters could replace rinse baths and use presumably less water. The costs and benefits were not specified.

Another technique also obtained from the literature suggested concentrating rinse waters into various rinse baths. Again no cost analysis was completed.

Finally, Lockheed Missile Martin Space (LMMS) changed cleaning operations for tanks. Instead of filling rinse tanks with 500 gallons of rinse water to clean them, they changed to manual operations of scrubbing with spray rinsing. They indicated that substantial savings were incurred, but did not indicate the associated costs with the change.

When the useful life of raw materials are increased through changes of in-process controls, then less new materials are needed and less waste materials are produced. This type of hazardous waste minimization was achieved a number of times in the SB 14 plans received. Some of the in-process controls used were filtration to remove contaminants, extending chemical bath lives before changing baths, installing monitoring devices, and using more dilute solutions. Cost savings of $550,000 per year were identified by Komag Inc. LSI Logic achieved 60 to 90 percent reductions in quantities of material used. Another company rejected measures to install monitoring equipment based on cost/benefit data.

In general, the cost/benefit details are vague, but trends for extending the useful life of raw materials were positive. LMMS installed a new coolant system that effectively eliminated 200,000 pounds of hazardous waste. This system relied on in-situ recycling and filtration to extend the useful life of raw materials. Usually, the cost of the new equipment must be less than the cost of the raw materials saved for projects to be considered.

Often times raw materials are wasted in chemical process baths because the materials soaking in the baths are not allowed proper time to drip back into the bath solution upon their removal. This is typically called "drag-out." Waste quantities were reduced by 75 percent as indicated in one SB 14 plan. Other examples did not specify the specific cost of the increased time for dripping costs. This type of change would be ideal if a mechanical process is used or if the operator has other tasks to accomplish while waiting for the materials to drip-dry.

Although the SB 14 plans provided a long list of types of the improvement methods, they rarely identified the actual costs savings of the quantities of waste reduced. Conversely, some of the plans that did identify cost savings did not clearly explain the methods used. Additionally, those SB 14 plans that did document their savings, often misallocated the type of minimization activity. Often, the true source control methods were confused with treatment or recycling methods. SB 14 plans with the greatest quantity of hazardous waste reduction activities tended to be the result of a combinations of source reduction, recycling, and treatment methods as applied to a single process.

Companies such as LMMS sometimes rejected process changes for the following reasons: a) long payback periods, b) increased worker safety and health hazards, c) generation of other hazardous waste, or d) economic impracticality. These and other issues are always of concern when a business considers implementing a proposed process change.

It should be noted that Komag Corporation achieved great successes with the implementation of in-process improvements. They documented the reduction of 150 tons of hazardous waste at a cost of six million dollars, which also resulted in improved product quality. Although the specific measures implemented were proprietary, 150 tons of waste minimization is a substantial reduction.

Equipment Modifications, Design, and Automation

The second type of input technology change identified in the literature is equipment changes. Equipment changes are made to reduce the toxicity or quantity of hazardous waste output from a process (Freeman 1990). These changes involve any one of three types of equipment modifications: 1) changes to operating parameters, 2) changes to design, and 3) automation of manual procedures. The equipment itself is seen as the input variable that, when altered, can produce the desired output response of hazardous waste source reduction.

Equipment modifications include changes in the parameters in which the equipment operates, such as temperature, agitation rates, feed and flow rates, turbulence, or intended capabilities that usually involves a retrofit. The adjustment of variables associated with the equipment will improve process efficiency while usually reducing hazardous waste generation (U.S. EPA, Office of Research and Development, Risk Reduction and Engineering Lab 1991).

The second type of equipment change is the change in equipment design. Equipment design changes involve planning equipment specifications, so that they produce little or no hazardous waste. This can be done in a number of ways including: a) up-front purchase of new equipment with hazardous waste minimization in mind (Katin 1991), b) design of customized equipment, c) substitute equipment in place of nonmechanical procedures that produce hazardous waste, for instance, using instrumentation in place of chemical processing, replacing solvent systems with mechanical abrasives, or using instrumental analysis in place of wet chemistry, and d) retrofit equipment so that the hazardous waste outputs are minimized.

The third type of equipment change is equipment automation. Equipment automation means replacing manual procedures with variables that can produce hazardous waste with an automated procedure. In order for source reduction to result from this change, the equipment must be able to perform the procedure more accurately than an operator, thus generating less hazardous waste, for instance, dripping, shaking, or rinsing systematically. This installation removes some of the waste generating variables associated with production and often caused by operator error (Cal/EPA, Alternative Technologies Division 1990).

Benefits

The source reduction benefits to making equipment changes are often overshadowed by the increased operating efficiency naturally achieved when old equipment is upgraded or process parameters are improved. Although new equipment or new changes to the equipment will almost always make the equipment run more efficiently, they also increase the potential (if purchased properly) to decrease the volume of hazardous waste being generated. The end result of a smoother running machine, set at optimum process conditions, will almost always reduce plant operating costs in the long run.

The benefits associated with process automation are assurances that parameters can be set and will remain constant throughout the process, thus reducing waste generation dependent on operator performance. Also, safety hazards associated with operator handling or hazardous materials can be reduced with automation (U.S. EPA, Office of Research and Development 1991).

Drawbacks

Purchasing or retrofitting equipment is always a capital expense and, therefore, can not be entered into lightly. Thorough analysis should be conducted based on all of the concerns, especially considering future usefulness. The environmental impact of the procedure must also be considered because environmental regulations are always changing and sometimes those changes effect equipment output. If an expensive type of equipment is purchased and the environmental regulations change, the machinery purchased could become obsolete. For example, many of the processes using CFCs, such as Freon 113, now must be altered to handle a different chemical because CFC production is being phased out.

If retrofits are performed with short term goals in mind, they can often cost more due to long term maintenance. Sometimes the troubles associated with maintaining a change can outweigh the cost of buying a new piece of equipment that already does what is needed.

An additional drawback to equipment changes is that it very rarely reduces the toxicity of the waste generated without the use of treatment technology. Reducing toxicity is usually dependent on the input materials identified in a company's initial review of processes.

Method Implementation

The literature and case studies did not discuss what should be considered when making new equipment purchases to minimize hazardous waste generation. Because equipment purchases are a capital expense, the obvious consideration for making a decision is a comparison of the short and long-term costs and benefits associated with modifying the process and existing equipment as necessary to the costs and benefits associated with acquiring new equipment. As a starting point, one must focus on the desired hazardous waste to be reduced and work back through the process to the equipment involved which contributes to the waste. The next step is to identify if there is other equipment on the market or available retrofits that could help to minimize waste output. The cost of proper disposal of hazardous waste and on-site treatment must be factored into the analysis.

Literature And Case Study Examples

The examples of equipment modifications were sparse in both the literature and SB 14 case studies. But the following were mentioned:

1) Use Mechanical to Replace Chemical Processes

- Replace wet chemistry with instrumental analysis when possible
- Replace solvent systems, such as wet stripping, with mechanical abrasives, such as dry stripping or mechanical wiping/grinding
- Replace chemical photoprocessing with electronic photo imaging
- Replace water wall booths with dry filter paint booths

2) Modify Equipment to Reduce Waste Output

- Modify tank and vessel design to maximize material drainage
- Use smaller batch tanks
- Install drainage racks to increase flow of drag-out materials back to process tanks
- Design equipment to minimize surface area exposed to process fluids

3) Change Equipment Parameters To Enhance Raw Material Efficiency

- Use heat units to control coating viscosity for surface coatings
- Increase temperature of rinsewaters
- Install a steel abrasive grit media to remove lead based paint. As compared to sand blast media, the steel grit is reusable 50 to 100 times mores and is more abrasive than sand. NASA Ames Research center

saved 2350 tons of waste per year was reduced by changing the grinding media

- Install a cryogenic vent recovery system to condense acid gases when equipment is evacuated for maintenance and the acid is then returned to the process. Prior to installing this equipment, these gases were neutralized in scrubbers. The resulting spent solutions were then considered hazardous waste. A 60 percent reduction in waste volume was achieved
- Regarding solvent recovery processes, plant equipment was installed to recover more solvent from the vapor stream during production. The recovered vapors were then reused. Solvent costs were reduced by $8,000 per year

4) Upgrade Equipment for Newer, More Efficient Technology

- At Hewlett-Packard's San Jose Site, new equipment was purchased (for $100,000) to improve the settling process for a procedure. It will use less water and generate 96 pounds per year less waste
- Replace Reverse Osmosis (RO) cellulose acetate membranes with Thin Film Composite (TFC) membranes will result in better water quality and reduce sulfuric acid used to adjust pH of RO feedwater. Analog Devices, reported 80 percent reduction in water and chemical usage after making the switch to TFC membranes

- Lockheed reduced hazardous waste metal scraps from a production process by 5.5 tons.[48] Previously, they had cutting dies with a hydraulic press to cut parts, but because of the way the process was designed and limitations of existing equipment, they were only able to use 50 percent of the raw materials. To increase the amount of raw materials used to 61 percent, they purchased a new ultrasonic cutting machine. Hazardous waste scraps were reduced by 38 percent
- Hewlett-Packard's photolithography area will buy a closed cleaning system (for $180,000) to realize a 10 percent reduction in isopropyl alcohol and acetone emissions. They will also experience added safety benefits of less handling of open containers and less environmental impact associated with volatile organic carbons (VOCs)
- Replacing old HVAC chillers and water towers with new ones will eliminate the use of CFCs and save energy

(Santa Clara Pollution Prevention Program 1994; U.S. EPA, Office of Research and Development 1991; Lindgren 1989; Freeman 1990).

Results

Often, equipment changes or upgrades involve large capital expenses. Companies without those types of resources, or without the resources to justify such purchases, often make do with existing inefficiencies. Most large

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[48] Also attributed to the reduction was a 35% decrease in the rate of production.

businesses with ample resources, like Hewlett-Packard, did not have problems buying new more efficient equipment. Rarely were there instances of new equipment purchases for source reduction measures identified from smaller businesses in their SB 14 plans.

There are a number of reasons why equipment purchases are not being accounted for in smaller business's SB 14 plans. For one, equipment modifications are not traditionally associated with source control methods. Another reason, is that resources are required to conduct a thorough analysis of the source reduction benefits associated with new equipment purchases. These benefits are not always evident or easy to access, and equipment purchases and modifications may be easier to leave off the list of measures instituted especially if the source reduction results cannot be readily calculated. A third reason is that typically a company will not see large volumes of waste reduction with just equipment changes unless the replaced equipment was archaic, and so the effect of equipment changes becomes easy not to include in any analysis.

In the case studies, examples given under the categories of source reduction were in fact treatment methods. Sometimes the treatment methods were used in congruence with source reduction. But when determining the quantity of waste reduced, deciphering which reductions were a result of source reduction and which were from treatment often was difficult.

CHAPTER 9

HAZARDOUS WASTE SOURCE CONTROL METHODS--GOOD OPERATING PRACTICES

Introduction

Good operating practices are the third and final category of hazardous waste source control methods identified and presented in this thesis. This chapter reviews the different types of good operating practices available to businesses for implementation of their SB 14 plans. In addition, it also evaluates the implementation process and provides specific examples of procedural modifications that improve operating practices obtained from some Santa Clara County SB 14 plans and the literature.

There are cases where hazardous raw materials[49] and corporate resources are not being fully utilized by industry. Although many factors contribute to the under-use of these resources, this chapter focuses specifically on how modifying existing procedures to improve operating efficiency can subsequently decrease resulting hazardous waste generation.

Policies, procedures, and practices that involve the use of hazardous materials or hazardous waste need to be analyzed from a multi-departmental perspective within a business to identify and correct inefficiencies. This

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[49] Chemicals that are classified by the manufacturer in their Material Safety Data Sheet as hazardous materials. Hazardous materials fall into four general categories; flammable, corrosive, toxic, and/or special hazards (e.g., radioactive, oxidizer, explosive, etc.).

analysis has the potential to create improvements that include reducing hazardous waste and increasing corporate efficiency (Freeman 1990). Unfortunately, these methods have only been recently recognized by industry as an important waste minimization technique (Freeman 1990).

More specifically, these operating practice modifications focus on policies, procedures, and practices that unnecessarily contribute to the generation of hazardous waste, but are not directly attributed to the production process--extrinsic hazardous waste.[50] Good operating practice modifications applied to extrinsic hazardous waste production generally involve the human aspect of plant operations and as such, the cooperation of individuals in different departments within a corporate structure. The representatives from a variety of departments may include purchasing, receiving, delivery, labs, environmental, and waste management. In most cases, the relative success of such projects is dependent upon the varied participants and their ability to work effectively together.

Most of good operating practice techniques are not new or unknown, but what needs to be reviewed are the practices in terms of the hazardous waste they generate. The types of operating practice modifications used to minimize hazardous waste generation can be blocked into general categories. These categories are procedural changes that involve hazardous material use,

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[50] These industrial procedural changes should not be confused with the input technology methods that identify intrinsic variables that change production related processes to achieve hazardous waste minimization objectives.

inventory management, and, shipping and receiving. Additionally, programs such as preventative maintenance and employee education/training can also be used to minimize hazardous waste generation.

With regard to implementing operating practice improvements for SB 14 compliance, the definitions for each type of operating practice are varied depending on the reference source. SB 14 mandates that operational improvements and administrative steps be considered and evaluated when implementing SB 14 plans. Although SB 14 regulations do not define "operational improvements," they do provide a limited definition for "administrative steps." SB 14 defines administrative steps to include inventory control, employee awards and training, in-house policies, and management support. The DTSC does provide an explanation of operational improvements for SB 14 compliance in their guidebook (Cal/EPA, DTSC 1994c). They define operational improvements to include loss prevention, waste segregation, product scheduling, maintenance, and site management. In addition to the above listed examples of good operating practice methods for hazardous waste minimization, the literature lists hazardous materials use, and shipping and receiving procedures. Each type of the good operating practice modification identified through the variety of sources is discussed and defined in the method implementation and examples section of this chapter.

Benefits

Implementing good operating practice modifications for hazardous waste minimization has many associated benefits. The primary benefit is that they are some of the easiest of all waste reduction methods to implement at a facility and can have a great hazardous waste reduction impact (Kobashi 1994; Cal/EPA, DTSC, OPPTD 1994b). In addition, it is beneficial that they generally involve administrative, procedural, or organizational changes that are low in technology, involve little up-front or long-term capital expenditure, effort, or time to implement, and therefore those changes are generally successful once identified (Walka 1991). Subsequently, company managers also have the greatest chance of getting these types of changes approved. Because of all those benefits, improving operating practices are now being recognized by industry as an important hazardous waste source control method (Freeman 1990).

Drawbacks

Unfortunately, there are a few drawbacks associated with implementing operating practice modifications. The major associated drawbacks are introduced with projects that exist between multiple departments within a corporate structure. These intradepartmental projects can incur problems at all phases of the project from their introduction to final results documentation. For example, if the needed changes are not introduced properly, either from outside or from within the company's departments, they may be resisted by those involved. This is particularly true if people feel that they are already optimizing resources or if the suggestion for change comes from outside the department controlling the project. Furthermore, some departments run under their own agendas and time constraints, and the waste minimization procedures that one group could benefit from may not be on the agenda of another department. Additionally, if the habits people perform are well established, substantial monitoring and training to change set behaviors may be required. Because a cohesive unit is needed to accomplish the operational improvements, all departments or divisions of a company must not only participate, but whole-heartily adopt the changes to maximize the efficient use of hazardous materials.

Regarding project accountability, quantifying the waste minimization results may not be easy because the reductions accrue in a variety of departments. As a result, department representatives may not receive instant gratification for their part in waste reduction activities. This is especially true regarding quantifying prevention efforts (e.g., a chemical not being purchased, or a spill not occurring). These types of activities are exceptionally difficult to attribute individual contributions.

Method Implementation and Examples

The literature and SB 14 plan case study information were reviewed to describe the improved operating practice method implementation process and find supporting examples for hazardous waste minimization. Waste minimization examples were categorized under topics of hazardous material use procedures, shipping and receiving, and inventory management (prepurchase review and inventory control), as well as preventative maintenance and employee education. Each of these categories are discussed in the following sections.

Hazardous Materials Use Procedures

Often hazardous raw materials are not fully utilized and their resulting hazardous waste is unnecessarily produced. This can be avoided if procedures governing hazardous materials handling and usage are evaluated and optimized. There are four major reasons why inappropriate or inefficient material usage contributes to hazardous waste generation: a) hazardous raw materials are under-utilized, b) careless operating procedures result in waste production, and c) stock materials become contaminated.

Hazardous raw materials can be under-utilized when polices and procedures impose potentially arbitrary or unnecessary standards on the specifications for those raw materials. For example, a certain grade, purity, concentration, or freshness is set. Traditionally, when standards and their resulting procedures were designed, they were not written with hazardous waste minimization in mind, therefore may need to be re-evaluated from that perspective. Businesses must reconsider the standards to determine if the standard's value outweighs the cost of hazardous waste generated for disposal. Pertinent questions regarding set standards revolve around the purity and concentration requirements for the procedure being adequately defined. Evaluating if raw materials be used longer without reducing the quality of the desired result must be done. Conversely, could improvements in purity increase efficiency, process yield, or lower toxicity (Lindgren 1989)? This will help determine what the true range of material use is so that hazardous waste is minimized and raw materials are maximized. See table 8 for some specific examples of how procedures that under-used raw materials can be improved.

Hazardous raw materials are also wasted through sloppy implementation of procedures that use those materials. As mentioned previously, wasted hazardous materials often become hazardous waste, therefore all aspects of procedures involving their usage, handling, storage, and transfer must be evaluated for hazardous waste minimization opportunities. See table 8 for specific examples of careless operating procedures that can improve material use.

The third source of inefficient hazardous material use that can contribute to hazardous waste generation is when raw materials are contaminated. Prevention of contamination is one of the best ways to extend the expected usefulness of these chemicals. There are many means of eliminating contamination through proper process design and layout (Lindgren 1989). Contamination of raw materials with waste materials, with wastewater, and other materials must be avoided. Often, because a technician is comfortable with all forms of the raw material being used, that is pure, contaminated, and waste forms, carelessness can result in mixing the wrong forms of the material together to render the raw material useless. Additional examples of how raw materials contamination can be avoided are cited in table 8.

Table 8.--Examples of Hazardous Materials Use Procedures

Type of Practice	Examples[51]
Hazardous Raw Materials Under-utilized	1) Solvent (especially Freon 113) vapor loss can be controlled if vapor recovery systems are installed (Freeman 1990). 2) Solvent vapors can also be controlled during chemical transfer. Gas pressurization should replace manual pumping mechanisms for chemical transfers. 3) Control viscosity through installing heating units to maximize efficiency of chemicals (Freeman 1990) 4) Regarding DI water conservation, production of DI water often uses sulfuric or hydrochloric acid. Switching from continuous flow to on-demand rinsing in the fabrication operations can minimize DI use and therefore, raw material use (Cal/EPA, DTSC, OPPTD 1994a). 5) Spray rinsing or allowing adequate time for drainage can minimize rinsewater use and dilution of process baths (Lindgren 1989).
Careless Operating Procedures	1) Use of proper equipment to do the job, such as, the use of good transfer pumps, funnels, and equipment connections to avoid leads and solvent losses. 2) Proper hazardous materials storage procedures, include adequate spacing between drums, chemical compatibility, secondary containment, and proper labeling (U.S. EPA, Office of Research and Development 1991). 3) Often, bulk materials must be transferred to smaller containers, and then moved to the area of immediate use. These types of procedures must not be performed hastily or sloppily because potential spills could result. 4) Parts need adequate time to drain chemicals back into process baths. If the time is cut short, then waste is also generated. 5) Using drip pans beneath valves to capture and reuse lost materials.
Contam-ination of Hazardous Materials	1) Use of rinses, covering or closing storage tanks and process baths, redesigning production lines to avoid activities above open baths. 2) Labeling of tanks and containers can minimize contamination. 3) Store hazardous materials, nonhazardous materials, and materials of different hazard classes separately to avoid contamination 4) A semiconductor manufacturer controlled rinsewaters after submerging wafers in hydrofluoric acid (HF). They are typically rinsed with large volumes of DI water and then treated. Segregation maximized treatment efficiency for materials and minimized contamination.

[51] Examples in table 8 were obtained from SB 14 plans and the literature review.

Hazardous Materials Inventory Management-Prepurchase Review

The primary position where improved operating procedures can prevent hazardous waste generation rests within the two basic aspects of inventory management planning: 1) control of purchasing through prepurchase review and 2) control of how the inventory is managed once it is on-site (Freeman 1990). To achieve a comprehensive inventory management plan, both prepurchase review and inventory control must be implemented properly to reduce the quantity of hazardous waste generated at the facility (Freeman 1989, 1990; Pine 1984). Although inventory management planning can be a very effective waste reduction method, it has not been widely recognized (Freeman 1990).

This section focuses on prepurchase review methods for inventory management of hazardous materials. They consider hazardous waste disposal costs, reduction of hazardous material volumes stored on-site, and material demand simultaneously to achieve hazardous waste minimization.

When developing a prepurchase review program, the following measures should be considered: a) centralizing pre-approval purchase procedures, b) checking existing stocks first, c) checking for the least hazardous practical alternative to that material, d) developing procedures to handle excess or expired materials, and e) knowing the purpose for which the materials are being purchased. For all these elements to be effective, it is essential that purchasing agents receive specialized training focusing hazardous materials reduction techniques.

Hazardous Materials Inventory Management-Inventory Control

Once materials are on-site, in the minimal volume and toxicity possible through an effective prepurchase review program, then inventory control is necessary to manage stock purchased. Inventory control is a waste minimization method that is increasingly popular in industry (Freeman 1989). Its great advantage is that it is not expensive to implement. The right purchasing procedures can control potential losses before they even enter the facility, but once they are on-site, gaining control over how they are managed is no simple endeavor (Freeman 1990). For inventory control to be an effective hazardous waste minimization method, hazardous materials must be viewed in light of their hazardous waste generation volumes and disposal costs. Additionally, in order to effectively reduce hazardous waste generation, inventory control requires knowledge of what chemicals are being used, where they are being used, in what quantity they are used, and why and what hazardous waste results from their use. With this in mind, sources of unneeded hazardous waste can be systematically eliminated. When developing inventory control procedures, numerous aspects of material management must be considered and they include the following: a) disposal costs of unused raw materials, b) stock-on-hand, c) hazardous properties and emergency controls, d) shelf-life, e) container size, and f) inventory tracking systems. All of these items must be evaluated in terms of their potential to eliminate the production of hazardous waste.

When methods of inventory control prepurchase reviews have failed and result in overstocked hazardous raw materials, there must be a disposal policy that minimizes that potential to become hazardous waste. Are the excess materials merely disposed of as hazardous waste, or are other methods of disposition pursued first? Some avenues of material management to consider before hazardous waste disposal is conducted include returning expired materials to the vendor and checking to if the materials has use to other departments.[52] Once the policy is established, it must be clearly communicated to all involved. To have a total inventory control system, the hazardous material's resulting hazardous waste generation is of primary importance. Examples of hazardous material inventory control measures are listed in table 9.

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[52] Some vendors are more cooperative than others. Purchasing agents should be instructed to negotiate terms of returns to facilitate further good relations (Freeman 1990). Keep in mind that these are hazardous materials and dangerous goods shipping regulations will apply.

Table 9.--Examples of Hazardous Materials Inventory Control Methods

Method	Examples
Prepurchase Review Program	1) Often, volume purchasing is performed without consideration for disposal costs (Higgins 1989). 2) If checks are in place for identifying existing stock and finding materials with less hazardous properties, then potential waste can be avoided (Freeman 1989, 1990). 3) If all hazardous materials go through a central contact for purchase approval, a number of unnecessary purchases may be avoided due to increasing efficiencies (Freeman 1990). 4) Purchasing agents can also calculate expiration dates and use-rates before purchasing to prevent excess stocks (Katin 1991).
Disposal Costs	1) Educate purchasing agents and employees that disposal costs of hazardous raw materials are almost always greater than the entire purchase price of the materials (Hill 1995; Freeman 1989). 2) Employees must take responsibility in this area by considering the disposal costs associated with each chemical purchase they request. 3) The main problem encountered when trying to reduce excess stock is that purchasing agents are trained to buy for the lowest purchase price, which often means buying in volume.
Stock-on-Hand	1) If too much stock is on hand, it could expire, tie-up funds that could be used for other purposes, pose health and safety hazards, or be rendered useless if procedures change (Freeman 1990). 2) On the contrary, if too little stock is on hand, there is a chance a company could run out of production materials, thus losing potential sales and profits. Within reason, materials should be ordered on an as-needed basis and expiration dates should not be exceeded (Freeman 1989, 1990; Katin 1991; Kobashi 1994; Nielsen 1994).
Hazard Properties and Emergency Controls	1) The hazards associated with materials once they are on-site must be recognized. Each hazard category presents its own unique set of hazards. This means that the more chemicals on-site, the greater the chance becomes of introducing an employee to safety and health hazards (Freeman 1990). 2) To reduce the inherent hazards associated with many chemicals, a business could reduce the different number of chemicals and reduce the number of similar products (Higgins 1989; Kobashi 1994; Katin 1991). 3) Institute a safety and health training program to instruct employees of the potential hazards, stock plenty of emergency response equipment, and ensure equipment does not leak through proper storage of materials (Katin 1991). 4) Most importantly, hazardous chemicals purchased should not exceed the emergency control systems capacity (Nielsen 1994; Freeman 1989; Lindgren 1991; Kobashi 1991).

Table 9.--Continued.

Method	Examples
Shelf-Life	1) If hazardous materials are not used before their shelf-life expires, they often have to be disposed of as hazardous waste (Freeman 1989, 1990; Katin 1991). 2) A first-in-first-out or rotating stocks inventory management procedure must be adopted to help prevent shelf-life expiration from being reached (Kobashi 1994; Cal/EPA, DTSC 1994b; Freeman 1990; Hill 1995; Higgins 1989). 3) Any expired materials present should attempt to be returned back to vendors (U.S. EPA, Office of Research and Development 1991; Freeman 1990). 4) Evaluate the manufacture's expiration dates set on materials to see if they are set too short (Freeman 1990).
Container Size and Empty Containers	1) When selecting the quantity of hazardous materials to purchase, pick the container size appropriate for the needed use as to reduce the need for material transfers. Transfers can result in evaporation or contamination of the bulk drum (Katin 1991; Hill 1995; Higgins 1989; Freeman 1989; Kobashi 1994). 2) Any increase in price associated with a smaller volume size is almost always offset by reduced hazardous waste disposal costs (Freeman 1990). 3) In California, containers greater than five gallons in size previously holding hazardous materials are considered hazardous waste. These extra treatment or disposal cost must be considered. It is best to avoid either option by trying to get manufacturers to take back the empty containers from their raw materials. 4) One manufacturer in San Jose, California, has changed from the use of disposable drums to refillable containers. They found that the use of bulk containers saved 37% on drum disposal costs and 67% on raw materials costs.
Inventory Tracking	1) Over-stocking of inventory contributors significantly to hazardous waste generation and inventory tracking system can help minimize overstocking. Computerized inventory data can be used for a variety of other corporate purposes including: regulatory reports, chemical sharing, MSDS matching, storage of extremely hazardous materials, and future purchasing (Freeman 1989, 1990; Katin 1991; U.S. EPA, Office of Research and Development 1991; U.S. EPA, Risk Reduction and Engineering Lab 1990; Cal/EPA, DTSC, Alternative Technologies Division 1990, 1994b; Nielsen 1994). 2) An internal material exchange holds perhaps the largest opportunity for keeping nonwaste from becoming waste. This method prevents surplus stock from being disposed of unnecessarily as hazardous waste. One could achieve this easily and inexpensively through a most basic system whereby people contact one central person before all nonroutine (nonstock) materials are purchased to see if they exist 'in-house' elsewhere. In a more advanced scenario, with a networked computer system in place within the industry, a chemical inventory could be put on the network with key information (chemical name, chemical abstract registry number, location of material, quantity, and contact person) for easier access and accuracy (Freeman 1990; U.S. EPA, Risk Reduction and Engineering Laboratory 1990; Nielsen 1994).

Preventative Maintenance

Hazardous waste from facility operations can be generated through faulty equipment, equipment failures and leaks, as well as during routine maintenance. Some sources in the literature suggest that an effective preventative maintenance (PM) program can reduce that hazardous waste generation (Freeman 1989, 1990; Cal/EPA, DTSC 1990). An added benefit to establishing an effective PM program is that it will cut costs associated with business interruptions resulting from unexpected equipment breakdowns. These unexpected equipment breakdowns and malfunctions are reduced through routine cleaning, lubricating, making minor adjustments, and testing, and replacement of minor parts (Freeman 1990). However, no PM program will work if maintenance is given a low priority. In many cases, the maintenance department is so busy responding to current problems that PM is overlooked or put off until it is too late (Freeman 1990).

The three basic elements of an effective PM program are, 1) routine inspections of equipment with special attention to leaks, 2) maintaining strict schedules, and 3) accurate recordkeeping of all maintenance activities (e.g., plant equipment location, what activities occur in that area, special notes on problem equipment, and maintenance manuals) (Freeman 1989; Noyes 1993).

The only specific preventative maintenance example identified in the SB 14 plans used to minimize hazardous waste generation was ensuring that all overflow alarms are in good working order and tested periodically.

Hazardous Materials Shipping and Receiving Procedures

It is important to have centralized shipping and receiving areas so that procedures can be implemented to reduce the unnecessary generation of hazardous waste resulting from those operations. Once the designated areas have been established, there are several simple, yet effective, methods for preventing waste generations from the shipping and receiving component of the total operation including: a) spill prevention measures, b) avoiding the acceptance of raw materials that are off-specification or incorrect, c) avoiding accepting materials that are damaged or leaking, d) use of proper labels, and e) instituting proper handling procedures (Kobashi 1994; Cal/EPA, DTSC 1994b; Freeman 1990).

None of the SB 14 plans reviewed mention the use of shipping and receiving procedures to minimize hazardous waste generation. The literature only cited only one specific application. It was in regard to the use of proper packaging materials and quality reliable shippers to ensure the hazardous material being shipped maintains their integrity while being shipped (Freeman 1990).

Employee Education and Training

Employee education and training is a key element of any hazardous waste minimization program, and several regulations require it when employees handle hazardous materials and/or hazardous waste. How the employee then applies that training and the effectiveness of the training will ultimately determine the success of any waste minimization program.

If employees do not know why hazardous waste minimization is important and what the proper procedures are to follow, they will not have incentive to institute those procedures or suggest further prevention measures. Hazardous waste minimization training topics should include at a minimum the following:

- correct hazardous materials handling and operating procedures, including appropriate personal protective equipment
- inspection procedures and schedules
- proper purchasing procedures with supplemental training offered to the purchasing agents
- emergency procedures including clean-up, contacts, and reporting.

When planning the training classes, it may be possible to add a segment on hazardous waste minimization procedure training to existing, already mandated training classes (e.g., hazard communication, hazardous waste management, chemical hygiene, etc.).

To enhance and enforce ideas presented in the formal training classes, an incentive program can be used. Incentives such as awards (e.g., a best waste minimization suggestion program), savings (waste minimization saving are passed on to departments identifying them), or recognition programs are all good steps to take to reinforce the training received.

The specific employee education examples provided from the SB 14 plans to reduce hazardous waste generation were numerous and include:

- Lenthor Engineering of Milpitas, California, a printed circuit board manufacturer, used training and incentives to training platers. They then held them responsible for minimizing drag-out of chemicals
- Micrometalics added waste minimization to existing training programs
- Hewlett-Packard trained operators to use less wipes to clean-up small spills and for housekeeping purposes. They were also taught to keep nonhazardous wipes out of the hazardous wipes bins. The cost to train was less than $10,000 and the estimated reduction in the hazardous waste generation was 10 percent of the total for that waste type
- Employees were trained on the principles of pollution prevention and the consequences of improper hazardous waste disposal (anonymous)
- LMMS conducted pollution prevention training to 400 engineers responsible for designing products. They also trained employees to wait for longer dripping time when pulling materials out of process baths.

Results

The results of many projects implemented using good operating practices were difficult to determine. Successes were not well documented in the SB 14 plans and examples provided by the literature and SB 14 plans were sparse. This may be because the procedures are so familiar to the employees that they are not recognized as having a hazardous waste minimization impact. Another reason may be that the waste minimization effect is too difficult or intangible to quantify and therefore is not being documented.

Specific results regarding the category of hazardous material use procedures indicate that procedures identified in the literature and SB 14 plans focused primarily on material loss during transfer, storage, and dispensing. They also focused on contamination, conservation and segregation of hazardous raw materials. The methods identified were not highly technical but were intended to aid in hazardous waste minimization. For example, regarding methods used to minimize contamination of raw materials and process baths were identified as the largest area of concern in the SB 14 plans. The nontechnical steps identified to minimize contamination were covering or closing storage tanks and process baths (Lindgren 1989), proper labeling, avoiding activities over open baths that could contribute to contamination, and using in-process filtration to extend bath lives and remove contaminants. All these efforts, although simple to implement, can reduce hazardous waste generation through accidental contamination of raw materials. No data was provided as the amount of reduction provided through the prevention of these types of mistakes.

In addition to the poor quantification of results regarding material use successes, the results regarding hazardous materials inventory management are even worse. They indicate a substantial amount of information available in the literature about inventory management techniques through prepurchase review and inventory control, but businesses are not documenting any efforts in this area in SB 14 plans. Data gathered from the SB 14 plans, in this case, tends to support Freeman's (1990) conclusions that these methods have not yet been widely recognized by industry.

Unfortunately, documentation in regards to the topics of preventative maintenance and hazardous materials shipping and receiving are no better. In these cases, the few examples that were cited in the literature and SB 14 plans were limited and provided nonspecific details. More research and documentation are needed in this area to determine if it is a viable hazardous waste minimization solution.

The most promising area of good operating practices results was demonstrated under the category of employee education and training. Numerous examples of training opportunities were provided in both the SB 14 plans and in the literature. This may be in part due to the fact that much training is already required by law and therefore to add hazardous waste minimization topics to existing training programs is relatively easy to achieve. This may also be due to the fact that the entire topic of good operating practice modifications is a behavioral approach that is practically impossible to achieve without instituting some training.

CHAPTER 10

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

It is well documented that rates of hazardous waste generation in the U.S. are increasing (Hirschhorn 1991). In response to the environmental and social problems associated with pollution, including hazardous waste generation, numerous environmental regulations have been instituted at the federal, state, and local levels. These regulations require elaborate management practices for the storage, transportation, and disposal of hazardous waste. Today's generators of hazardous waste incur substantial costs in complying with the requirements of these regulations. These compliance costs are expected to increase as hazardous waste management requirements continue to become more sophisticated and strict. Increased compliance costs increase business operating expenses and therefore detract from business profitability.

One proven way for businesses to control the costs associated with hazardous waste is the practice of hazardous waste minimization (Cal/EPA Reporter 1994; Ember 1992; Kerns 1992). Businesses that generate significant quantities of hazardous waste need to make hazardous waste minimization and the associated reduction in operating costs a priority if they are to remain competitive. Underwood (1994) and her colleagues have, for over a decade, conducted research that demonstrates that businesses can cut costs through hazardous waste minimization. If businesses consider both the lower costs of storing, transporting, and disposing of reduced quantities of hazardous waste and associated benefits, such as improved employee safety, the clear advantage of hazardous waste minimization over traditional pollution control methods for hazardous waste management becomes apparent.

The federal government has recognized the importance of hazardous waste minimization through the legislation of the Pollution Prevention Act of 1990. However, the Act does not mandate; it merely establishes a preferred hierarchy for hazardous waste management methods, with P2 as the preferred management method. While this legislation establishes the importance of P2 as a matter of public policy, the decision to actually implement P2 is left to the discretion of industry.

In contrast to the federal regulations, California legislation requires that businesses consider hazardous waste minimization opportunities and report on the progress of those activities. This legislation is referred to as "SB 14." SB 14 legislation, like the federal legislation, does not mandate that businesses curb hazardous waste production. While California requires the evaluation of hazardous waste minimization practices, the actual implementation of the practices, as at the federal level, is essentially voluntary.

Weak federal and state P2 mandates, in combination with other factors, appear to undermining P2 implementation. Underwood, whose research demonstrates the economic benefits of P2, indicates that many hazardous waste minimization measures are being underused by industry. Although regulators and businesses are cooperating to establish P2 practices in industry, hazardous waste minimization is not yet practiced widely in the U.S. or locally in Santa Clara County, California. The infrequency with which local businesses practice hazardous waste minimization can be demonstrated by the high rate of noncompliance with SB 14 plan requirements.

Summary of SB 14 Plan Compliance in Santa Clara County, California

Santa Clara County has two regulatory agencies with local or state jurisdiction over county SB 14 compliance. The local agency is the Santa Clara County, Environmental Management Agency, Pollution Prevention Office. The state (and lead) agency for SB 14 regulatory compliance is the DTSC. Representatives from both agencies were interviewed regarding the status of SB 14 compliance within the county. Neither agency had documented the extent of SB 14 compliance. Instead, the DTSC currently focuses on compiling industry and product-specific information on hazardous waste minimization. At present, DTSC is not focusing on SB 14 compliance per se.

In order to determine the previously undocumented extent of SB 14 compliance in Santa Clara County, a telephone survey was conducted of local businesses required to comply SB 14 regulations. Survey results indicate that, of the 327 Santa Clara County businesses known by the state of California to generate greater than threshold amounts of hazardous waste in 1993, only 37 percent of the businesses consenting to participate in the poll had SB 14 plans in place.

The survey results indicate a high rate of businesses not completing SB 14 plans and therefore not evaluating P2 options. This suggests that locally the P2 practice is not being implemented. Local businesses, like businesses nationwide, have yet to embrace P2 because of a wide variety of obstacles.

Summary of Barriers to Implementing Hazardous Waste Minimization Strategies

The hazardous waste minimization literature identifies several obstacles that businesses throughout the U.S. face when trying to implement hazardous waste minimization projects. As described in chapter 4, these barriers include: 1) institutional business practices, 2) scarcity of procedural and technical information, 3) lack of perceived incentives, and 4) lack of resources to or uncertainty regarding the costs of undertaking hazardous waste minimization projects. The combination of these many barriers hamper businesses during the implementation phase of hazardous waste minimization projects.

The 63 percent of Santa Clara County businesses polled that were out of compliance with SB 14 regulations appear to face the same obstacles. Of those businesses willing to discuss impediments to SB 14 compliance, the majority fit into the category of scarcity of information. The largest percentage of businesses (45 percent) that acknowledged that they were out of compliance with SB 14 stated that they were unaware of SB 14 requirements. An additional 25 percent of out-of-compliance businesses were familiar (some vaguely) with SB 14, but believed that they did not need to complete a SB 14 plan. Other businesses fit into the category of technological and resource barriers. These businesses were aware of the regulatory requirements, but stated that they did not know which methods they could use to implement projects and did not have staff time available to devote to the topic of SB 14 compliance. Of the businesses surveyed, 20 percent knew about SB 14 regulations but indicated that they did not have the resources to comply with regulations at that time. The remaining 10 percent would not discuss why they did not have a plan in place.

Santa Clara County is not alone in experiencing informational resource and technological barriers to P2 practice. These barriers are faced by businesses throughout the United States. Noyes (1993) states that although hazardous waste minimization practices are considered economically desirable, the information available to help companies to implement hazardous waste minimization practices is of limited use. Noyes also indicates that the literature is not sufficiently detailed to transfer specific information from one company to another. Companies generating pollutants not only have poor access to pollution prevention methodologies and regulatory requirements, they often also lack the technical expertise to institute pollution prevention strategies (U.S. EPA 1990; Cal/EPA Reporter 1994; Noyes 1993; Breen 1992).

This thesis summarizes information about hazardous waste source control methods from the hazardous waste minimization literature and from sixteen SB 14 plans collected as part of this thesis. These efforts were conducted to determine what information is available to businesses for implementation of their SB 14 plans and how this information can be more effectively utilized.

Summary of Source Control Methods for Hazardous Waste Minimization

The two major methods of hazardous waste minimization are source reduction and recycling. There are two types of source reduction methods of hazardous waste minimization: product changes and source control. This thesis only addresses the source reduction method of hazardous waste minimization and, within that, only source control methods.

Source control methods include input material changes, technology changes, and good operating practices. Input material changes usually involve changes in raw materials to reduce their toxicity. Technology changes include refining manufacturing process controls and automating of equipment. Both types of technology changes can improve the efficiency of raw material use in manufacturing, thereby generating less hazardous waste. The last type of source control method, good operating practice, consists of procedural changes that improve existing procedures to reduce accidental hazardous waste generation. Each of these source control methods is described in more detail below.

Input material changes are made with the goal of reducing the overall volume or toxicity of the final wastestream. The major benefits of employing this approach are reduced disposal costs and reduced employee exposure to toxic materials. The drawbacks to making input material changes are the costs to change the manufacturing process and the potentially undesirable effects the change may have on the final product. The input material changes identified most frequently in SB 14 plans were for solvents, specifically ozone depleting substances (ODSs) (e.g., chlorofluorocarbons or "freons"). The next most frequently used input material substitution was to replace solutions containing heavy metals (e.g., chromium and cadmium) with solutions containing no heavy metals. These material changes were intended to produce a less toxic waste output and to comply with environmental requirements other than SB 14.

There were numerous successful material input changes identified in the SB 14 reports. Many successful material changes resulted in annual savings in hazardous materials management costs of thousands of dollars.

(Hewlett-Packard, for example, identified two changes that saved $300,000 per year). So if done properly, implementing input material changes can have an enormous positive effect on corporate profitability. However, both DuPont and Lockheed Martin Missiles and Space (LMMS) identified replacements to ODS without a gain in competitive economic advantage. LMMS spent over three million dollars to replace trichloroethane and Freon 113 with non-ODS. This is primarily because the changes were driven by regulations other than SB 14 without which the businesses may not have implemented those changes.

Input material change data from some SB 14 plans were too general and failed to specify brand names for all substituted materials. Therefore, some data submitted was not as useful as it could be. Additionally, because of the proprietary nature of the product reformulations, specific examples of product substitutions are scarce.

Input technology changes involve modifying in-process controls or upgrading manufacturing equipment to make the process run more efficiently. Such changes can decrease the quantities of routinely generated hazardous waste if selected and implemented properly. Modifying in-process controls to increase operating efficiency has the highest potential to reduce operating costs (Freeman 1989). These types of changes are the least likely to be implemented because of two associated drawbacks: the amount of initial analysis and design work required to make the changes and the capital expense needed for equipment upgrades. In-process control modifications identified in SB 14 plans included the following: controlling rinse waters (e.g., water conservation and reuse), extending the useful life of raw materials (e.g., installing sensors to detect useful life of raw materials), and controlling the dispensing of materials (e.g., installing flow regulators, allow for longer drainage of equipment soaked in chemical solutions).

The following equipment changes are identified in the literature: changing operating parameters, changing design, and automation of manual procedures. The SB 14 plans frequently used the varying types of equipment changes including: replacing chemical process with mechanical processes, modifying equipment or operating parameters to reduce waste output, and upgrading equipment to newer, more efficient technology.

Good operating practices, the third category of source control methods, involves changing manufacturing procedures with waste minimization in mind. Improving operating practices can minimize the unnecessary generation of hazardous waste. The literature identifies six types of operating procedural improvements that can be made to minimize waste generation: 1) hazardous materials use, 2) hazardous materials inventory management, 3) preventative maintenance, 4) hazardous materials shipping and receiving procedures, and 5) employee education. The SB 14 plans typically identified material use improvements that reduced material loss during transfers, methods that attempt to avoid cross-contamination of chemicals, and material conservation. Some plans also cited improved inventory management practices (instituting material segregation and inventory control procedures) as a method to reduce waste generation.

Conclusions and Recommendations

Conclusions and Recommendations Regarding SB 14 Compliance in Santa Clara County, California

Although the advantages of implementing hazardous waste minimization programs are well documented, in practice, Santa Clara County businesses did not make hazardous waste minimization planning a priority, as evidenced by widespread noncompliance with SB 14 plan preparation. SB 14 compliance was deficient in two ways. First, a majority of Santa Clara County businesses did not even complete the plans. Second, many "completed" plans were inaccurate or incomplete.

Preparation of incomplete, inaccurate, or otherwise poorly-devised SB 14 plans is a widespread problem in California. The roots of this problem lie in part with the obstacles discussed earlier that face all companies trying to implement hazardous waste minimization programs and in part with the lack of defined minimum quality requirements for SB 14 plans. DTSC's Dave Hartley indicated that the DTSC views many of the SB 14 plans it has received to be of poor quality: many are inaccurate or even incomplete. Without proper guidance, businesses do not know what is expected to attain compliance. The DTSC's low assessment of the quality of SB 14 plans was corroborated by the poor quality of many of the SB 14 plans voluntarily submitted for this study by Santa Clara County businesses. SB 14 plan regulations do not prescribe standards for the quality or success of measures evaluated for minimization projects, a shortcoming that appears to contribute to the generally poor quality of SB 14 plans. Many of the SB 14 plans submitted to the DTSC, although self-certified as "complete," in all likelihood do not comply fully with SB 14 regulations. Although SB 14 legislation allows for the preparation of a SB 14 plan without actually minimizing hazardous waste generation, the plan must include some prescribed elements. However, there is little guidance regarding quality standards for the prescribed elements.

When Santa Clara County businesses were surveyed and asked for copies of their completed plans, there was general reluctance by businesses to share their SB 14 plans with the public. Presumably, a number of factors govern businesses' willingness to share information with the public and the poor quality of plans and resulting impacts to the businesses' public image are among them. Businesses may be unwilling to share SB 14 plans with the public as much because of poor quality or incomplete preparation, as for reasons of proprietary information or competitive advantage.

Other businesses were forthcoming with copies of their plans and offered additional help with this study. These businesses were, without exception, large corporations with ample resources, such as Hewlett-Packard, IBM, and LMMS. These plans were complete, thorough, and of generally exceptional quality. Both Hewlett-Packard and IBM value their public relations and often promote an eco-friendly image. This may be related to the completeness of their plans and the willingness to cooperate with this study.

Although some businesses are doing excellent work in the area of hazardous waste source reduction planning and implementation, businesses in Santa Clara County are generally out of compliance or only marginally complying with SB 14 requirements. Not only are plans not being written as required under SB 14 mandates, but regulatory agencies are not enforcing the regulations to ensure that plans of adequate quality are prepared.

Conclusions and Recommendations Regarding Barriers to Implementing Hazardous Waste Minimization Strategies and SB 14 Plans

The implementation of hazardous waste minimization strategies, and more specifically SB 14 plans in Santa Clara County, California, are impeded by a multitude of barriers. Because both federal hazardous waste minimization strategies in the Pollution Prevention Act of 1990 and California's SB 14 mandates are the first generation of essentially voluntary compliance legislation, these laws are weak from the perspective of regulatory enforcement and project implementation.

Regarding regulatory enforcement at the federal level, the Pollution Prevention Act of 1990 does not set mandates for hazardous waste minimization and therefore no enforcement action is required. California's SB 14 legislation, although without specific waste reduction mandates, does have other regulatory mandates for the preparation of SB 14 plans. Unfortunately, those current mandates are not being enforced by the DTSC and California businesses have not experienced punitive action from lack of waste minimization activity or noncompliance with SB 14 plans.

In California, the level of awareness about SB 14 mandates and lack of enforcement action by DTSC are probably related. From an enforcement perspective, punitive action may impart to businesses a greater incentive to comply with and awareness of the requirements of SB 14. A majority of Santa Clara County businesses polled regarding SB 14 compliance were unaware of SB 14 mandates, and are therefore out of compliance with those mandates. If those same businesses had incurred penalties for noncompliance, then their awareness and level of compliance would no doubt improve.

Regarding SB 14 plan implementation barriers, California businesses still experience problems in the development and implementation phases of hazardous waste minimization projects. Progress in this area is impeded by poor access to information on waste minimization methods and resources to use this information effectively. These barriers often result in the production of unsuccessful, inaccurate, and incomplete SB 14 plans.

The informational barriers are caused by numerous contributing factors that this study can only begin to discuss. One barrier identified is the poor dissemination of information. SB 14 regulations are the early examples of a new type of regulation involving cooperation, collaboration, and information sharing between industry and regulators. SB 14 regulations require that companies share with the business community and regulators the results of hazardous waste minimization efforts for the collaborative benefit of all in order to prevent duplication of research efforts. Yet, the information is not being shared among similar businesses. This, particularly among companies in similar businesses, contributes to the scarcity of information for selecting and implementing the most effective waste minimization methods.

The informational barrier is not just the result of businesses' failure to cooperate with each other. Regulators also have a valuable, but as yet only nascent, role to play in the dissemination of information. Regulators are undertaking to collect and collate resources to aid businesses in their SB 14 plan implementation. However, Santa Clara County businesses are experiencing that useful informational resources are not yet available. These informational resources are being developed by regulators, but it will take more time, perhaps several years, before the majority of businesses generating hazardous waste have useful information readily available.

The primary objective of SB 14 is to promote and regulate hazardous waste minimization activities. But SB 14 plans are also serving an implicit and perhaps more important function: they themselves are a valuable information source. Because there is a scarcity of information in the literature, SB 14 plans can serve as a comparatively rich source of new and previously undocumented methods for waste minimization. The DTSC appreciates this and, as a result, is currently focusing its efforts on collecting plans to collate industry-specific and material-specific information, rather than broad-sweeping compliance enforcement. The information gleaned from those plans will be compiled into guidance documents and made available by the DTSC to related businesses. The first round of businesses that prepared plans in order to comply with SB 14 did not have access to the resources that are currently being developed. These businesses completed their plans largely through trial and error.

As a result of the scarcity of waste minimization information, the effectiveness, accuracy, and efficiency of initial SB 14 plans has been greatly limited. For example, SB 14 plans received by the author and the DTSC are not accurate and waste minimization and treatment methods are not being distinguished in the plan. Although the regulations state that SB 14 plans evaluate and document 'source reduction' measures, many of the plans received evaluated waste treatment methods instead. Another perplexing example of an informational problem surrounding the SB 14 regulations is that of businesses that use wastewater neutralization systems. Although wastewater minimization is heavily targeted by SB 14 regulations, there was virtually nothing in the literature explaining how to minimize these massive aqueous waste streams at the source. If the DTSC does not review most plans or institute a system of certified reviewers to standardize plan content and quality, the quality and utility of plans is unlikely to improve in the near future.

Even if information on waste minimization method selection and implementation were readily available, many businesses may not have ample resources to make use of the data. Clearly if SB 14 plan implementation is not a company priority, other regulatory compliance issues will come first and hazardous waste minimization projects will suffer.

Because of the potential financial and product quality risk involved with waste minimization methods, businesses are reluctant to try implementing minimization measures without the proper information to ensure success. If further work is done documenting various waste minimization methods and associated information on costs and implementation considerations, other companies will be able to use such information to implement their own programs. The DTSC is currently trying to achieve these objectives, but they too have limited staff resources and technical expertise and have only issued a few such publications. Since high-technology and biotechnology companies are the backbone of Santa Clara County's economy and are expected to continue to grow, it is important that information is collected, collated and disseminated to aid the SB 14 compliance efforts by these industries. If an increasing number of companies are to comply with SB 14 regulations, cost-effective, useful implementation will require guidance documents.

One potential source of funds to augment DTSC resources could be the implementation of punitive fines against businesses for noncompliance. The resulting funds could be applied to speed the development and dissemination of guidance information to the regulated community.

Businesses and regulators are two sources of hazardous waste minimization information, but there are others. For example, other public groups or private consultants could be contracted by businesses to evaluate hazardous waste minimization potential for a business.

Conclusions and Recommendations Regarding Source Control Methods for Hazardous Waste Minimization

Input Material Changes

Although there is great potential for an input change to substantially affect the quantity, toxicity, and associated management costs of the resulting hazardous waste stream, there are many obstacles that must be overcome to successfully implement an input change. Not all substitutes create a net beneficial change, and the consequences of a proposed change must be considered carefully before implementing it. For example, some changes merely shift pollution from one medium to another, for example, from liquid to air, introducing new health hazards to employees, or adversely affect product quality. Though the objective of minimizing hazardous waste generation is met, other associated problems and pollution may develop. This problem was evident in some examples cited in the literature. Freon 113, an ODS, is being replaced with chlorinated solvents, such as, methylene chloride and perchloroethylene. Although the replacement solvents are not ODSs, they are carcinogens. When making input material changes, the costs associated with the increased health hazard to the employee must be considered. The literature states only to consider these other adverse effects, but does not offer methods on how to evaluate the likelihood of these adverse effects.

The most widely implemented P2 measure reported in Santa Clara County SB 14 plans was input changes to replace freons. The freon replacement measure is popular because ODS are being phased out of production and the availability of those materials is diminishing, which has substantially increased their price. Businesses have little choice but to find freon alternatives and may be rushing to find a substitute or be forced into using a less desirable input material. Most measures implemented in the SB 14 plans did not adequately document the net benefits of the change or the total waste volume that is reduced. In the case of input changes to replace ODS, the motivations for corporate action are to replace a necessary, but shortly un-available raw material, rather than a desire to implement P2. As a result, these measures, while financially beneficial, may not constitute true hazardous waste minimization. This is a general problem that is exacerbated by the scarcity of guidance on conducting SB 14 plans. Many measures documented as P2 measures in SB 14 plans may not be true hazardous waste minimization: the substitute material must be demonstrated to be less toxic and/or produce less hazardous waste. This information was not presented in the majority of SB 14 plans.

The literature states that the easiest input material changes to implement are those that are not product related (e.g., maintenance chemicals). These require the least capital investment and the least risk to production processes. Unfortunately, these types of operations generate relatively small quantities of hazardous waste when compared to manufacturing operations.

Input Technology Changes

Although the SB 14 plan input technology change case studies are diverse and process-specific, some general trends were identified. The implementation of input technology changes can require relatively costly design and capital expenditures, but the long-term benefits are almost always the following: a) increased process efficiency, b) reduced raw material usage, and c) reduced costs for hazardous waste disposal. Payback periods identified in some SB 14 plans were often very short, six months to a few years. Input technology changes tend to reduce operating costs, resulting in net, long-term economic benefit, even accounting for design and capital costs.

Although the SB 14 case studies provided numerous examples of process improvement methods, they rarely identified the actual cost savings or the amount of waste reduced. Conversely, in instances where the cost savings were discussed, the changes to manufacturing processes were not clearly described. To improve the usefulness of SB 14 plans to other prospective users, future SB 14 guidance documents need to outline specific requirements for documenting both savings in operating costs and resulting reductions in quantities of waste generation, and to clearly convey to preparers of SB 14 plans the distinction between source control and treatment methods. For example, the SB 14 plans reviewed often confused true source control methods with treatment or recycling methods. Additionally, the greatest waste volume reductions tended to result from a combination of source reduction, recycling, and treatment methods applied to a single process. In these cases, it is not clear how to quantify the reduction in waste quantities attributed solely to source control methods.

Berglund (1991) found that input technology changes are usually deferred until after administrative and process changes have been implemented. He states that for long-term P2, input technology changes that affect product design must focus on three areas: preventing the products from entering the environment, making the removal of such products from the environment easier, and facilitating their ability to be reprocessed.

The reason process changes are typically needed after a process has been implemented is that newer and improved technologies that reduce hazardous waste generation and its associated costs are introduced. Companies that had resources and foresight able to challenge their existing assumptions were often able to substantially reduce resource use, that is, to use the minimum concentration of raw materials required to successfully manufacture a product.

Good Operating Practice Methods

Good operating practice improvements can be made in the following areas: 1) hazardous materials use, 2) hazardous materials inventory management, 3) preventative maintenance, 4) hazardous materials shipping and receiving procedures, and 5) employee education and training.

There were numerous examples in the literature of changes to operating practices that resulted in reduced material use and therefore, potentially, reduced hazardous waste generation. Although all successfully-instituted changes in operating practice will save resources and therefore save money, neither the SB 14 plans nor the literature reviewed measured the resulting cost savings or the raw materials conserved from implemented changes. Because neither the literature nor SB 14 plans quantified the savings, how significant these methods will be in minimizing waste at the source is not known.

Material use methods appear to add value when applied to manufacturing processes in the semi-conductor industry, which typically uses large quantities of bulk materials, such as 500-gallon tanks of chemicals. Semi-conductor manufacturers typically focus material use efforts on methods to reduce material loss and cross-contamination associated with the transfer of materials. Although there were many examples of measures instituted to reduce tank contamination, there was no quantitative information provided in SB 14 plans or the literature regarding the resulting cost savings or quantity use reductions. Common sense appears to be the motivation for these types of changes: if the cost to implement a material use change is small, the measure is worth trying, even without precise estimates on the potential savings.

The final material use method that was widely used on in SB 14 plans was wastewater conservation or wastewater segregation from washing procedures. The reason that businesses frequently try to reduce waste in this way may stem from the way the SB 14 regulations are written, rather than the choice of regulated businesses. SB 14 requires that all waste streams that constitute more than 5 percent of the total waste generated at a facility be evaluated for reduction potential. For most industries, wastewater consists of 95 percent or more of the total waste-streams generated. The easiest approach to reducing wastewater volume is to conserve water use. This can reduce the load on the neutralization system and, presumably, lessen the use of neutralization chemicals. The benefits of such changes have not been determined and may in fact be marginal. Though almost all manufacturers with wastewater neutralization systems are affected by this rule, there is no available publication that addresses this topic of major regulatory concern. SB 14 targets wastewater treatment systems, but regulators and academics do not furnish industry with the tools truly to prevent pollution in this area, nor do they provide data on the cost effectiveness of implementing such measures. This is a major deficiency in the literature and on the part of the regulators for insisting on the concentration in this area without providing supporting data on its effectiveness.

In general, potential costs and savings from material use do not appear to drive businesses' decisions to make material use process improvement. Most measures documented in SB 14 plans did not adequately describe how much volume was reduced, how the reduction was achieved, or what the resulting cost savings were.

The literature provides numerous examples of the benefits associated with good operating practice methods of inventory control. While there is ample general discussion of inventory control in the literature, there is no discussion of specific types of inventory control measures being instituted. Inventory control methods seem to have the greatest appeal for R&D facilities because they work with a large number of chemicals, many of which are used in small quantities and have a distinct shelf-life and use. For R&D facilities to maximize the use of their chemicals, the facilities must know what chemicals are stored on-site and the quantities and ages of those chemicals. Initial implementation of inventory control methods for R&D applications is time consuming and expensive. The return on investment from instituting inventory control systems includes reduced waste generation and associated lower operating costs, which accrue slowly over time, and a more immediate improvement in organization which result in time savings for the scientists who use the materials.

One SB 14 plan evaluated centralizing purchasing efforts. While this business claimed success with this form of good operating practice, no specifics were provided as to the kind of success, making the plan of little use to other businesses considering this approach.

Installing chemical inventory systems in order to improve operations is successful only if the material is readily available and the material inventory system is easily accessed. It must be easier to use the system than to place an order for a new material. The system also needs support from management, including training and "advertising" to the end-users. One company's SB 14 plan indicated that an inventory system was easy to maintain if it was linked to the annual inventory requirement for the fire department, which was installed on the company's internal computer network. In this company's experience, real-time access for end-users was not a capability that was critical to the system's success. Although automated inventory systems can potentially reduce the amount of materials purchased, they have the drawback of encouraging transfer of hazardous materials throughout buildings and between buildings. This practice can lead to spills, with resulting waste of materials and employee injury.

Information about the good operation practices of hazardous materials shipping and receiving procedures, as well as preventative maintenance were virtually absent from both the literature and SB 14 case studies. Therefore, information is insufficient to conclude where these approaches can effectively minimize hazardous waste generation.

With regard to employee education and training, many businesses included training in their SB 14 plans as an approach to minimization hazardous waste generation. However, the plans did not document the results, costs, and benefits associated with that training. One exception was LMMS, which had an exceptional training idea. Where other industries focused their training on reducing operator error that unnecessarily generates hazardous waste, LMMS took the training one step deeper in the fundamental manufacturing process. They offered training to 400 engineers responsible for the design of all their technology and systems. This is a truly preventative approach that potentially reduces or eliminates hazardous waste production from the next generation of manufacturing processes before these processes are even designed or implemented. Such a far-sighted approach avoids the expensive and at times marginally beneficial exercise of modifying an existing manufacturing process.

When selecting from the plethora of available hazardous waste minimization methods, a given method will be better suited to certain industries or manufacturing operations. It would therefore be useful if SB 14 plans, regulatory guidance, and professional literature indicated the types of manufacturing activities for which a methods is generally well suited. For example, R&D labs tend to use many different chemicals and hazard classes in small volumes, so good operating practices, and in particular inventory management procedures are generally the best means to effectively reduce their hazardous waste generation. Manufacturing facilities, in contrast, typically process large volumes of materials continuously, so input procedures and material transfer procedures can often produce greater gains in waste minimization and associated cost savings.

General Conclusions

U.S. industry generates enormous quantities of hazardous waste that can potentially cause grave adverse environmental and social consequences. Environmental regulations, which have grown more sophisticated and strict over the last several decades, are undergoing a paradigm shift that has resulted in the first examples of a new generation of regulations. These regulations seek to minimize pollution generation at the source. In California, early efforts at P2 under the SB 14 program have had mixed results. There are examples of excellent P2 initiatives that improve the competitiveness of the implementing company while protecting the environment and worker health. These cases, however, are the exception rather than the rule. Most regulated companies have not complied with SB 14 plan requirements, and many that have done so have only responded perfunctorily. Few companies have followed through with essentially voluntary implementation. The result is few documented projects, and a scarcity of information on methods, extent of compliance, and the costs and benefits of P2 implementation.

In view of the uncertainties regarding the costs and benefits of P2, it seems an important matter of public policy whether we should wait until P2 projects demonstrate themselves and more useful guidance is available to industry, or we should forge ahead, under the assumption that more needs to be done. If, in fact, we are not doing enough to minimize pollution production, then more aggressive governmental efforts in technical support and compliance enforcement are needed. Given the trends of increasing hazardous waste production, and sporadic SB 14 compliance, industry and government need to work with more urgency and cooperation.

Pollution prevention through hazardous waste source reduction, though demonstrated repeatedly to be an economically-viable business practice, has yet to enjoy widespread use by or yield significant reduction in hazardous waste generation from local industry. Despite the economic, environmental, and social benefits of P2, there is much resistance to change. Local regulators are working with a body of regulations that, while novel in their approach to waste control, are essentially voluntary in character. Regulators' efforts to encourage compliance through loans and technical assistance programs have not resulted in widespread adoption of P2 practices. Businesses still face many obstacles, both internal and external to their organizations, to incorporating P2 into their business model and manufacturing operations.

Carefully planned and well implemented SB 14 plans demonstrate that local companies have the ability to reduce hazardous waste generation and reduce operating costs. However, SB 14 legislation alone cannot address the problem of hazardous waste generation faced by the world's industrialized cities. SB 14's current effectiveness is questionable, but it is not a failure. SB 14 is a legislative and regulatory experiment in a new and evolving societal approach to managing hazardous waste without stunting industrial growth. SB 14, and subsequently regulatory initiative in P2, are only part of an evolving approach that includes other regulations, development and sharing of P2 technology, financing for remunerative but capital-intensive P2 methods, and education of policy makers and industrial employees and managers in P2 philosophy and technology. There are strong incentives at play that motivate such an integrated approach to P2. The stakes are high--sustained industrial growth without commensurate decline in environmental quality and health--and all parties stand to benefit. It should be viewed as just one component among a long list of approaches that include other appropriate regulation, technology sharing, and general assistance in implementing effective plans. "Unless the huge output of industrial waste is reduced at the source, humankind can expect little real improvement in the critical risks affecting the world environment and human life" (Underwood 1994).

GLOSSARY

CERCLA. The federal Comprehensive Environmental, Response, Compensation, and Liability Act (CERCLA) requires businesses to record and notify where wastes were disposed of. Under CERCLA, liability for the clean-up of uncontrolled hazardous waste sites is strict and severe. A generator can be held liable for total site clean-up costs, including the pollution that resulted from practices that, although illegal today, were legal at the time of release. Clean-up costs in the multimillion dollar range are commonplace (McClintock 1987).

Hazardous waste. Any waste that is toxic, flammable, reactive, or corrosive (Sell 1992).

Hazardous Waste Source Reduction. Either of the following is source reduction: 1) any action which causes a net reduction in the generation of hazardous waste; and (2) any action taken before the hazardous waste is generated that results in lessening of the properties which cause it to be classified as a hazardous waste (Cal/EPA, DTSC 1994b). Source reduction does not include actions taken after a hazardous waste is generated, actions that merely concentrate the constituents of hazardous waste to reduce its characteristics, actions that merely shift hazardous waste from one environmental medium to another, or treatment (Cal/EPA, DTSC 1994b).

Pollution prevention (P2). A multimedia approach that eliminates or reduces the volume and/or toxicity of a waste at the source prior to discharge. This reduces the need to manage hazardous waste at all levels from cradle to grave (inventory control to Superfund liability associated with clean-up) (Cal/EPA Reporter 1994; Cheremisinoff 1992; Cal/EPA Reporter 1994). The P2 act of 1990 goes beyond hazardous waste minimization to include the maximum elimination of all waste types incorporated in the waste management hierarchy.

Recycling. "The use, reuse, or reclamation of hazardous constituents. Recycling is second in the waste management hierarchy because the hazardous waste is generated, thus representing some hazard to the environment if mismanaged (Cal/EPA, DTSC 1994b).

RCRA. Resource Conservation and Recovery Act (1976) authorizes federal mandates for hazardous waste management. RCRA requires the supervising of hazardous waste streams from "cradle to grave," thus ensuring that hazardous waste is being managed in an environmentally sound manner (Clayton Environmental Consulting Inc. 1994).

RCRA Amendments. The 1984 Hazardous and Solid Waste Amendments to RCRA requires generators of hazardous waste, who dispose of waste off-site, to certify that they have an economically practicable program in place to reduce pollution production. They must also create biennial reports describe their pollution prevention efforts. Because there is no inquiry by government into the content of the program, generators to make a good faith effort to minimize waste (Bobertz 1992; Cheremisinoff 1992).

SB 14. The Hazardous Waste Source Reduction and Management Review Act of 1989, requires hazardous waste generators (producing >13.2 tons of hazardous waste or 25.5 lbs. of extremely hazardous waste) to consider source reduction as the preferred method of managing hazardous waste and prepare numerous reports documenting this effort (Cal/EPA Reporter 1994; Cal/EPA, DTSC, OPPTD 1993).

Small Business. "A small business means: 1) A business activity, unless excluded in paragraph (2), that is all of the following:

(A) Independently owned and operated.

(B) Not dominant in its field of operation.

(C) Not exceeding the following annual gross receipts in the categories of: (i) Agriculture, one million dollars. (ii) General construction, nine million five hundred thousand dollars. (iii) Special trade construction, five million dollars. (iv) Retail trade, two million dollars. (v) Wholesale trade, nine million five hundred thousand dollars. (vi) Services, two million dollars. (vii) Transportation and warehousing, one million five hundred dollars.

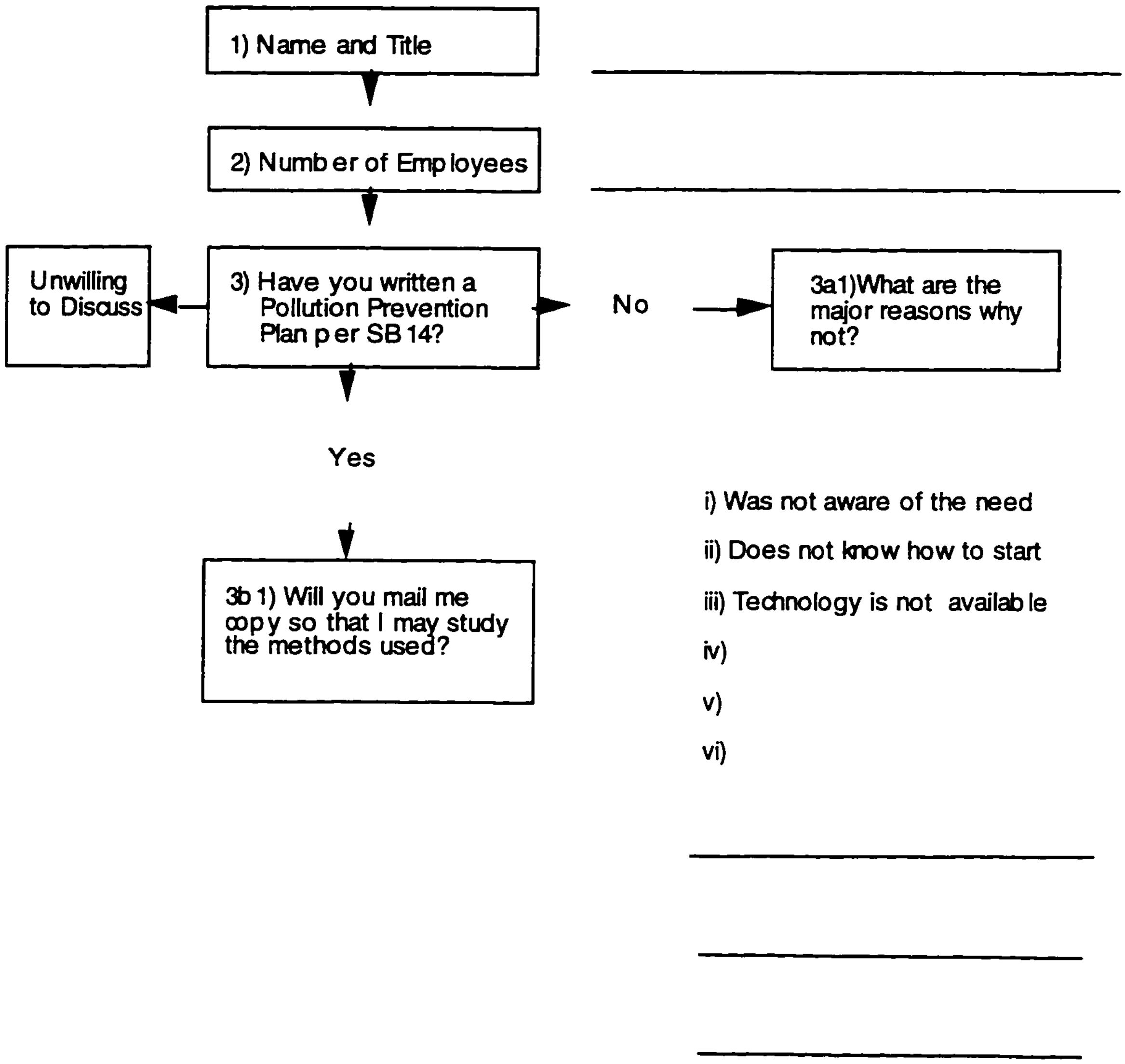
(D) Not exceeding the following limits in the categories of: (i) A manufacturing enterprise, 250 employees. (ii) A health car facility, 150 beds or one million five hundred thousand dollars in annual gross receipts. (iii) Generating and transmitting electric power, 4.5 million kilowatt hours annually" (Cal/EPA, DTSC 1994c). See Government Code, Article 2, Section 11342 for a list of businesses that are excluded because of the type of business activity conducted (Cal/EPA, DTSC 1994c).

Toxic Release Inventory (TRI). A required report under the Community Right-to-Know act of the Superfund Amendments and Reauthorization Act (SARA) Title III, Section 313. As of July 1992, it requires companies to report publicly on chemical releases to the environment and report on toxic reduction efforts through TRI reports.

Waste minimization. It "includes anything that reduces the load on hazardous waste treatment, storage or disposal facilities by reducing the quantity or the toxicity of hazardous wastes" (Higgins 1989).

APPENDIX 1 TELEPHONE SURVEY

Person Interviewed -Manages Hazardous Waste Issues



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