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Environmental Pollution
Prevention Project

Introduction To Pollution Prevention

Training Manual

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PURPOSE AND ORGANIZATION OF THIS MANUAL

This manual provides an introduction to the application of pollution prevention techniques. It discusses the role of pollution prevention in a broad based environmental management program. It provides businesses with practical information on how to approach and implement a pollution prevention program. The intended audience comprises owners, managers and responsible employees of public and private industrial enterprises.

Chapter 1 introduces the concept of pollution prevention and examines the reasons for pollution prevention. Chapter 2 discusses the pollution prevention assessment methodology procedures developed by the United Nations Environmental Programme. Chapter 3 presents the Environmental Pollution Prevention Project (EP3) assessment methodology and several case studies of assessments done at industrial facilities participating in EP3. Chapter 4 illustrates some issues and methodologies for calculating the financial benefits of pollution prevention opportunities. Chapter 5 addresses some of the organizational issues encountered in implementing pollution prevention opportunities.

THE ENVIRONMENTAL POLLUTION PREVENTION PROJECT (EP3)

The Environmental Pollution Prevention Project (EP3) is a five-year program sponsored by the United States Agency for International Development (USAID) to address urban and industrial pollution and environmental quality in developing countries. The objectives of the program are:

- to establish sustainable pollution prevention programs in developing countries
- to transfer urban and industrial pollution prevention expertise and information
- to support efforts to improve environmental quality.

EP3 was launched in spring 1993. The Project operates though a contract with RCG/Hagler Bailly, Inc. and 16 subcontractors, a cooperative agreement with the Water Environment Federation, and an interagency agreement with the U.S. EPA. Activities in developing countries are initiated through buy-in agreements with USAID country missions. The first country to host EP3 activities was Chile, where an EP3 office was established in fall 1993. Since then, EP3 operations have begun in Tunisia, Egypt, Ecuador and Indonesia. EP3 offices in each country develop partnerships with environmental NGOs, government agencies, and industry associations.

EP3's objectives are achieved through several activities:

- on-site industrial assessments to identify pollution prevention opportunities
- institutional support to help industry and governments develop and implement programs to manage industrial waste and pollution
- an EP3 headquarters clearinghouse and in-country clearinghouses to disseminate pollution prevention-related materials
- training for environmental professionals.

EP3's pollution prevention assessments for industrial facilities are conducted by teams of U.S. industry facility specialists, pollution prevention experts, and local environmental consultants. The U.S. experts are made available on either a paid or pro bono basis. To provide this expertise, the Coalition for International Environmental Research and Assistance (CIERA) and the Water Environment Federation (WEF) have worked with EP3 to develop an extensive network of environment and industry experts who are available to participate in these assessments. Through their interaction with facility managers and local consultants, these experts help to build pollution prevention knowledge in the host country.

The pollution prevention assessments are conducted in such industrial sectors as textiles, leather tanning, food processing, metal finishing, printing, paper/paperboard, and chemicals. Generally, EP3 targets its assessments in small- to medium-sized facilities that present pollution prevention opportunities. The assessment's recommendations focus on low- or no-cost management practices and operational improvements, and on medium-level capital equipment and process modifications with projected cost savings and environmental benefits. Local EP3 staff help the facilities with the implementation of these recommendations.

Training workshops and seminars are conducted to transfer the results of the facility assessments to the remainder of the industrial sector. Inherent to the goals of EP3 is the creation of demand for pollution prevention. EP3 achieves this objective by demonstrating the environmental and economic benefits of pollution prevention and developing a supply of local professionals trained in pollution prevention techniques. As such, industry management and local environmental professionals are trained in the principles of pollution prevention, environmental cost accounting, and facility assessments. Through its network of clearinghouses, EP3 also provides access to pollution prevention and clean technology information.

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CHAPTER 1
INTRODUCTION

Rapid industrialization and urbanization in many countries have led to severe pollution: water that is unfit for drinking or bathing, extreme levels of air contamination, and growing quantities of municipal and hazardous wastes that are disposed improperly. Initial efforts to manage urban and industrial pollution have concentrated on what is commonly referred to as "end-of-pipe" treatment which focuses on what to do with the waste once it has been created. While improvements in treatment and disposal technology have led to dramatic reductions in the quantity and types of pollutants discharged into the environment for many countries, "end-of-pipe" methods have proven to be costly and ultimately unsustainable.

Pollution prevention focuses attention away from the treatment and disposal of wastes and towards the elimination or reduction of undesired byproducts within the production process itself. Experience in the United States and other countries has demonstrated that in the long run, pollution prevention through waste minimization and cleaner production is more cost-effective and environmentally sound than traditional pollution control methods. Pollution prevention techniques apply to any manufacturing process, and range from relatively easy operational changes and good housekeeping practices to more extensive changes such as the substitution of toxic substances, the implementation of clean technology, and the installation of state-of-the-art recovery equipment. Pollution prevention can improve plant efficiency, enhance the quality and quantity of natural resources for production, and make it possible to invest more financial resources in economic development.

1.1 WHAT IS POLLUTION PREVENTION?

1.1.1 What is Pollution?

Pollution is any contamination of the air, water, or land that results from human activity. Pollution results from inefficiencies in the manufacturing process, both operational practices and improperly designed and utilized equipment. Pollutants are unused raw materials or by-products resulting from the production process. Pollution represents a loss of profits in manufacturing.

In simplest terms, all outputs from a manufacturing facility can be put into two classifications: product and waste. Anything that the customer pays for is product; all else

that leaves the facility is waste. In an ideal world, manufacturing activities would produce zero waste. In the real world, industry must strive to reduce the waste from manufacturing since this represents an inefficient use of scarce resources. It can be argued that all waste can be indirectly associated with pollution since the management of waste consumes resources that would not otherwise be used, and pollution is often generated in these waste management activities.

1.1.2 What is Prevention?

Prevention is the act of taking advance measures against something possible or probable. Prevention is generally contrasted with control or cure. For instance, vaccines *prevent* illnesses, while antibiotics *control* illnesses; similarly design for quality *prevents* defects, while inspection *controls* defects; seat belts prevent injury, while casts and crutches help cure injury from car accidents. Generally speaking, the effort, time, and money associated with prevention is less than that of control or cure. This idea is captured in the maxim "An ounce of prevention is worth a pound of cure." Thus, in many cases it is worthwhile for industry to prevent pollution rather than control it.

1.1.3 Definitions of Pollution Prevention

The United States Environmental Protection Agency (US EPA) defines pollution prevention as any practice which:

- reduces the amount of any hazardous substance, pollutant, or contaminant reentering any waste stream or otherwise released into the environment prior to recycling, treatment, and disposal; or
- reduces the hazards to public health and the environment associated with the release of such substances, pollutants, or contaminants; or
- reduces or eliminates the creation of pollutants through (1) increased efficiency in the use of raw materials; or (2) protection of natural resources by conservation.

The Canadian Ministry of Environment defines pollution prevention as:

> any action which reduces or eliminates the creation of pollutants or wastes at the source, achieved through activities which promote, encourage or require changes in the basic behavioral patterns of industrial, commercial and institutional generators or individuals.

Many terms similar to pollution prevention are in use today. In 1989, the United Nations Environment Programme coined the term cleaner production. Other terms in use include: clean technology, waste reduction, waste prevention, eco-efficiency, and waste minimization. There is no universal consensus on what these terms mean. For clarity, this manual uses the US EPA definition of pollution prevention.

Pollution Prevention Opportunities in Auto Painting

Problem:

It is common for auto companies to change paint color with each car that goes through the paint process. As a result, old paint must be purged from the lines before painting each car. This results in excess paint sludge waste and fugitive emissions of toluene and xylene. Additionally, the purging and refilling qualifies as a setup activity that adds time to the process.

Pollution Prevention Solution #1:

Block painting, the process of painting batches of like colored cars, is a manufacturing process change that reduces the purged paint sludge and solvent emissions. Further, block painting not only decreases the waste, but also the setup time involved in the process.

Pollution Prevention Solution #2:

The technology now exists to paint cars without the toxic toluene and xylene solvents. Similar to the way a photocopier affixes ink to paper, electrostatic painting can adhere paint to treated metal. While the scrubber represents treatment and block painting represents waste reduction, shifting to the electrostatic painting process represents **pollution prevention by design**. According to data from Toyota, the electrostatic technology exists, and actually exhibits better quality characteristics than solvent-based painting. Unfortunately, paint booths represent a large capital investment (upwards of $10 million) that is usually amortized over ten years. In the U.S., however, because the big three automakers have all invested in new solvent-based paint booths within the past five years, electrostatic painting will not become commonplace for another five to ten years.

1.1.4 The Environmental Management Hierarchy

Environmental management encompasses a variety of strategies for dealing with wastes. A hierarchy has been developed to prioritize these strategies. Strategies that reduce or eliminate wastes before they are created are preferable to those that deal with treating or disposing wastes that are already generated. This hierarchy is:

- **Prevention:** The best waste reduction strategy is one that keeps waste from being formed in the first place. Waste prevention may in some cases require significant changes to process, but it provides the greatest environmental and economic rewards.
- **Recycling:** If waste generation is unavoidable in a process, then strategies that minimize the waste to the greatest extent possible should be pursued, such as recycling and reuse.
- **Treatment:** When wastes cannot be prevented or minimized through reuse or recycling, strategies to reduce their volume or toxicity through treatment can be pursued. While "end-of-pipe" strategies can sometimes reduce the amount of waste, they are not as effective as preventing the waste in the first place.
- **Disposal:** The last strategy to consider is alternative disposal methods. Proper waste disposal is an essential component of an overall environmental management program; however, it is the least effective technique.

ENVIRONMENTAL MANAGEMENT HIERARCHY			
Priority	**Method**	**Example**	**Applications**
1	Prevention (Source reduction)	▸ Process Changes ▸ Design of Products that Minimize Environmental Impacts ▸ Source Elimination	▸ Modify Process to Avoid/Reduce Solvent Use ▸ Modify Product to Extend Coating Life
2	Recycling	▸ Reuse ▸ Reclamation	▸ Solvent Recycling ▸ Metal Recovery from a Spent Bath ▸ Volatile Organic Recovery
3	Treatment	▸ Stabilization ▸ Neutralization ▸ Precipitation ▸ Evaporation ▸ Incineration ▸ Scrubbing	▸ Thermal Destruction of Organic Solvents ▸ Precipitation of Heavy Metals from a Spent Plating Bath
4	Disposal	▸ Disposal at a Permitted Facility	▸ Land Disposal

1.2 REASONS TO PREVENT POLLUTION

In most countries there is a need to balance economic growth with environmental protection. It is increasingly being recognized that economic development and the health and welfare of a society are closely linked to proper management of a country's natural resources and environment. In these countries pollution prevention offers the government and industrial sector a way to manage the impacts of industrial growth on the environment while enabling economic development. Specifically, pollution prevention addresses three important components of the environmental protection/ economic development issue:

- **Environment:** offers a better solution for environmental management than "end-of-pipe" pollution solutions
- **Quality:** encourages evaluation of production processes and product quality
- **Cost:** improves a facility's bottom-line by reducing treatment costs, saving on material and resource inputs, and reducing risk and liability insurance

1.2.1 Environmental Issues

The overriding purpose of pollution prevention is to improve and protect environmental quality, particularly in areas that are becoming increasingly polluted as a result of rapid industrialization and urban growth. Pollution prevention measures reduce the need for scarce raw materials, toxic materials, and energy and reduce the discharge pollutants both toxic and non-toxic into the environment. This need is even more critical in areas that rely on scarce resources for their well-being.

Dealing with environmental wastes through "end-of-pipe" measures (such as wastewater treatment systems, hazardous waste incinerators and other treatment technologies, secure landfills, monitoring equipment, solid waste hauling equipment, air pollution control equipment, and catalytic converters) has proven to be very costly and does not address all environmental problems. Pollution prevention offers industry the advantages of:

- less need for costly pollution control equipment
- "getting ahead" of environmental regulations
- reduced reporting and permitting requirements
- less operation and maintenance of pollution control equipment.

1.2.2 Improving Product Quality Through TQEM

The process of identifying pollution prevention opportunities also provides a facility with the opportunity to identify measures to improve product quality. A pollution prevention assessment requires a facility to examine its production process in-depth. Finding ways to reduce wastes also requires a firm to examine the root causes for generating wastes and improve its processes.

Total Quality Management (TQM) is the management system developed to achieve the goal of high product and service quality. The management elements of TQM include: 1) Customer focus; 2) Continuous improvement; 3) Teamwork; and 4) Strong management commitment.

At first glance, TQM seems unrelated to these environmental concerns. Yet the inherent strengths of the TQM methodology can effectively address some of these issues. Professionals who apply TQM concepts to environmental issues have coined the term Total Quality Environmental Management (TQEM). TQEM is a logical method for achieving pollution prevention.

Customer focus: In the context of quality, the customer is defined as the person who employs the "product and service characteristics." Customers fall into two categories, internal and external. The internal customer is the next person in the production chain, while the external customer is the end-user of the product. In the auto industry, the person who installs the

bumper is an internal customer to the department producing the bumpers. The external customer is the consumer who purchases the finished car. If the definition of the customer is expanded to include those people and environments that are affected by the production process waste, total quality management requires us to understand the impact of this waste on those customers, and take steps to reduce it. Both W. Edwards Deming and Kiyoshi Suzaki, legends in the field of TQM, have defined waste as that which does not add value.[1] Here, we define waste more specifically to be the physical by-products of a process. This can be excess paper in an insurance office as well as waste chemicals from a paper mill. By more narrowly defining waste, the principles of its elimination put forth by Deming and Suzaki are no less pertinent.

CASE STUDY: TRICHLOROETHYLENE (TCE)

Recognizing the Customer...

Many industries use the solvent trichloroethylene (TCE) in their operations. This highly toxic chemical must be contained in a closed system, as releases of TCE can be fatal. Such releases often require the evacuation of the facility. Here the plant workers are the unwilling internal customers of TCE fumes. The external environment is also an unwilling customer. Rivers downstream can be effected by the effluent of a paper mill or oil refinery. Aquatic life in the river and people dependent on the river for drinking water are unwilling customers of this effluent.

Continuous Improvement: Those who have embraced TQM understand that quality can only be built into, not inspected into the product. This requires the producer to continuously identify and eliminate the root cause of the impediments to quality. Continuous improvement is also the key to reducing the environmental impacts of the production process. The traditional approach to industrial waste has been to view it as a necessary, though unwanted, by-product of manufacturing. While production generates the waste, the responsibility to dispose of the waste in a safe and legal manner usually falls on the environmental engineering department. Because environmental engineers receive the waste after it has been created, they are not intimately familiar with the processes that create it. Further, because waste reduction is not a component of their performance review, environmental engineers do not have the institutional motivation to reduce the waste.

TQEM is the logical method for producing the results of pollution prevention. Pollution prevention calls for industry to prevent pollution wherever possible. Employing a customer focus, and classifying the waste itself and the activities required to control it as non-value-

added, TQEM calls for waste generation to be brought to a minimum.[2] Operators and process engineers, not environmental engineers, are responsible for identifying and eliminating the root causes of process waste. Employing the continuous improvement approach, "zero waste" is as much a goal as "zero defects."

As a result of TQEM projects, product quality often improves while waste is reduced. One possible explanation might be that TQEM efforts empower employees to become more familiar with all aspects of the process, and not just those associated with production. When forced to question wastes from the process, improvements to quality characteristics can result.

Teamwork: The team approach allows all factors of the environmental issue to be considered. Accountants are familiar with cost considerations; product engineers are familiar quality considerations; process and chemical engineers are familiar with feasibility considerations; and environmental engineers are familiar with environmental impacts. Because environmental engineers are trained to deal with waste after it has been generated, and not in methods of preventing it from being created in the first place, engineers with knowledge of the process characteristics must be involved.

CASE STUDY: TRICHLOROETHYLENE (TCE), cont.

Ford Team eliminating TCE through Continuous Improvement...

Degreasing certain aluminum components with TCE has required extensive safety mechanisms and procedures. Building better containment systems reduces the risk of exposure, but does not get to the root cause of the problem — the use of TCE. With this in mind, the U.S. automobile manufacturer Ford, an active TQEM proponent, looked for a TCE-free solution to degreasing radiator coils. Ford formed a team that included a chemical engineer, an environmental engineer, a process engineer, an accountant, and a product engineer. The variety of backgrounds on the team ensured that the pertinent issues of cost, product quality, process feasibility and environmental impact were all addressed. The Ford team designed an aqueous degreasing system (i.e., soap and water) to replace the TCE. Not only is the toxic chemical removed from the plant, but the water in the new system is recycled as well. Significantly, the aqueous degreaser exhibits better quality characteristics than the TCE degreaser.

The above project is an example of the best of all worlds: improved quality, reduced cost, and reduced environmental impact. Certainly not all projects will prove so fruitful. Some "clean"

alternatives may cost more than their polluting rivals, but that cost must be balanced with the benefits of the environmental improvement.[3] To justify this viewpoint, one needs only to look to the increasing expectations of external customers for "environmentally friendly" products.

Strong Management Commitment: It should now be clear that three of the elements of TQM — customer focus, continuous improvement, team approach — readily apply to environmental issues. As in traditional TQM settings, the last — strong management commitment — is perhaps the most important. No TQEM program will succeed without the commitment of senior management. Senior management, those who have built their careers when waste was seen as a necessary by-product, must come to understand that both internal and external customer expectations include environmentally conscious products and processes. They must learn to see the value of applying TQEM to get to the root causes of waste, and call on the cross-disciplinary teams to employ continuous improvement to implement ever "cleaner" solutions.

1.2.3 Improving the Bottom Line

In many cases, pollution prevention measures can have clear environmental benefits in terms of pollution that is not generated, reductions in the toxic materials used in the production process, savings in energy use and other raw materials. Savings can accrue in five areas:

- a company can save on raw materials;
- a company can save on labor costs;
- disposal costs can be reduced or eliminated;
- a facility can save on waste handling/treatment costs both in its own use of labor to collect, store, and process wastes and incur costs to transport wastes off-site;
- decreasing the amount of toxic materials used, handled, and transported at a facility can reduce its future liability costs.

Chapter 4 focuses on the financial considerations associated with pollution prevention projects. Additionally, the case studies included in this manual demonstrate this concept.

CHAPTER 2
A METHODOLOGY FOR POLLUTION PREVENTION[1]

This Chapter describes a step-by-step approach for carrying out a pollution prevention assessment. It is designed to be generic to apply to a broad spectrum of industry. The approach comprises three phases; a preassessment phase for assessment preparation; a data collection phase to derive a material balance; and a synthesis phase where the findings from the material balance are translated into a waste reduction action plan.

It is possible that not all of the assessment steps will be relevant to every situation. Similarly, in some situations additional steps may be required. However, the following approach should form the basis of your investigations.

2.1 PHASE 1: PREASSESSMENT

2.1.1 Step 1: Assessment Focus and Preparation

A thorough preparation for a pollution prevention assessment is a prerequisite for an efficient and cost-effective study. Of particular importance is to gain support for the assessment from top-level management, and for the implementation of results; otherwise there will be no real action.

The pollution prevention assessment team should be identified. The number of people required on an assessment team will depend on the size and complexity of the processes to be investigated. A pollution prevention assessment of a small factory may be undertaken by one person with contributions from the employees. A more complicated process may require at least 3 or 4 people: technical staff, production employees and an environmental specialist. Involving personnel from each stage of the manufacturing operations will increase employee awareness of waste reduction and promote input and support for the program.

A pollution prevention assessment will probably require external resources, such as laboratory analytical facilities and possibly equipment for sampling and flow measurement. You should attempt to identify external resource requirements at the outset of the project.

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[1] This chapter is derived from The United Nations Industrial Development Organization's manual "Audit and Reduction Manual for Industrial Emissions and Wastes."

Analytical services and equipment may not be available to a small factory. If this is the case, investigate the possibility of forming a pollution prevention associations with other factories or industries; under this umbrella the external resource costs can be shared.

It is important to select the focus of your assessment at the preparation stage. You may wish the pollution prevention assessment to cover a complete process or you may want to concentrate on a selection of unit operations within a process. The focus will depend on the objectives of the pollution prevention assessment. You may wish to look at waste minimization as a whole or you may wish to concentrate on particular wastes, for example.

- raw material losses;
- wastes that cause processing problems;
- wastes considered to be hazardous or for which regulations exist;
- wastes for which disposal costs are high.

A good starting point for designing a pollution prevention assessment is to determine the major problems/wastes associated with your particular process or industrial sector. The Rapid Assessment of Sources of Air, Water and Land Pollution published by the World Health Organization (WHO, 1982) is a useful reference for identifying the typical quantities of wastes associated with particular industries. For example, **Exhibit 2-1** describes the likely waste quantities for the tanning industry.

Exhibit 2-1: Manufacture of Leather and Products of Leather, Leather Substitutes and Fur, except Footwear and Wearing Apparel

		Pulp hair/ chrome tanning/ finishing	Save hair/ chrome tanning/ finishing	Save hair/ vegetable tanning finishing
Waste volume	(m^3 of hides)	53	63	50
BOD_5	(kg/t of hides)	95	69	67
COD	(kg/t of hides)	260	140	250
Suspended Solids	(kg/t of hides)	140	145	135
Total Solids	(kg/t of hides)	525	480	345
Total Chromium	(kg/t of hides)	4.3	4.9	0.2
Sulphides	(kg/t of hides)	8.5	0.8	1.2
Oil and Grease	(kg/t of hides)	19	43	33
Total N	(kg/t of hides)	17	13	9.2
pH	(kg/t of hides)	1-13	4-12.6	2-13

(Source: WHO, 1982)

All existing documentation and information regarding the process, the plant or the regional industrial sector should be collated and reviewed as a preliminary step. Regional or plant surveys may have been undertaken; these could yield useful information indicating the areas for concern and will also show gaps where no data are available. The following prompts give some guidelines on useful documentation.

- Is a site plan available?
- Are any process flow diagrams available?
- Have the process wastes ever been monitored -- do you have access to the records?
- Do you have a map of the surrounding area indicating watercourses, hydrology and human settlements?
- Are there any other factories/plants in the area which may have similar processes?

Other general data which may be collated quickly and which are useful orientation material are described below.

- What are the obvious wastes associated with your process?
- Where is water used in greatest volume?
- Do you use chemicals that have special instructions for their use and handling?
- Do you have waste treatment and disposal costs -- what are they?
- Where are your discharge points for liquid, solid and gaseous emissions?

The plant employees should be informed that the assessment will be taking place, and they should be encouraged to take part. The support of the staff is imperative for this type of interactive study. It is important to undertake the assessment during normal working hours so that the employees and operators can be consulted, the equipment can be observed in operation and, most importantly, wastes can be quantified.

2.1.2 Step 2: Listing Unit Operations

Your process will comprise a number of unit operations. A unit operation may be defined as an area of the process or a piece of equipment where materials are input, a function occurs and materials are output, possibly in a different form, state or composition. For example, a process may comprise the following unit operations: raw material storage, surface treatment, rinsing, painting, drying, product storage and waste treatment.

Any initial site survey should include a walk around the entire manufacturing plant in order to gain a sound understanding of all the processing operations and their interrelationships. This will help the assessment team decide how to describe a process in terms of unit operations. During this initial overview, it is useful to record visual observations and

discussions and to make sketches of process layout, drainage systems, vents, plumbing and other material transfer areas. These help to ensure that important factors are not overlooked.

The assessment team should consult the production staff regarding normal operating conditions. The production or plant staff are likely to know about waste discharge points, unplanned waste generating operations such as spills and washouts, and give the assessors a good indication of actual operating procedures. Investigations may reveal that night-shift procedures are different from day-shift procedures; also, a plant may disclose that actual material handling practices are different from those set out in written procedures.

A long-standing employee could give some insight into recurring process problems. In the absence of any historical monitoring this information can be very useful. Such employee participation must however be a non-blaming process; otherwise it will not be as useful as it could be.

During the initial survey, note imminent problems that need to be addressed before the assessment is complete.

The pollution prevention assessment team needs to understand the function and process variables associated with each unit operation. Similarly, all the available information on the unit operations and the process in general should be collated, possibly in separate files. It is useful to tabulate this information, as shown in **Exhibit 2-2.**

Exhibit 2-2: Identification of Unit Operations

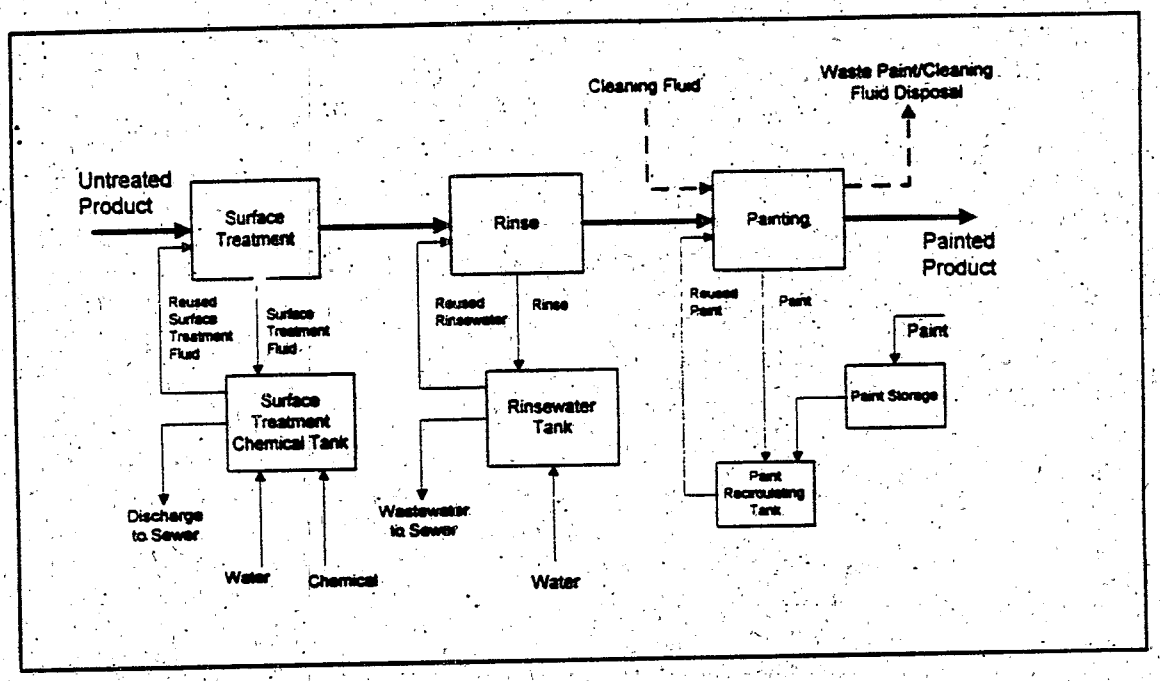
Unit Operation	Function	File Number
(A) Surface Treatment	Surface treatment of metal products 10 m^3 spray chamber, 6 jets, 100/min pump	1
(B) Rinsing	Washing metal products before painting	2

Identification of materials handling operations (manual, automatic, bulk, drums, etc.) covering raw materials, transfer practices and products is also an important aspect which could usefully be included in the above tabulation as a prelude to development of a materials balance (Phase 2).

2.1.3 Step 3: Constructing Process Flow Diagrams

By connecting the individual unit operations in the form of a block diagram you can prepare a process flow diagram. Intermittent operations such as cleaning, make-up or tank dumping may be distinguished by using broken lines to link the boxes. **Exhibit 2-3** is an example of a simplified process flow diagram for a metal finishing process.

Exhibit 2-3: A Process Flow Diagram for a Metal Finishing Process



For complex processes prepare a general flow diagram illustrating the main process areas and, on separate sheets of paper, prepare detailed flow diagrams for each main processing area.

Now you must decide on the level of detail that you require to achieve your objectives.

It is important to realize that the less detailed or larger scale the assessment becomes, the more information is likely to be lost or masked by oversimplification. Establishing the correct level of detail and homing in on specific areas is very important at an early stage.

Pay particular attention to correcting any obvious waste arising which can be reduced or prevented easily, before proceeding to the development of a material balance (Phase 2). By making simple changes at this early stage, the resultant benefits will help enlist the participation and stimulate the enthusiasm of employees for the total pollution prevention assessment/reduction program.

Phase 1: Summary

At the end of the pollution prevention assessment preassessment stage the assessment team should be organized and be aware of the objectives of the pollution prevention assessment.

Plant personnel should have been informed of the assessment purpose is order to maximize co-operation between all parties concerned.

Any required financial resources should have been secured and external facilities checked out for availability and capability.

The team should be aware of the overall history and local surroundings of the plant.

The scope and focus of the pollution prevention assessment should have been established, and a rough timetable worked out to fit in with production patterns.

The assessment team should be familiar with the layout of the processes within the plant and should have listed the unit operations associated with each process. Sources of wastes and their causes should also have been identified.

It should be possible to draw process flow diagrams highlighting those areas to be covered in the pollution prevention assessment.

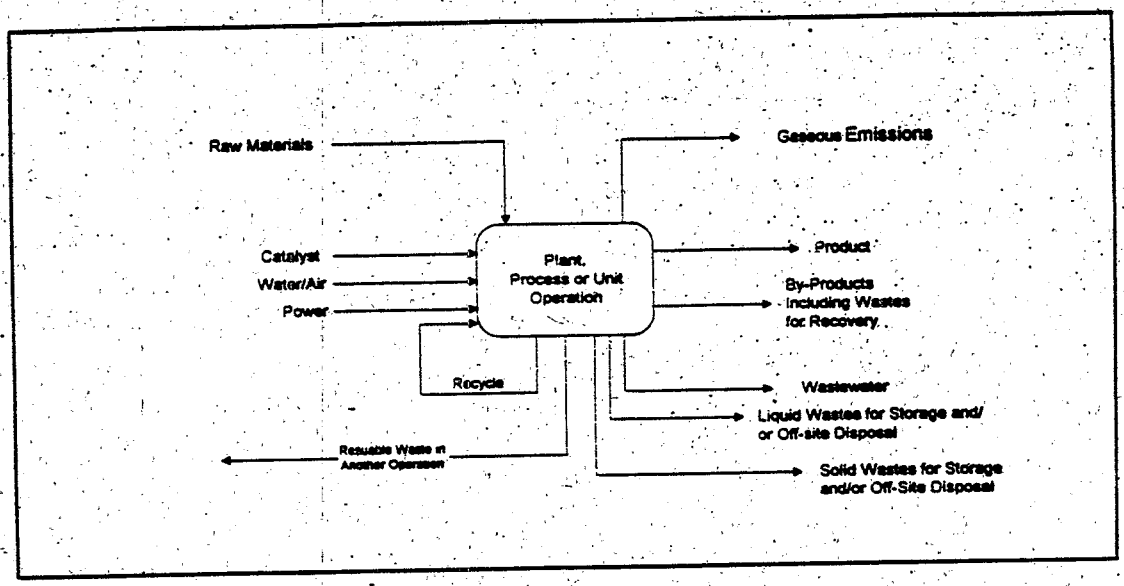
Any very obvious waste saving measures which can be introduced easily should be implemented immediately.

The findings of the Phase 1 investigations could usefully be presented to the management in the form of a brief preassessment report in order to reaffirm their commitment into the next phase.

A material balance may be defined as a precise amount of the inputs and outputs of an operation.

This phase describes a procedure for the collection and arrangement of input and output data. The procedure can be applied to derive the material balance of a plant, a process or a unit operation. **Exhibit 2-4** is an example of a set of components that need to be quantified to derive a material balance. Note that infrequent outputs (e.g., the occasional dumping of an electroplating bath) may be as significant as continuous daily charges.

Exhibit 2-4: Components to a Material Balance



2.2 PHASE 2: MATERIAL BALANCE: PROCESS INPUTS AND OUTPUTS

A material balance may be defined as a precise account of the inputs and outputs of an operation.

This phase describes a procedure for the collection and arrangement of input and output data. The procedure can be applied to derive the material balance of a plant, a process, or a unit operation. **Exhibit 2-4** is an example set of components that need to be quantified to derive a material balance. Note that infrequent outputs (e.g. the occasional dumping of an electroplating bath) may be as significant as continuous daily discharges.

The manual uses unit operations to illustrate the pollution prevention assessment procedure.

Although the procedure is laid down in a step-by-step fashion it should be emphasized that the output information can be collected at the same time or before the input data; it is up to you to organize your time efficiently.

2.2.1 Step 4: Determining Inputs

Inputs to a process or a unit operation may include raw materials, chemicals, water, air and power (Exhibit 2-4). The inputs to the process and to each unit operation need to be quantified.

As a first step towards quantifying raw material usage, examine purchasing records, this rapidly gives you an idea of the sort of quantities involved.

In many situations the unit operations where raw material losses are greatest are raw material storage and transfer. You should look at these operations in conjunction with the purchasing records to determine the actual net input to the process.

Make notes regarding raw material storage and handling practices. Consider evaporation losses, spillages, leaks from underground storage tanks, vapor losses through storage tank pressure-relief vents and contamination of raw materials. Often these can be rectified very simply.

Record raw material purchases and storage and handling losses in a table in order to derive the net input to the process (**Exhibit 2-5**).

Once the net input of raw materials to your process has been determined you should proceed with quantifying the raw material input to each unit operation.

If accurate information about raw material consumption rates for individual unit operations is not available then you will need to take measurements to determine average figures.

Measurements should be taken for an appropriate length of time. For example, if a batch takes one week to run, then measurements should be taken over a period of at least three weeks; these figures can be extrapolated for monthly or annual figures.

Exhibit 2-5: Raw Material Storage and Handling Losses

Raw Material	City of Raw Material	City of Raw Material Purchased (per annum)	Type of Storage Used in Production (per annum)	Average Length of Storage	Estimated Annual Raw Material Losses
Raw Material 1 (Surface treatment chemical)	100 kg	95 kg	Closed	1 month	5 kg
Raw Material 2					
Raw Material 3					

Some quantification is possible by observation and some simple accounting procedures.

- For solid raw materials, ask the warehouse operator how many sacks are stored at the beginning of the week or prior to unit operation; then ask him again at the end of the week or unit operation. Weigh a selection of sacks to check compliance with specifications.

- For liquid raw materials such as water or solvents, check storage tank capacities and ask operators when a tank was last filled. Tank volumes can be estimated from the tank diameter and tank depth. Monitor the tank levels and the number of tankers arriving on site.

While investigating the inputs, talking to staff and observing the unit operations in action, the pollution prevention assessment team should be thinking about how to improve the efficiency of unit operations. Consider the following questions.

- Is the size of the raw material inventory appropriate to ensure that material-handling loses can be minimized?
- Transfer distances between storage and process or between unit operations -- could these be reduced to minimize potential wastage?
- Do the same tanks store different raw materials depending on the batch product? Is there a risk of cross contamination?
- Are sacks of materials emptied or is some material wasted?

- Are viscous raw material used on site -- is it possible to reduce residual wastage in drums?
- Is the raw material storage area secure? Could a building be locked at night, or could an area be fenced off to restrict access?
- How could the raw materials be protected from direct sunlight or from heavy downpours?
- Is dust from stockpiles a problem?
- Is the equipment used to pump or transfer materials working efficiently? Is it maintained regularly?
- Could spillages be avoided?
- Is the process adequately manned?
- How could the input of raw materials be monitored?
- Are there any obvious equipment items in need of repair?
- Are pipelines self-draining?
- Is vacuum pump water recirculated?

The energy input to a unit operation should be considered at this stage; however, energy use deserves a full assessment in its own right. For pollution prevention assessment purposes make a note of the energy source and whether waste reduction could reduce energy costs. If energy usage is a particularly prominent factor maybe you should recommend that an energy assessment be undertaken.

Input data should be recorded on your process flow diagram or in tabular form as shown in **Exhibit 2-6.**

Water is frequently used in the production process, for cooling, gas scrubbing, washouts, product rinsing and steam cleaning. This water usage needs to be quantified as an input.

Some unit operations may receive recycled wastes from other unit operations. These also represent an input.

Steps 5 and 6 describe how these two factors should be included in your pollution prevention assessment.

Exhibit 2-6: Input

Unit Operation	Raw Material 1 (m^3/annum)	Raw Material 2 (tons/annum)	Water (m^3/annum)	Energy Source
Surface Treatment (A)				
Rinse (B)				
Painting (C)				
Total Raw Material Used in All Unit Operations				

2.2.2 Step 5: Recording Water Usage

The use of water, other than for a process reaction, is a factor that should be covered in all pollution prevention assessments. The use of water to wash, rinse and cool is often overlooked, although it represents an area where waste reductions can frequently be achieved simply and cheaply.

Consider these general points about the site water supply before assessing the water usage for individual units.

- Identify water sources? Is water absorbed directly from a borehole, river or reservoir; is water stored on site in tanks or in a lagoon?
- What is the storage capacity for water on site?
- How is water transferred -- by pump, by gravity, manually?
- Is rainfall a significant factor on site?

For each unit operation consider the following.

- What is water used for in each operation? Cooling, gas scrubbing, washing, product rinsing, dampening stockpiles, general maintenance, safety quench, etc.
- How often does each action place?
- How much water is used for each action?

It is unlikely that the answers to these questions will be readily available -- you will need to undertake a monitoring program to assess the use of water in each unit operation. Again, the measurements must cover a sufficient period of time to ensure that all actions are monitored. Pay particular attention to intermittent actions such as steam cleaning and tank washouts;

water use is often indiscriminate during these operations. Find out when these actions will be undertaken so that detailed measurements can be made.

Record water usage information in a tabular form -- ensure that the units used to describe intermittent actions indicate a time period (**Exhibit 2-7**).

Exhibit 2-7: Water Usage

	Cleaning	Steam	Cooling	Other
Unit Operation A				
Unit Operation B				
Unit Operation C				

All measurements in standard units, for example m^3/annum or m^3/day.

Using less water can be a cost-saving exercise. Consider the following points while investigating water use:

- tighter control of water use can reduce the volume of wastewater requiring treatment and result in cost savings -- in the extreme, it can sometimes reduce volumes and increase concentrations to the point of providing economic material recovery in place of costly wastewater treatment;
- attention to good house-keeping practices often reduces water usage and, in turn, the amount of wastewater passing to drain;
- the cost of storing wastewater for subsequent reuse may be far less than the treatment and disposal costs;
- counter-current rinsing and rinse water reuse are highlighted in the case studies as useful tips for reducing water usage.

2.2.3 Step 6: Measuring Current Levels of Waste Reuse/Recycling

Some wastes lend themselves to direct reuse in production and may be transferred from one unit to another (e.g., reuse of the final rinse in a soft-drink bottle washing plant as the initial rinse); others require some modifications before they are suitable for reuse in a process. These reused waste streams should be quantified.

If reused wastes are not properly documented double-counting may occur in the material balance particularly at the process or complete plant level; that is, a waste will be quantified as an output from one process and as an input to another.

The reuse or recycling of wastes can reduce the amount of fresh water and raw materials required for a process. While looking at the inputs to unit operations think about the opportunities for reusing and recycling outputs from other operations.

Steps 4, 5 and 6 Summary

By the end of Step 6 you should have quantified all your process inputs.

The net input of raw materials and water to the process should be established having taken into account any losses incurred at the storage and transfer stages.

Any reused or recycled inputs should be documented.

All notes regarding raw material handling, process layout, water losses, obvious areas where problems exist should all be documented for consideration in Phase 3.

2.2.4 Step 7: Quantifying Process Outputs

To calculate the second half of the material balance the outputs from unit operations and the process as a whole need to be quantified.

Outputs include primary product, by-products, wastewater, gaseous wastes (emissions to atmosphere), liquid and solid wastes which need to be stored and/or sent off-site for disposal and reusable or recyclable wastes (**Exhibit 2-4**). You may find that a table along the lines of **Exhibit 2-8** will help you organize the input information. It is important to identify units of measurement.

Exhibit 2-8: Process Outputs

Unit Operation	Product	By-Product	Waste to be Reused	Waste-water	Gaseous Emissions	Stored Wastes	Liquid/ Solid Wastes Off-Site
Unit Operation A							
Unit Operation B							
Unit Operation C							
Total							

The assessment of the amount of primary product or useful product is a key factor in process or unit operation efficiency.

If the product is sent off-site for sale, then the amount produced is likely to be documented in company records. However, if the product is an intermediate to be input to another process or unit operation then the output may not be so easy to quantify. Production rates will have to be measured over a period of time. Similarly, the quantification of any by-products may require measurement.

Hints on how to approach the quantification of wastewater, gaseous emissions and wastes for off-site removal are described in Steps 8, 9 and 10.

2.2.5 Step 8: Accounting for Wastewater

On many sites significant quantities of both clean and contaminated water are discharged to sewer or to a watercourse. In many cases, this wastewater has environmental implications and incurs treatment costs. In addition, wastewater may wash out valuable unused raw materials from the process areas.

Therefore, it is extremely important to know how much wastewater is going down the drain and what the wastewater contains. The wastewater flows, from each unit operation as well as from the process as a whole, need to be quantified, sampled and analyzed.

Here are some suggestions on how to carry out a thorough survey of wastewater flows on your site.

- Identify the effluent discharge points; that is, where does wastewater leave the site? Wastewater may go to an effluent treatment plant or directly to a public sewer or

watercourse. One factor that is often overlooked is the use of several discharge points -- it is important to identify the location, type and size of all discharge flows.

- Identify where flows from different unit operations or process areas contribute to the overall flow. In this way, it is possible to piece together the drainage network for your site. This can lead to startling discoveries of what goes where!

- Once the drainage system is understood it is possible to design an appropriate sampling and flow measurement program to monitor the wastewater flows and strengths from each unit operation.

- Plan your monitoring program thoroughly and try to take samples over a range of operating conditions such as full production, start up, shut down and washing out. In the case of combined storm water and wastewater drainage systems, ensure that sampling and flow measurements are carried out in dry weather.

- For small or batch wastewater flows it may be physically possible to collect all the flow for measurement using a pail and wristwatch. Larger or continuous wastewater flows can be assessed using flow measurement techniques.

The sum of the wastewater generated from each unit operation should be approximately the same as that input to the process. As indicated in Step 6, note that double-counting can occur where wastewater is reused. This emphasizes the importance of understanding your unit operation and their interrelationships.

The wastewater should be analyzed to determine the concentration of contaminants.

- You should include wastewater analyses such as pH, chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), suspended solids and grease and oil.

- Other parameters that should be measured depend on the raw material inputs. For example, an electroplating process is likely to use nickel and chromium. The metal concentrations of the wastewater should be measured to ensure that the concentrations do not exceed discharge regulations, but also to ensure that raw materials are not being lost to drain. Any toxic substances used in the process should be measured.

- Take samples for laboratory analysis. Composite samples should be taken for continuously-running wastewater. For example, a small volume, 100 ml, may be collected every hour through a production period of ten hours to gain a 1 liter composite sample. The composite sample represents the average wastewater conditions over that time. Where significant flow variations occur during the discharge period, consideration should be given to varying the size of individual

samples in proportion to flow rate in order to ensure that a representative composite sample is obtained. For batch tanks and periodic drain down, a single spot sample may be adequate (check for variations between batches before deciding on the appropriate sampling method).

Wastewater flows and concentrations should be tabulated (**Exhibit 2-9**).

Exhibit 2-9: Wastewater Flows

	Discharge to									
	Public Sewer		Storm water Drain		Reuse		Storage		Total Waste-water Output	
Source of Wastewater	Flow	Conc'n	Flow	Conc'n	Flow	Conc'n	Flow	Conc'n	Flow	Conc'n
Unit Operation A										
Unit Operation B										
Unit Operation C										

Flows in m^3/d; concentrations of contaminants of concern in mg/l)

2.2.6 Step 9: Accounting for Gaseous Emissions

To arrive at an accurate material balance some quantification of gaseous emissions associated with your process is necessary.

It is important to consider the actual and potential gaseous emissions associated with each unit operation from raw material storage through to product storage.

Gaseous emissions are not always obvious and can be difficult to measure. Where quantification is impossible, estimations can be made using stoichiometric information. The following example illustrates the use of indirect estimation.

Consider coal burning in a boiler house. The assessor may not be able to measure the mass of sulphur dioxide leaving the boiler stack due to problems of access and lack of suitable sampling ports on the stack. The only information available is that the coal is of soft quality containing 3% sulphur by weight and, on average, 1000 kg of coal is burned each day.

First calculate the amount of sulphur burned:

1000 kg coal x 0.03 kg sulphur/kg coal = 30 kg sulphur/day.

The combustion reaction is approximately:

$$S + O_2 = SO_2$$

The number of moles of sulphur burned equals the number of moles of sulphur dioxide produced. The atomic weight of sulphur is 32 and molecular weight of sulphur dioxide is 64. Therefore:

kg-moles S = 30 kg/32 kg per kg-mole = kg-mole of SO_2 formed

kg SO_2 formed = (64 kg SO_2/kg-mole) x kg-moles SO_2 = 64 x 30/32 = 60 kg

Thus, it may be estimated that an emission of 60 kg sulphur dioxide will take place each day from the boiler stack.

Record the quantified emission data in tabular form and indicate which figures are estimates and which are actual measurements.

The assessor should consider qualitative characteristics at the same time as quantifying gaseous wastes.

- Are odors associated with a unit operation?
- Are there certain times when gaseous emissions are more prominent -- are they linked to temperature?
- Is any pollution control equipment in place?
- Are gaseous emissions from confined spaces (including fugitive emissions) vented to the outside?
- If gas scrubbing is practiced, what is done with the spent scrubber solution? Could it be converted to a useful product?
- Do employees wear protective clothing, such as masks?

2.2.7 Step 10: Accounting for Off-Site Wastes

Your process may produce wastes which cannot be treated on-site. These need to be transported off-site for treatment and disposal. Wastes of this type are usually non-aqueous liquids, sludges or solids.

Often, wastes for off-site disposal are costly to transport and to treat. Therefore, minimization of these wastes yields a direct cost benefits.

Measure the quantity and note the composition of any wastes associated with your process which need to be sent for off-site disposal. Record your results in a table (**Exhibit 2-10**).

Exhibit 2-10: Wastes for Off-site Disposal

Unit Operation	Qty	Liquid Composition	Qty	Sludge Composition	Qty	Solid Composition
Unit Operation A						
Unit Operation B						
Unit Operation C						

Quantities in m^3/annum or t/annum

You should ask several questions during the data collection stage.

- Where does the waste originate?
- Could the manufacturing operations be optimized to produce less waste?
- Could alternative raw materials be used which would produce less waste?
- Is there a particular component that renders the whole waste hazardous -- could this component be isolated?
- Does the waste contain valuable materials?

Wastes for off-site disposal need to be stored on-site prior to dispatch. Does storage of these wastes cause additional emission problems? For example, are solvent wastes stored in closed tanks? How long are wastes stored on-site? Are stockpiles of solid waste secure or are dust storms a regular occurrence?

Steps 7, 8, 9, and 10 Summary

At the end of Step 10 the pollution prevention assessment team should have collated all the information required for evaluating a material balance for each unit operation and for a whole process.

All actual and potential wastes should be quantified. Where direct measurement is impossible, estimates based on stoichiometric information should be made.

The data should be arranged in clear tables with standardized units. Throughout the data collection phase the assessors should make notes regarding actions, procedures and operations that could be improved.

2.2.8 Step 11: Assembling Input and Output Information for Unit Operations

One of the basic laws applied to chemical engineering is that of the material balance which states that the total of what goes into a process must equal the total of what comes out. Prepare a material balance at a scale appropriate for the level of detail required in your study. For example, you may require a material balance for each unit operation or one for a whole process may sufficient. In this manual the preparation of a material balance for unit operation scale is illustrated.

Preparing a material balance is designed to gain a better understanding of the inputs and outputs, especially waste, of a unit operation such that areas where information is inaccurate or lacking can be identified. Imbalances require further investigation. Do not expect a perfect balance -- your initial balance should be considered as a rough assessment to be refined and improved.

Assemble the input and output information for each unit operation and then decide whether all the inputs and outputs need to be included in the material balance. For example, this is not essential where the cooling water input to a unit operation equals the cooling water output.

Standardize units of measurement (liters, tons or kilograms) on a per day, per year or per batch basis.

Summarize the measured values in standard units by reference to your process flow diagram. It may have been necessary to modify your process flow diagram following the in-depth study of the plant.

2.2.9 Step 12: Deriving a Preliminary Material Balance for Unit Operations

Now it is possible to complete a preliminary material balance. For each unit operation utilize the data developed in Steps 1-10 and construct your material balance. Display your information clearly. **Exhibit 2-11** is one way of presenting the material balance information.

Exhibit 2-11: Preliminary Material Balance for Each Unit Operation

Inputs (amounts in standard units per annum)
Raw Material 1
Raw Material 2
Raw Material 3
Waste Reuse
Water.
Total

↓

Unit Process A

↓

Outputs (amounts in standard units per annum)
Product
By-product
Raw Material Storage and Handling Losses
Reused Wastes
Wastewater
Gaseous Emissions
Stored Wastes
Hazardous Liquid Waste Transported Off-Site
Hazardous Solid Waste Transported Off-Site
Non-Hazardous Liquid Waste Transported Off-Site
Non-Hazardous Solid Waste Transported Off-Site
Total

Note that a material balance will often need to be carried out in weight units since volumes are not always conserved. Where volume measurements have to be converted to weight units, take account of the density of the liquid, gas or solid concerned.

Once the material balance for each unit operation has been completed for raw material inputs and waste outputs it might be worthwhile repeating the procedure with respect to each contaminant of concern. It is highly desirable to carry out a water balance for all water inputs and outputs to and from unit operations because water imbalances may indicate serious underlying process problems such as leaks or spills. The individual material balances may be summed to give a balance for the whole process, a production area or factory.

2.2.10 Step 13: Evaluating the Material Balance

The individual and sum totals making up the material balance should be reviewed to determine information gaps and inaccuracies. If you do have a significant material imbalance then further investigation is needed. For example, if outputs are less than inputs look for potential losses or waste discharges (such as evaporation). Outputs may appear to be greater than inputs if large measurement or estimating errors are made or some inputs have been overlooked.

At this stage you should take time to re-examine the unit operations to attempt to identify where unnoticed losses may be occurring. It may be necessary to repeat some data collection activities.

Remember that you need to be thorough and consistent to obtain a satisfactory material balance. The material balance not only reflects the adequacy of your data collection, but by its very nature, ensures that you have a sound understanding of the processes involved.

2.2.11 Step 14: Refining the Material Balance

Now you can reconsider the material balance equation by adding those additional factors identified in the previous step. If necessary, estimates of unaccountable losses will have to be calculated.

Note that, in the case of relatively simple manufacturing plants, preparation of a preliminary material balance and its refinement (Steps 13 and 14) can usefully be combined. For more complex pollution prevention assessments however, two separate steps are likely to be more appropriate.

Remember, the inputs should ideally equal the outputs but in practice this will rarely be the case and some judgement will be required to determine what level of accuracy is acceptable.

In the case of high-strength or hazardous wastes, accurate measurements are needed to design waste reduction options.

It is possible that the material balance for a number of unit operations will need to be repeated. Again, continue to review, refine and, where necessary, expand your database. The compilation of accurate and comprehensive data is essential for a successful pollution prevention assessment and subsequent waste reduction action plan. You cannot reduce what you do not know is there.

Steps 11, 12, 13 and 14 Summary

By the end of Step 14, you should have assembled information covering process inputs and process outputs. These data should be organized and presented clearly in the form of material balances for each unit operation.

These data form the basis for the development of an action plan for waste minimization.

2.3 PHASE 3: SYNTHESIS

Phases 1 and 2 have covered planning and undertaking a pollution prevention assessment, resulting in the preparation of a material balance for each unit operation.

Phase 3 represents the interpretation of the material balance to identify process areas or components of concern.

The material balance focuses on the attention of the assessor. The arrangement of the input and output data in the form of a material balance facilitates your understanding of how materials flow through a production process.

To interpret a material balance it is necessary to have an understanding of normal operating performance. How can you assess whether a unit operation is working efficiently if you do not know what is normal? A member of your team must have a good working knowledge of the process. This knowledge can be supported by texts such as the Rapid Assessment of Sources of Air, Land and Water Pollution (WHO, 1982).

To a trained eye the material balance will indicate areas for concern and help to prioritize problem wastes.

You should use the material balance to identify the major sources of waste, to look for deviations from the norm in terms of waste production, to identify areas of unexplained losses and to pinpoint operations which contribute to flows that exceed national or site discharge regulations. Process efficiency is synonymous with waste minimization.

Different waste reduction measures require varying degrees of effort, time and financial resources. They can be categorized as two groups.

- Obvious waste reduction measures, including improvements in management techniques and house-keeping procedures that can be implemented cheaply and quickly.
- Long-term reduction measures involving process modifications or process substitutions to eliminate problem wastes.

Increased reuse/recycling to reduce waste falls between the immediate and the more substantial waste reduction measures.

Steps 15, 16 and 17 describe how to identify waste reduction measures.

2.3.1 Step 15: Examining Obvious Waste Reduction Measures

It may have been possible to implement very obvious waste reduction measures already, before embarking on obtaining a material balance (ref Step 3). Now consider the material balance information in conjunction with visual observations made during the whole of the data collection period in order to pinpoint areas or operations where simple adjustments in procedure could greatly improve the efficiency of the process by reducing unnecessary losses.

Use the information gathered for each unit operation to develop better operating practices for all units.

Significant waste reductions can often be achieved by improved operation, better handling and generally taking more care. The following list of waste reduction hints can be implemented immediately with no or only small extra costs.

Specifying and Ordering Materials

- Do not over-order materials especially if the raw materials or components can spoil or are difficult to store.
- Try to purchase raw materials in a form which is easy to handle, for example, pellets instead of powders.
- It is often more efficient and certainly cheaper to buy in bulk.

Receiving Materials

- Demand quality control from suppliers by refusing damaged, leaking or unlabelled containers. Undertake a visual inspection of all materials coming on to the site.
- Check that a sack weighs what is should weigh and that the volume ordered is the volume supplied.
- Check that composition and quality are correct.

Material Storage

- Install high-level control on bulk tanks to avoid overflows.
- Bund tanks to contain spillages.
- Use tanks that can be pitched and elevated, with rounded edges for ease of draining and rinsing.
- Dedicated tanks, receiving only one type of material, do not need to be washed out as often as tanks receiving a range of materials.
- Make sure that drums are stored in a stable arrangement to avoid damaging drums while in storage.
- Implement a tank checking procedure -- dip tanks regularly and document to avoid discharging a material into the wrong tank.
- Evaporation losses are reduced by using covered or closed tanks.

Material and Water Transfer and Handling

- Minimize the number of times materials are moved on site.
- Check transfer lines for spills and leaks.
- Is flexible pipework too long?
- Catch drainings from transfer hoses.
- Plug leaks and fit flow restrictions to reduce excess water consumption.

Process Control

- Feedback on how waste reduction is improving the process motivates the operators -- it is vital that the employees are informed of why actions are taken and what it is hoped they will achieve.
- Design a monitoring program to check the emissions and wastes from each unit operation.
- Regular maintenance of all equipment will help to reduce fugitive process losses.

Cleaning Procedures

- Minimize the amount of water used to wash out and rinse vessels -- on many sites indiscriminate water use contributes a large amount to wastewater flows. Ensure that hoses are not left running by fitting self-sealing valves.
- Investigate how washing water can be contained and used again before discharge to drain. The same applies to solvents used to clean; these can often be used more than once.

Tightening up house-keeping procedures can reduce waste considerably. Simple, quick adjustments should be made to your process to achieve a rapid improvement in process efficiency. Where such obvious reduction measures do not however solve the entire waste disposal problem, more detailed consideration of waste reduction options will be needed (Steps 16-18).

2.3.2 Step 16: Targeting and characterizing Problem Wastes

Use the material balance for each unit operation to pinpoint the problem areas associated with your process.

The material balance exercise may have brought to light the origin of wastes with high treatment costs or may indicate which wastes are causing process problems in which operations. The material balance should be used for your priorities for long-term waste reduction.

At this stage, it may be worthwhile considering the underlying causes as to why wastes are generated and the factors which lead to these; for example, poor technology, lack of maintenance and non-compliance with company procedures.

Additional sampling and characterization of your wastes might be necessary involving more in-depth analysis to ascertain the exact concentrations of contaminants.

List the wastes in order of priority for reduction actions.

2.3.3 Step 17: Segregation

Segregation per se is arguably not properly part of a pollution prevention assessment's step-by-step sequence, being but one of numerous measures which can lead to waste reduction activities. It is however the most central of such options and is a universal issue which needs to be addressed.

Segregation of wastes can offer enhanced opportunities for recycling and reuse with resultant savings in raw material costs. Concentrated simple wastes are more likely to be of value than dilute or complex wastes.

Mixing wastes can enhance pollution problems. If a highly-concentrated waste is mixed with a large quantity of weak, relatively uncontaminated effluent the result is a larger volume of waste requirement treatment. Isolating the concentrated waste from the weaker waste can reduce treatment costs. The concentrated waste could be recycled/reused or may require physical, chemical and biological treatment to comply with discharge consent levels whereas the weaker effluent could be reused or may only require settlement before discharge.

Therefore, waste segregation can provide more scope for recycling and reuse while at the same time reducing treatment costs.

Review your waste collection and storage facilities to determine if waste segregation is possible. Adjust your list of priority wastes accordingly.

2.3.4 Step 18: Developing Long-Term Waste Reduction Options

Waste problems that cannot be solved by simple procedural adjustments or improvements in house-keeping practices will require more substantial long-term changes.

It is necessary to develop possible prevention options for the waste problems.

Process or production changes which may increase production efficiency and reduce waste generation include:

- changes in the production process -- continuous versus batch;
- equipment and installation changes;
- changes in process control -- automation;
- changes in process conditions such as retention times, temperatures, agitation, pressure, catalysts;
- use of dispersants in place of organic solvents where appropriate;
- reduction in the quantity or type of raw materials used in production;
- raw material substitution through the use of wastes as raw materials or the use of different raw materials that produce less waste or less hazardous waste;
- process substitution with cleaner technology.

Waste reuse can often be implemented if materials of sufficient purity can be concentrated or purified. Technologies such as reverse osmosis, ultrafiltration, electrodialysis, distillation,

electrolysis and ion exchange may enable materials to be reused and reduce or eliminate the need for waste treatment.

Where waste treatment is necessary, a variety of technologies should be considered. These include physical, chemical and biological treatment processes. In some cases the treatment method can also recover valuable materials for reuse. Another industry or factory may be able to use or treat a waste that you cannot treat on-site. It may be worth investigating the possibility of setting up a waste exchange bureau as a structure for sharing treatment and reuse facilities.

Consider also the possibilities for product improvements or changes yielding cleaner, more environmentally-friendly products, both for existing products and in the development of new products.

Steps 15, 16, 17 and 18 Summary

At the end of Step 18 you should have identified all the waste reduction options which could be implemented.

2.3.5 Step 19: Environmental and Economic Evaluation of Waste Reduction Options

In order to decide which options should be developed to formulate a waste reduction action plan each option should be considered in terms of environmental and economic benefits.

a) Environmental Evaluation

It is often taken for granted that reduction of a waste will have environmental benefits. This is generally true; however, there are exceptions to the rule. For example, reducing one waste may give rise to pH imbalances or may produce another which is more difficult to treat, resulting in a net environmental disadvantage.

In many cases, the benefits may be obvious such as the result of the removal of a toxic element from an aqueous effluent by segregating the polluted waste or by changing the process in such a way that the waste is prevented.

In other cases the environmental benefits may be less tangible. Creating a cleaner, healthier workplace will increase production efficiency but this may be difficult to quantify.

For each option a series of questions should be asked:

- Consider the effect of each option on the volume and degree of contamination of process wastes.
- Does a waste reduction option have cross-media effects? For example, does the reduction of a gaseous waste produce a liquid waste?
- Does the option change the toxicity, degradability or treatability of the wastes?
- Does the option use more or less non-renewable resources?
- Does the option use less energy?

b) Economic Evaluation

A comparative economic analysis of the waste reduction options and the existing situation should be undertaken. Where benefits or changes cannot be quantified (e.g., reduction in future liability, worker health and safety costs) some form of qualitative assessment should be made; it may be necessary to consult an expert for advice on how to judge a change.

Economic evaluations of waste reduction options should involve a comparison of operating costs to illustrate where cost savings would be made. For example, a waste reduction measure that reduces the amount of raw material lost to drain during the process results in reduced raw material costs. Raw material substitution or process changes may reduce the amount of solid waste that has to be transported off-site. Therefore, the transport costs for waste disposal would be reduced.

In many cases, it is appropriate to compare the waste treatment costs under existing conditions with those associated with the waste reduction option.

The size of treatment plant and the treatment processes required may be altered significantly by the implementation of waste reduction options. This should be considered in an economic evaluation.

Calculate the annual operating costs for the existing process indicating waste treatment and estimate how these would be altered with the introduction of waste reduction options. Tabulate and compare the process and waste treatment operating costs for both the existing and proposed future waste management options. **Exhibit 2-12** shows the typical cost components. In addition, if there are any monetary benefits (e.g., recycled or reused materials or wastes), then these should be subtracted from the total process or waste treatment costs as appropriate.

Now that you have determined the likely savings in terms of annual process and waste treatment operating costs associated with each option, consider the necessary investment required to implement each option.

Investment can be assessed by looking at the payback period for each option. Payback period is the time taken for a project to recover its financial outlay. A more detailed investment analysis may involve an assessment of the internal rate of return (IRR) and net present value (NPV) of the investment based on discounted cash flows.

Analysis of investment risk allows you to rank options.

Consider the environmental benefits and the savings in process and waste treatment operating costs along with the payback period for an investment, to decide which options are viable.

Exhibit 2-12: Annual Process and Waste Treatment Operating Costs

Process Operating Costs	Annual Cost
Raw Material 1	
Raw Material 2	
Water	
Energy	
Labor	
Maintenance	
Administration	
Other	
Total	

Waste Treatment Operating Costs	Annual Cost
Raw Material e.g., Lime	
Raw Material e.g., Flocculent	
Water	
Energy	
Trade Effluent Discharge Costs	
Transportation	
Off-Site Disposal	
Labor	
Maintenance	
Administration	
Other, e.g., violation, fines	
Total	

2.3.6 Step 20: Developing and Implementing An Action Plan: Reducing Wastes and Increasing Production Efficiency

Consider the immediate reduction measures identified in Step 15 along with the long-term waste reduction measures that have been evaluated in Steps 18 and 19. These measures should form the basis of the waste reduction action plan. Discuss your findings with members of staff and develop a workable action plan.

Prepare the ground for the waste reduction action plan. Its implementation should be preceded by an explanation of the ethos behind undertaking a pollution prevention assessment: Waste Prevention Makes Sense.

It is necessary to convince those who must work to new procedures that the change in philosophy from end-of-pipe treatment to waste prevention makes sense and serves to improve efficiency.

Use posters around the site to emphasize the importance of waste reduction to minimize production and waste treatment/disposal costs and, where appropriate, for improving the health and safety of company personnel.

Set out the intended action plan within an appropriate schedule. Remember it may take time for the staff to feel comfortable with a new way of thinking. Therefore, it is a good idea to implement waste reduction measures slowly but consistently to allow everyone time to adapt to these changes.

Set up a monitoring program to run alongside the waste reduction action plan so that actual improvements in process efficiency can be measured. Relay these results back to the workforce as evidence of the benefits of waste reduction. Adopt an internal record-keeping system for maintaining and managing data to support material balances and waste reduction assessments.

It is likely that you will have highlighted significant information gaps or inconsistencies during the pollution prevention assessment investigations. You should concentrate on these gaps and explore ways of developing the additional data. Is outside help required?

A good way of providing waste reduction incentives is to set up an internal waste charging system, those processes that create waste in great volume or that are difficult and expensive to handle having to contribute to the treatment costs on a proportional basis. Another method of motivating staff to offer financial reward for individual waste-saving efforts, drawing on the savings gained from implementing waste reduction measures.

Pollution prevention assessments should be a regular event -- attempt to develop a specific pollution prevention assessment approach for your own situation, keeping abreast of technological advances that could lead to waste reduction and the development of 'cleaner' products. Train process employees to undertake material balance exercises.

Training people who work on the process to undertake a pollution prevention assessment will help to raise awareness in the workforce. Without the support of the operators waste reduction actions will be ineffectual -- these are the people who can really make a difference to process performance.

Step 20 Summary

Prepare the ground for the waste reduction action plan, ensuring that support for the assessment, and implementation of the results, is gained from senior management. Implement the plan slowly to allow the workforce to adjust.

Monitor process efficiency.

Relay results back to the workforce to show them the direct benefits.

Train personnel to undertake your own pollution prevention assessment for waste reduction.

2.4 CASE STUDY: LEATHER MANUFACTURE

Company B operates a tannery in south-east Asia processing cattle hides into finished leather, mainly for side upper leather in shoe manufacture. Treatment of the hides involves a series of batch operations involving application of a wide range of physical and chemical processes. Wastewaters discharged contain pollutants from the hides, products from their decomposition, and chemicals and various spent solutions used for hide preparation and during the tanning process. Solid wastes and some atmospheric emissions also arise.

The company was required to meet new government standards for discharge of wastewater to the local watercourse. This necessitated improvements to existing treatment facilities which were then limited to crude settlement in three lagoons operated in series. Primary sludge produced was disposed of in liquid form on a large area of surrounding land.

In the light of this situation, the company engaged a local consulting engineering firm to assist their staff in carrying out a pollution prevention assessment and waste reduction program with a view to developing the best and most cost-effective solution to the waste treatment and disposal problems.

The principal tannery operations carried out, typical of many tanneries throughout the world, may be summarized as follows.

Pretanning (or Beamhouse) Operations

- soaking of the imported, preserved (wet-salted) hide in water overnight to remove blood, dung, curing salt and water-soluble and saline-soluble proteins;
- unhairing (complete dissolving of all hair) by immersion in lime and sodium sulphide - and subsequent reliming;
- trimming and mechanical removal of extraneous tissue from the flesh side of the hides - and subsequent splitting (lime splitting) of the upper two-thirds grain layer from the lower, less valuable split layer;
- deliming by treatment with a weak acid (lactic acid) and bating with an enzyme-based chemical to remove hair remnants and degraded proteins;
- pickling using salt and sulphuric acid solutions to give the required acidity to the skins to prevent subsequent precipitation of chromium salts on the skin fibers - pickled splits are then sold to other tanneries for further processing, only the grain layers being tanned and finished by Company B.

Thus, wastewaters from the beamhouse contain high levels of suspended solids and dissolved organic matter, curing salt and grease, in addition to unused process chemicals (particularly sulphides); they will also be alkaline, having a high oxygen demand.

Tanning

Chrome tanning is carried out using sulphate. The tanning process stabilizes the proteineous (collagen) network of the hide. Acidic effluents are produced which contain unused trivalent chromium salts.

Post-Tanning Operations

These involve:

- pressing (samming) to remove moisture;
- a second leveling by shaving;
- dyeing and softening of the tanned hide with emulsified oils (fatliquoring), preceded by occasional secondary tanning using synthetic tannins (syntans) and tanning extracts;
- drying and final trimming;

- surface coating and buffing (finishing)

The following case study describes the pollution prevention assessment/waste reduction approach taken.

PHASE 1: PREASSESSMENT

Step 1: Assessment Focus and Preparation

It was decided that the study investigations would be carried out by a chemical engineer from the consulting firm's staff who had previous experience of carrying out pollution prevention assessments, assisted by the tannery's plant chemist.

Company B's own laboratory was not equipped to carry out many of the tests normally associated with wastewater analysis and so arrangements had to be made to deliver samples to a local private company providing laboratory analytical services.

In view of government pressures, it was decided to concentrate on wastewater discharges arising from the beamhouse and subsequent tanning operations. However, atmospheric emissions were also investigated having particular regard to health and safety. Solid waste arisings, in particular wastewater treatment plant sludges, were also studied.

The pollution prevention assessment team was keen to gain the support of production personnel in order to ensure that comprehensive information on all tannery operations could be readily obtained. As a first step therefore, the study objectives were fully explained to selected staff responsible for the various production activities.

The investigations were initiated by gathering relevant information from company files. This preliminary search yielded site and drainage plans, raw material purchase records and water meter records associated with on-site borehole abstraction.

A preliminary check on water usage was carried out by calculating the water usage per ton of wet-salted hide processed. This was found to be 61 m^3/ton. It was noted that this was some 22% higher than the typical average working figure of 50 m^3/ton reported in technical literature, suggesting that ways of introducing considerable water savings should be possible as a result of the pollution prevention assessment/waste reduction study.

Step 2: Listing Unit Operations

The consultant and the plant chemist started the tannery study by walking around the processing and waste treatment areas, listing all the unit processes and making notes on their function and use. Help was also sought from various plant operators who were familiar with

the day to day plant operations. The unit operations were listed in **Exhibit 2-13**, with processes which did not produce liquid waste shown in brackets.

Exhibit 2-13: Unit Operations

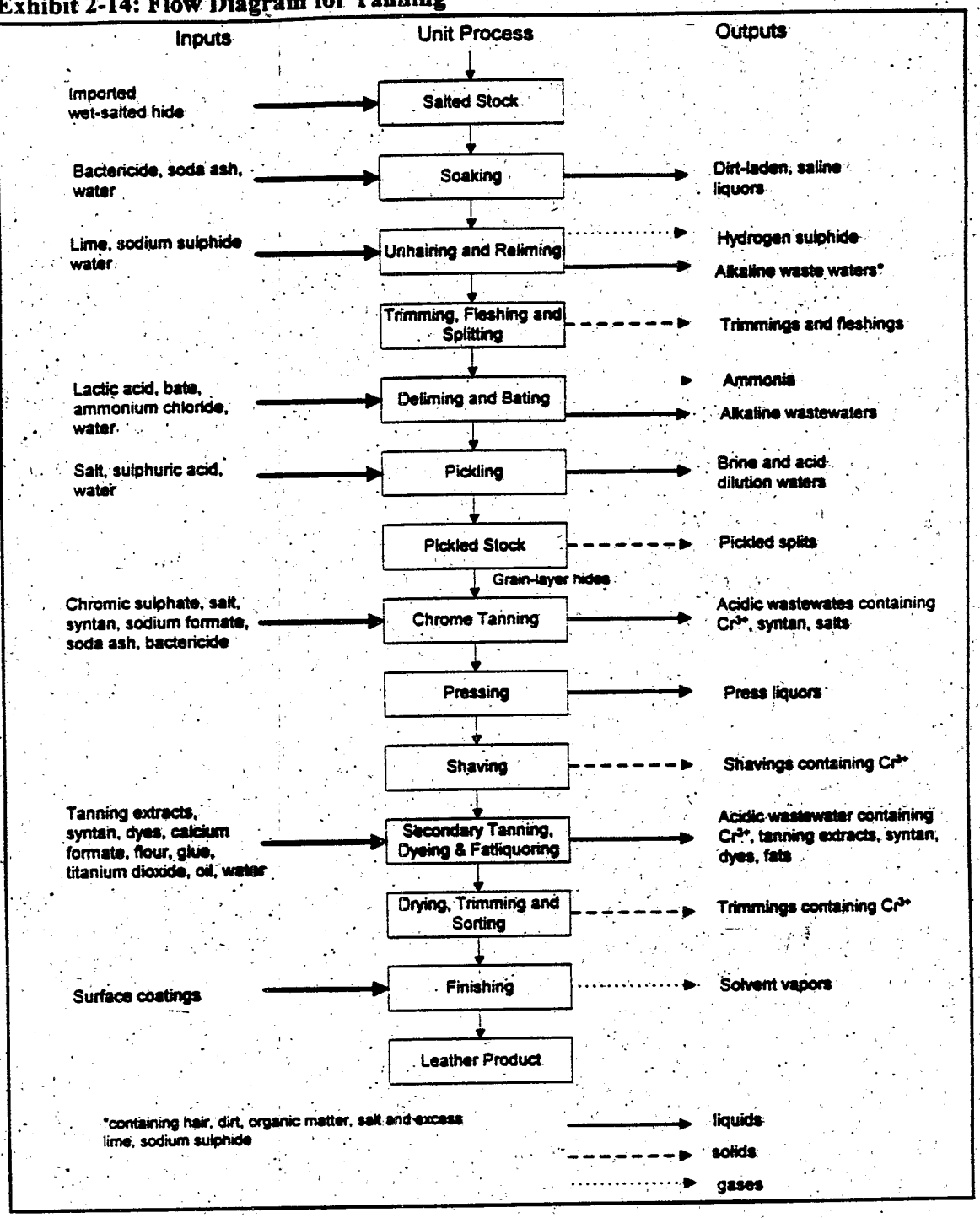
Soaking
Unhairing and Reliming
(Trimming, Fleshing and Splitting)
Deliming and Bating
Pickling
Chrome Tanning
Pressing
(Shaving)
Secondary Tanning, Dyeing and Fatliquoring
(Drying, Trimming and Sorting)
(Finishing)

As part of the company's long-term planning, the plant chemist noted that consideration was being given to moving the hide splitting operations further downstream the process line (after tanning) in order to improve the accuracy of splitting and hence overall process control, as commonly practiced at other tanneries. The existing arrangement and design of process units, many of which were relatively old, did not however lend themselves to this change being implemented rapidly.

Step 3: Constructing Process Flow Diagrams

A flow diagram was then prepared to illustrate the interrelationship between the various unit operations **(Exhibit 2-14)**.

Exhibit 2-14: Flow Diagram for Tanning



PHASE 2: MATERIAL BALANCE: PROCESS INPUTS AND OUTPUTS

Step 4: Determining Inputs

The assessment preparation phase (Step 1) had already highlighted the availability of well-documented raw material purchasing records. The data produced also proved to be a good check on the raw material quantities quoted by the plant foremen per unit operation.

The raw material usage data obtained were set out as in **Exhibit 2-15.**

Exhibit 2-15: Annual Consumption of Process Chemicals

Process Chemicals	tons/annum
Sodium Chloride (other than curing salt present in raw hide)	622
Hydrated Lime	1,123
Sodium Sulphide (62% Na_2S)	445
Sulphuric Acid	160
Soda Ash (anhydrous sodium carbonate)	74
Bate (95% ammonium sulphate, 5% enzymes)	65
Calcium Formate	40
Lactic Acid (30%)	35
Sodium Formate	26
Bactericide	19
Ammonium Chloride	9
Sub-total	**2,618**
Chemicals Absorbed by the Hide (I)	
Tanolin (16% chromium)	760
Syntans A & B	424
Dyes	77
D-1 Oil	17
Other Oils	295
Tannin Extracts	190
Soyarich Flour	45
Titanium Dioxide	30
Methyl Cellulose	9
Semi-Sol Glue	17
Sub-total	**1,864**
Total	**4,482**

(I) Absorption estimated at 90%, 10% discharged to waste - except for Tanolin, absorption 75%, 25% discharge to waste

Due to the nature of the raw materials and the well-organized materials storage system which was found to be in operation, no significant handling losses were occurring.

It was noted that the company incurred no charges for consumption of water drawn from a site borehole. A separate town water (potable) supply was available for domestic use. Domestic wastewater passed to the nearby watercourse via a septic tank.

Having already tabulated the key production stages (Step 2), raw material usage listed in Exhibit 2 was used to derive average quantities per unit operation throughout the tannery, on both a daily basis and per ton of hid processed. The data compiled were set out in **Exhibit 2-16**.

Step 5: Recording Water Usage

The next step was to record the water usage at the tannery and determine how it was used. It was noted that water obtained by the company from the site borehole was pumped to a covered storage tank at ground level and then pumped again to a high-level storage tank. Water then gravitated to the site distribution mains under static head via a water meter, readings for which were recorded weekly in a log book.

Analysis of these records indicated a daily average total water consumption for the site of 2,450 m^3/d. This figure was then broken down into average water usage per tannery unit operation in a similar manner to that carried out for the process chemicals. Since the tannery wet processes were all carried out in revolving vessels of known capacity, providing mechanical agitation to accelerate the wet-chemical operations, batch process water inputs were readily quantifiable. Rinsewater usage which was continuous for a fixed duration per batch was also known from previous work carried out by the company. This had involved checking the time taken to fill a vessel of known volume for a given water valve setting.

The results were summarized as set out in **Exhibit 2-17**.

Exhibit 2-16: Chemical Inputs per Tannery Unit Operation

Unit Operation	kg/ton hide (at unit operation)	kg/ton wet-salted hide	kg/d
Soaking:			
Bactericide	1.6 (I)	1.6	64
Sodium Carbonate	0.8 (I)	0.8	32
Unhairing/Reliming:			
Hydrated Lime (unhairing)	48 (I)	48	1,920
Sodium Sulphide (62% Na_2S)	43 (I)	43	1,720
Hydrated Lime (reliming)	58 (I)	58	2,320
Deliming/Bating:		4.3	
Lactic Acid	5 (ii)	8.7	172
Bate Ammonium Chloride	10 (ii)	1.1	348
	1.3 (ii)		44
Pickling:			
Sodium Chloride	60 (ii)	51.9	2,076
Sulphuric Acid	21 (ii)	18.2	728
Chrome Tanning:			
Tanolin (basic chromic sulphate, 16% Cr^{3+})	60 (ii)	51.9	2,076
Sodium Chloride	60 (ii)	51.9	2,076
Syntan A	25 (ii)	21.6	864
Sodium Formate	8.9 (ii)	7.7	308
Sodium Carbonate	10 (ii)	8.7	348
Bactericide	1 (ii)	0.9	36
Syntan B	41 (ii)	35.5	1,420
Secondary Tanning, Dyeing and Fatliquoring:			
Dyes	20 (iii)	7.0	280
Calcium Formate	10.3	3.6	145
Syntan B	44 (iii)	15.4	616
Soyarich Flour	16 (iii)	5.6	224
Titanium Dioxide	8 (iii)	2.8	112
Glue/Methyl Cellulose	8 (iii)	2.8	112
Tannin Extracts & Oils	118 (iii)	41.3	1,652
Total			**19,693**

(I) Based on 40 tons wet-salted hide per day
(ii) Based on fleshed, split/trimmed hide, after reliming - 34.6 tons per day
(iii) Based on chrome tanned leather, after pressing/shaving - 14.0 tons per day

Exhibit 2-17: Water Inputs per Tannery Operation

Unit Operation	m³/ton hide (at unit operation)	m³/ton wet-salted hide	m³/d
Soaking:			
Prewash	4.3 (I)	4.3	172.0
Process Water	1.9 (I)	1.9	76.0
Rinse Water	2.1 (I)	2.1	84.0
Unhairing/Reliming:			
Process Water	1.9 (I)	1.9	76.0
Rinse Water	11.0 (I)	11.0	440.0
Soak Water (reliming)	1.9 (I)	1.9	76.0
Rinse Water	2.1 (I)	2.1	84.0
Deliming/Bating:			
Pre-rinse	4.2 (ii)	3.635	145.4
Process Water	1.0 (ii)	0.865	34.6
Rinse Water	1.385 (ii)	1.2	48.0
Pickling:			
Brine Water	2.49 (ii)	0.215	8.6
Acid Dilution Water	0.84 (ii)	0.073	2.9
Chrome Tanning:			
Process Water	0.586 (ii)	0.507	20.3
Rinsing	4.51 (ii)	3.9	156.0
Pressing:	0.202 (ii)	0.175	7.0
Secondary Tanning, Dyeing and Fatliquoring:			
Pre-rinse	9.15 (iii)	3.2	128.0
Process Water	0.4 (iii)	0.14	5.6
Rinse Water	18.6 (iii)	6.5	260.0
Process Water	0.4 (iii)	0.14	5.6
General Floor and Plant Washwater		15.5	620.0
Total - Process Waters	-	**12.115**	**484.6**
- Rinse Waters	-	**33.635**	**1,345.4**
- General Washdown	-	**15.500**	**620.0**
- Total	-	**61.250**	**2,450.0**

(I) Based on 40 tons wet-salted hide per day
(ii) Based on fleshed, split/trimmed hide, after reliming - 34.6 tons per day
(iii) Based on chrome tanned leather, after pressing/shaving - 14.0 tons per day

Step 6: Measuring Current Levels of Waste Reuse/Recycling

It was noted that no wastes were reused/recycled at the tannery.

Step 7: Quantifying Process Outputs

The assessment team listed the process outputs from each tannery unit operation as set out in **Exhibit 2-18** below.

Exhibit 2-18: Process Outputs

United Operation	Wastewater	By-Product/ Waste Reuse	Atmospheric Emissions
Soaking	Process and Wash/Rinse Waters	-	-
Unhairing/Reliming	Process and Rinse Waters	-	Hydrogen Sulphide
Trimming, Fleshing and Splitting	-	Trimmings and Fleshings	-
Deliming/Bating	Process and Rinse Waters	-	Ammonia
Pickling	Process Brine/ Acid Dilution Waters	-	-
Pickled Hide Storage	-	Pickled Splits	-
Chrome Tanning	Process and Rinse Waters	-	-
Pressing and Shaving	Press Liquors	Shavings	-
Secondary Tanning, Dyeing and Fatliquoring	Process and Rinse Waters	-	-
Drying, Trimming, and Sorting	-	Trimmings	-
Finishing	-	-	Solvent Vapors
Final Product	-	Finished Leather (grain layer)	-

Action was then taken to quantify these outputs in Steps 8, 9 and 10.

Step 8: Accounting for Wastewater

Process wastewater flows were based on totaling up batch water inputs and making allowances where appropriate for water retention by the hide at each process stage based on percentages reported in technical literature.

Composite samples of the various discharges were also taken for laboratory analysis.

The results of this exercise were summarized in **Exhibit 2-19**.

Exhibit 2-19: Average Flows, Strengths and Pollution Loads of Strong Liquors

Unit Operation	Flow			BOD			SS		
	m³/d	% of total	pH	mg/l	kg/d	& of total	mg/l	kg/d	% of total
Soaking	276	42.1	6.8	2,200	607	19.8	4,400	1,215	30.0
Unhairing	103	15.7	11.5	15,500	1,597	52.0	22,100	2,276	56.1
Reliming	103	15.7	11.7	650	67	2.2	1,650	170	4.2
Delime and Bating	66	10.1	9.5	6,000	396	12.9	2,100	139	3.4
Pickling	37	5.6	2.7	2,900	108	3.5	5,200	192	4.7
Chrome Tan & Press Liquors	33	5.0	3.6	6,500	215	7.0	1,100	36	0.9
Secondary Tanning, Dying & Fatliquoring									
- 1st dump	19	2.9	4.0	2,000	38	1.2	600	11	0.3
- 2nd dump	19	2.9	3.7	2,200	42	1.4	850	16	0.4
Total	**656**	**100.0**	-	-	**3,070**	**100.0**	-	**4,055**	**100.0**

It was decided that having quantified the main, strong-liquor pollution loads per unit operation, separate quantification of running rinsewater pollution loads per unit operation was not justified since this would have meant setting up numerous V-notch weirs and many additional sampling points, thus increasing significantly the time input and analytical work required.

The relatively weak continuous-flow rinse waters were thus monitored using a V-notch weir located in a common drain within the tannery and combining frequent spot samples to give a daily composite for the whole tannery. Total rinsewater flow including general floor and plant washdown was estimated to be 1,944 m³/d with an associated BOD and SS strength of 273 mg/l and 396 mg;l SS. Corresponding pollution loads (flow x strength) were thus 530 kg BOD/d and 770 kg SS/d.

The overall wastewater flows and BOD and SS strengths and pollution loads were then tabulated in **Exhibit 2-20.**

Exhibit 2-20: Combined Wastewater Flows, Strengths and Pollution Loads

Wastewater	Flow m^3/d	BOD		SS	
		mg/l	kg/d	mg/l	kg/d
Strong Liquors	656	4,680 (I)	3,070	6,180 (I)	4,055
Rinse Waters/General Washdown	1,944	273	530	396	770
Total	2,600	1,430 (I)	3,600	1,950 (I)	4,825

(I) Concentrations calculated from flow/pollution load data

Based on an average 40 tons of wet-salted hide processed, it was noted that these overall figures equate to 65 m^3 wastewater/ton, 90 kg BOD/ton and 121 kg SS/ton, ie fairly typical unit loads compared with average figures for similar tanneries elsewhere but some 20-25% high in terms of wastewater flow.

An assessment was also made of chromium and sulphide pollution loads based on selected additional wastewater analyses carried out. This yielded pollution loads of 198 kg Cr/d and 412 kg S"/d, equivalent to 4.9 kg Cr/ton and 10.3 kg S"/ton. Again, it was noted that these loads were fairly typical in the consultant's experience even for well operated tanneries, although somewhat higher (14% and 21% respectively) with respect to figures reported by WHO, 1982.

A number of other checks were also made. It was noted that while it was difficult to measure combined wastewater flows entering the wastewater treatment system, the final lagoon effluent discharged via a rectangular weir. In order to obtain some cross-check on the combined raw wastewater flow set out in **Exhibit 2-20**, the final effluent flow to the nearby watercourse was monitored using this weir. An average flow over the study period of 2,200 m^3/d was recorded.

A limited number of samples of the lagoon effluent were taken and results compared with the raw wastewater analyses tabulated in **Exhibit 2-20.** These indicated pollution load reductions averaging 40% BOD and 70% SS. Based on an average sludge concentration of 6% dry

solids, calculations indicated that the volume of primary sludge generated averaged 56 m^3/d. The assessment team noted that while this sludge was periodically being disposed of on surrounding land, this practice would not be allowed to continue in the future as liquid run-off caused additional pollution problems in the nearby watercourse, particularly during wet weather.

Step 9: Accounting for Gaseous Emissions

It was decided that consideration of atmospheric pollution issues in the context of this project did not justify the need for making use of portable gas detection equipment, such facilities in any case not being readily available. It we also considered that resources required to quantify gaseous emissions would be out of proportion to the extent of the problems occurring. However, various useful observations were made during the site survey.

A strong smell of hydrogen sulphide (H_2S) gas was evident at the primary sedimentation stage of the wastewater treatment plant. H_2S was also evident, although only to a limited extent, within the tannery processing areas where alkaline beamhouse liquors combined with subsequent acidic streams within the internal drainage system.

The plant chemist knew that the hydrogen sulphide was a highly-toxic gas having a threshold limit value (TLV) of 15 mg/m^3 (100 ppm by volume) in air. He also knew that the extent to which H_2S could be released from solution to atmosphere was pH dependent, high pHs favoring the ionized form (HS^-) and hence reduced risk of sulphide stripping. He therefore noted that any future wastewater treatment scheme would be best designed to allow pretreatment of alkaline beamhouse liquors (pH at least 10) before they were allowed to mix with other, acidic waste flows.

No release of ammonia associated with deliming/bating was apparent but it was noted that release of some solvent vapors in the working areas associated with leather finishing could be a potential health risk to production staff. Discussions with the management subsequently revealed that plans were already underway to install forced-ventilation equipment to cater for this problem.

Step 10: Accounting for Off-Site Wastes

The only wastes which were recycled were fleshings which were transported to a local rendering company; these amounted to an average of 9,200 kg/d.

Trimmings and shavings were disposed of to a local municipal landfill site and amounted to 14,600 kg/d.

No sale costs associated with disposal of the fleshings could be readily identified at the time of the pollution prevention assessment. It was later established that no charge was levied by the

tannery in return for the rendering company providing transportation facilities at their cost. Trimmings and shavings were disposed of at an annual cost of US$14,000.

Step 11: Assembling Input and Output Information for Unit Operations

From the information collected the preliminary material balances were started by assembling the input and output data for the tannery and the wastewater treatment plant. These were tabulated under Step 12.

Step 12: Deriving a Preliminary Material Balance for Unit Operations

A preliminary material balance of data associated with operation within the tannery was first drawn up on an overall input/output materials basis. The information was tabulated as set out below.

Inputs	kg/d
Raw Hide	40,000
Chemicals (other than curing salt present in raw hides)	19,693
Water	2,450,000
Total	**2,509,693**

↓

Overall Tannery Operations

↓

Outputs	kg/d
Trimmings and Shavings	14,600
Fleshings	9,200
Pickled Split Layer	13,500
Finished Leather	5,600
Wastewater	2,600,000
Gaseous Emissions	Not quantified but not considered to be a major output
Total	**2,642,900**

A material balance was then drawn up on a unit operation basis with specific reference to chromium and sulphide. A material balance for the wastewater treatment plant was also compiled.

Inputs	kg/d S"	
Unhairing	430	(a)

(a) Based on 1,720 kg/d sodium sulphide containing 25% S"

↓

Unhairing

↓

Outputs	kg/d S"	
Unhairing	412	(a)
Reliming	412	(a)
Delime and Bating	412	(a)
Rinsewaters	5	(b)
Total	417	

(a) Based on 103 m^3/d unhairing liquors at 4,000 mg/l S"
(b) Based on 1,944 m^3/d rinsewaters containing 2.5 mg/l S"

Inputs	kg/d Cr	
Chrome Tanning	332	(a)

(a) Based on 2,076 kg/d Tanolin containing 16% Cr^{3+}

↓

Chrome Tanning

↓

Outputs	kg/d Cr	
Chrome Tan & Press Liquors	83	(a)
Chrome Leather	249	(b)
Rinsewaters	3	(c)
Total	335	

(a) Based on 33 m^3/d chrome liquors at 2,500 mg/l Cr^{3+}
(b) Based on 2,076 kg/d Tanolin containing 16% Cr^{3+} and 75% chrome absorption into hide
(c) Based on 1,944 m^3/d rinsewaters containing 1.5 mg/l Cr^{3+}

Inputs	m^3/d
Raw Wastewater	2,600

↓

Wastewater Treatment Plant	
↓	
Outputs	**m^3/d**
Primary Effluent	2,200
Primary Sludge	56
Total	**2,256**

Step 13: Evaluating the Material Balance

The pollution prevention assessment team was confident that the material balance was adequate (within 5-10%) for the tannery as a whole as well as for the specific chromium and sulphide chemicals used.

The material balance for the wastewater treatment plant was also considered reasonable taking into account that some water seepage was possibly occurring through the base of the crude lagoons, thus contributing to the 13% difference between inflow and total outflows recorded.

Step 14: Refining the Material Balance

It was considered that the material balance information obtained was sufficient to meet immediate requirements but that it would be useful to carry out a further pollution prevention assessment once any waste reduction measures had been implemented.

PHASE 3: SYNTHESIS

Step 15: Examining Obvious Waste Reduction Measures

It was noted that the rinsewater usage following unhairing was appreciable, amounting to some 18% of the total water usage throughout the tannery.

It was considered that significant savings could be achieved at this stage by changing from a 4-hour running rinse to a two-stage batch wash operation, each of 20-25 minutes duration. It was anticipated following a short-term trial that it should be possible to achieve a consistent 60% reduction in rinsewater usage, that is, from 440 m^3/d to 176 m^3/d.

The assessment team also realized that considerable water wastage was taking place by tannery staff leaving numerous hoses running in between general floor and equipment

washdown operations. On the basis of an average of 15 hoses in continuous use, it was estimated that water passing to drain surplus to actual requirements could be as much as 136 m^3/d, some 5% of the total wastewater flow. Recommendations were therefore made for the fitting of pistol-grip self-closing valves on all hoses in use throughout the tannery.

Thus, it was concluded that total wastewater flows could be reduced from 2,600 m^3/d to 2,200 m^3/d, reducing the wastewater production to a more respectable 55 m^3/ton wet-salted hide processed.

Step 16: Targeting and Characterizing Problem Wastes

a) Sulphide Liquors

As indicated in Step 9, it was evident that pretreatment of all sulphide-containing liquors was needed before they became mixed with other acidic flows; the possibility also existed of at least partial recycle of fine-screened sulphide liquors in subsequent unhairing operations.

The management favored a flexible approach with the treatment system designed to handle the total daily sulphide liquor flow if required, conscious that sulphide liquor recycle would probably require a higher level of surveillance of the efficiency of the unhairing operation which might not be readily achieved on a consistent basis in practice.

The assessment team then proceeded to draw up design flow and strength data for the pretreatment of sulphide-bearing waste streams; and also for the subsequent combined wastewater treatment facility required to meet the government's new discharge requirements.

Sulphide-bearing liquors were taken as being all the process and rinsewaters associated with the unhairing process and all wastewater associated with deliming/bating other than the final rinse. The resultant average design flow and sulphide load assessed were as shown in **Exhibit 2-21.**

Exhibit 2-21: Characteristics of Sulphide-Bearing Wastewater

Parameter	Actual		Design	
Flow	590 m³/d	*	600 m³/d	
Sulphide		(700 mg/l)	420 kg/d	(700 mg/l - ave.)
			600 kg/d	(1,000 mg/l - max.)

* assuming unhairing-stage rinsing carried out on a 2-stage batch basis to reduce water usage (equivalent to 27% of total wastewater flows following instigation of water saving)

An assessment was made of the likely BOD reduction due to oxidation of sulphide. The theoretical oxygen uptake rate due to oxidation of sulphide was taken as 0.75-2.0 kg O_2/kg S" depending on the ratio of the thiosulfate: sulphate oxidation products. Taking an average 1.4 kg O_2/kg S" and a 97% S" reduction (down to 20 mg/l S"), this gave a BOD reduction of 560 kg/d.

With reference to Exhibit 2-20; the combined wastewater BOD load can be expected to reduce from 3,600 kg/d to 3,040 kg/d, equivalent to 1,380 mg/l BOD in a reduced flow of 2,200 m³/d. Regarding the effect on suspended solids loads as a result of fine-screening of sulphide liquors, actual removals were difficult to predict accurately without further test work. As a conservative approach therefore, it was decided that the calculated total SS load of 4,825 kg/d (Exhibit 2-20) should be carried forward as a design SS load for sizing and budgetary costing of the combined wastewater treatment plant; this gave a concentration of 2,190 mg/l SS at the predicted future reduced flow.

b) Chrome Liquors

The assessment team considered the possibility of recovering chrome from the chrome-bearing liquors by fine screening, addition of sodium carbonate to precipitate chrome hydroxide (at pH 8-8.5), filter-plate pressing of the resultant sludge and then conversion of the chrome precipitate to soluble chromic sulphate using sulphuric acid.

Discussions with the management revealed that this possibility had been considered in the past but was not favored on overall technical and cost grounds unless the benefits of economy of scale could be introduced by providing a centralized chrome recovery plant to serve all tanneries in the local area. While some preliminary discussions had been held through the national tannery association, such a scheme was not foreseen at this stage.

It was agreed therefore that for the present, the design of a new wastewater treatment plant should assume that chrome would be precipitated and disposed of off-site as part of the primary sludge generated.

Step 17: Segregation

In order to segregate sulphide liquors for separate pretreatment, it was decided to divert existing drainage outlets in the unhairing area to a batch treatment plant located within the existing tannery process building.

Treated flows would then be combined with all other wastewaters at a new treatment plant located close to the existing settlement lagoon facility.

Step 18: Developing Long-Term Waste Reduction Options

The pollution prevention assessment consultant was responsible for drawing up outline proposals for the required new wastewater treatment facilities.

Consideration was given to available methods of sulphide treatment. These included:

- acidification to pH 2-3 and aeration, with absorption of the resultant hydrogen sulphide gas in caustic soda solution within packed-tower scrubbers prior to discharge of the resultant liquor to drain or reuse;
- precipitation with ferrous or ferric salts;
- oxidation using chlorine or hydrogen peroxide;
- oxidation using aeration with a manganese catalyst.

The latter method was considered the most technically satisfactory and cost-effective solution following fine screening. This view was supported by reference to available information sources concerning operational experience elsewhere.

It was decided to divert existing drainage outlets in the unhairing area to a mechanical self-cleaning screen (1 mm) located in a modified floor channel, the upper end being designed to convey screenings to an adjacent skip.

Screened flows would then gravitate to a submersible pumping station to lift flows into one of two batch-treatment oxidation tanks, one to be used for treatment and the other to be

available for receiving the next batch of liquor. A diffused-air system, using non-clog coarse-bubble diffusers, was selected to provide mixing and aeration in each tank and a facility for dosing a solution of manganese sulphate catalyst was incorporated.

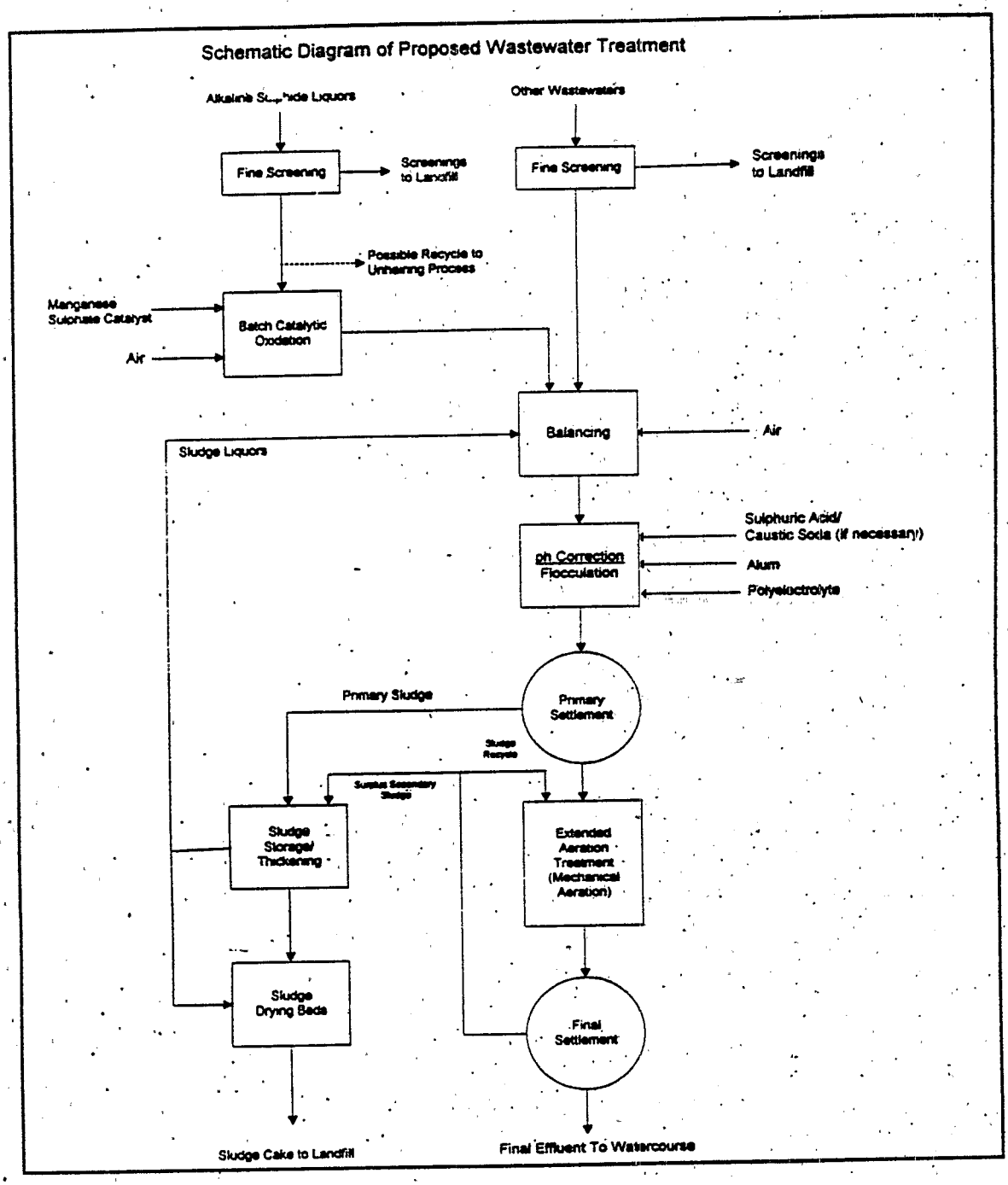
The main treatment plant for pretreated sulphide liquors combined with all other wastewater flows involved the following features:

- flow/pollution load balancing incorporating coarse-bubble aeration/mixing;
- pH correction (if required), chemical flocculation with alum and polyelectrolyte and subsequent primary settlement;
- extended aeration treatment using low-speed mechanical surface aerators (sized to provide a robust biological system capable of withstanding fluctuating loads);
- batch storage/thickening of mixed primary and surplus secondary sludges prior to pumping to drying beds and subsequent disposal of sludge cake to landfill.

Provision for iron salt dosing to the sludge storage/thickening tank was incorporated to precipitate any sulphide formed as a result of anaerobic activity within the tank and hence to minimize odor problems occurring.

A schematic diagram of the proposed treatment plant was compiled as illustrated in **Exhibit 2-22.**

Exhibit 2-22


Schematic Diagram of Proposed Wastewater Treatment
Alkaline Sulphide Liquors
Other Wastewaters
Fine Screening
Screenings to Landfill
Fine Screening
Screenings to Landfill
Possible Recycle to Unhairing Process
Manganese Sulphate Catalyst
Air
Batch Catalytic Oxidation
Balancing
Air
Sludge Liquors
Sulphuric Acid/ Caustic Soda (if necessary)
ph Correction Flocculation
Alum
Polyelectrolyte
Primary Sludge
Primary Settlement
Sludge Recycle
Surplus Secondary Sludge
Sludge Storage/ Thickening
Extended Aeration Treatment (Mechanical Aeration)
Sludge Drying Beds
Final Settlement
Sludge Cake to Landfill
Final Effluent To Watercourse

Step 19: Environmental and Economic Evaluation of Waste Reduction Options

Company B was placed in a position of having to upgrade its wastewater treatment system in order to comply with new discharge standards imposed by the government, part of a new emphasis on the need to control pollution of the environment.

The new effluent discharge standards laid down were 40 mg/l BOD and 60 mg/l SS. Hence, provision of a new treatment facility designed to meet these standards consistently was expected to improve the quality of the local watercourse substantially.

There was a clear need to minimize capital and operating costs of the treatment scheme to ensure the overall financial viability of the company's operations. Therefore, in preparing outline designs for budgetary purposes, particular attention was paid to providing a plant which would be robust and relatively simple to operate.

The cost of the treatment scheme drawn up was estimated at US$500,000 including contingencies and design/construction supervision fees. This reflected a conservative approach to the sizing of the activated sludge process, particularly in terms of aeration capacity. It also took into account the availability to two redundant water storage vessels suitable for use a s sulphide-liquor treatment tanks.

This approach was adopted to provide some flexibility over the mode of operation of the plant with a view to minimizing operating costs - it would allow the primary settlement stage to operate without addition of chemical flocculants if desired, with consequent higher strength effluent passing forward to the biological stage; overall sludge yields requiring ultimate disposal off-site would also be minimized. Provision for chemical flocculants at the primary stage was included however since it was felt that their use could enable the required final effluent quality to be achieved more consistently.

Step 20: Developing and Implementing an Action Plan: Reducing Wastes and Increasing Production Efficiency

The consultants engaged to carry out the pollution prevention assessment/waste reduction studies presented the results of their findings to Company B's management. The data presented were used as a basis for submitting a planning application to the local government office for approval to design and install the proposed wastewater treatment plant.

During a subsequent meeting with the government concerning timing of the proposed design and construction work, Company B was informed that the introduction of a charging system for borehole abstraction was under consideration for possible implementation the following year. This development emphasized to the tannery management the importance of having

carried out the pollution prevention assessment/waste reduction investigations and the need to be alive to further water-saving possibilities in the future.

The pollution prevention assessment/waste reduction investigations achieved the following objectives.

- A thorough appreciation of all the sources of waste at the tannery.
- Identification and quantification of the major sources of wastewater including waste sulphide and chromium contributions.
- Evaluation of processing efficiencies from assembled information on unit operations, raw materials, water usage, products and waste generation.
- Reduction of water usage and associated wastewater disposal problems.
- Identification of problem wastes (ie sulphide liquors) requiring special attention.
- Development of a waste management system which would comply with discharge regulations and result in a much-improved local environment.

CHAPTER 3
THE EP3 POLLUTION PREVENTION PROCEDURES

These procedures provide a guide for EP3 consultants and in-country staff in preparing for, conducting, and following up on pollution prevention assessments at facilities in EP3 countries. The procedures cover three phases of activities associated with completing EP3 pollution prevention assessments:

- Pre-Assessment, which covers the steps leading up to an assessment, including selecting facilities, negotiating agreements with facilities selected for assessments, and gathering data on facility operations to help focus the assessment team's efforts;

- Assessment, which includes the steps associated with conducting the actual pollution prevention assessment. The assessment phase covers the identification and analysis of opportunities and preparation of a report summarizing findings and recommendations; and

- Post-Assessment, which includes the activities that in-country staff and consultants are primarily responsible for after an assessment is completed. This phase continues indefinitely and is intended to ensure that facilities receive ongoing support in implementing pollution prevention programs.

For each phase of the assessment process, the Procedures identify and describe the steps involved; provide an estimated level of effort; identify the party that is generally responsible for conducting the activity, list cautions and assumptions related to the activity, and identify deliverables (if any) associated with that activity.

EP3 emphasizes that these procedures are a guide, not a set of rules, for conducting pollution prevention assessments. For example, the level of effort estimates will vary depending on the complexity of a facility's operations. Some assessments may require significantly less time to complete than the estimates listed in the Procedures, while others may require substantially more. Similarly, while the Procedures identify a responsible party for each activity, responsibilities may vary depending on the conditions surrounding a particular assessment. Also, it may be appropriate to streamline the process in certain situations, eliminating or abbreviating certain steps that are unnecessary. EP3 invites you to use these procedures and intends to use them in its in-country programs. EP3 will revisit these procedures periodically and modify them as appropriate.

EP3 ASSESSMENT PROCESS: Pre-Assessment Preparation Phase
(6/8/94)

Step to Accomplish Activity	Description	Level of Effort	Cautions/Assumptions	Deliverables (if any)
1. Identify Companies and Rank	Consult local sources/clearinghouse to collect any published information on facility's operations and activities. Local sources include: AID Mission, local government entities, NGOs, trade associations Build interest and momentum by holding an industry-wide meeting to announce the project and solicit interested facilities Provide brief training/introduction to pollution prevention to facility owners/managers Use the following criteria to assist in selecting companies: - Scale/size of facility (ft^2, # employees, level of production) - Number of processes with toxic metals, hazardous chemicals, air emissions - Extent to which plant is representative of the industry in terms of processes, age, etc. - Public perception - Government perception: compliance/regulatory status of the facility; has sector been targeted? - Size relative to other plants in the industry - Environmental impacts: does facility threaten any critical resources (e.g., H_2O supplies)? - Willingness of company to invest, innovate - Financial status - Leader or well known in trade association - Personal knowledge of facility/managers - Willingness to participate in the project; interest in potential benefits of applying pollution prevention techniques	2.5 days to develop list of candidates 1-2 months lead time required to prepare for such a meeting	Assumes use of EP3 protocol for selecting industries Size/scale of facility should be appropriate to EP3 resources/capabilities Could also target selected processes in an plant rather than full facility if opportunities are significant Requires conscious effort to gather all possible data on facility This is critical activity as it impacts ultimate success of full assessments later Circulation of documentation on selection process to EP3/Core for review? Provides opportunity to understand historical context for what/why of past action/inaction Follow up by providing information on no- and low cost opportunities to other facilities in that sector	Documentation on facilities considered and chosen/rejected, including qualitative information gathered from contacts List of more candidate facilities than will be assessed in case some are determined poor candidates for full assessments

Step to Accomplish Activity	Description	Level of Effort	Cautions/Assumptions	Deliverables (if any)
2. Contact Facilities and Conduct Initial Information Visits	Prior to visit: - Contact via phone to identify top person to contact, describe project, gather initial information and schedule visit At visit: - Provide standard EP3 briefing package Sample Contract Example report Description of EP3 Example timeline of activities - Determine capability for implementation - Identify obstacles to implementation - Determine commitment and availability of personnel - Determine what information may be available if decision is made to conduct full assessment	1-2 hours per facility 1/2 day per facility	Use local contact if available for introduction: trade association, etc. Have some knowledge specific to each facility to better engage in discussion Plan sufficient time to cover presentation materials Always get to highest management level possible - don't want a lower level missionary to management Standard EP3 briefing package needed Seek management OK to take pictures during the assessment	Brief summary of initial findings directed at comparing facility with other candidates for final decision on assessment Initial list of information/data that is available about the facility (e.g., cost data, waste generation, water effluent #s, etc.) Written confirmation letter to facility thanking them and setting up an additional meeting to gather facility data to assist in making selection decision
3. Inspect to Determine Whether Full Assessment is Appropriate	Collect preliminary data on facility operations: - Identify operational units with high waste loads - Note equipment maintenance and age, housekeeping, operational procedures, materials handling, etc. - Inspect outside of facility (residential proximity, material storage, outfalls) - Determine who makes decisions regarding each operational unit - Verify that company meets selection criteria (see list under Step 1) Request "Letter of Commitment" (LOC) from facility	1 day per facility (2 people @ 1/2 day each) (Consider conducting this step concurrent with Step 2)	Results should be circulated to EP3 Core for review and discussion Gather overview information only - don't do assessment! Consider developing checklist for this activity (?) Standard LOC has been developed by EP3 Core and will translated by the local office	Brief summary of initial findings directed at comparing facility with other candidates for final decision on assessment Summary should include discussion of observations organized at the unit operation level. List of data/information to be collected during pre-assessment data collection if chosen for full assessment Letter of Commitment
4 Select Facility	Based on information collected, make decision, including preliminary schedule for assessment	--	It is possible that the facility will decline EP3's offer to conduct the assessment	List of facilities selected Documentation on those rejected

Step to Accomplish Activity	Description	Level of Effort	Cautions/Assumptions	Deliverables (if any)
5. Draft and Finalize Contract with Facility	Use prototype contract developed by EP3 Core: - Require management to commit to a continuing program of pollution prevention and clean production. - Require management to commit to participate in the process - Require facility to accept no/low cost options based on trials and provide list of acceptable rejection reasons - Specify baseline information needed and require facility to provide certain baseline information, as appropriate - Clearly state what EP3 does and does not provide - Address issue of confidentiality and dissemination of assessment results - Include workplan and schedule (see Step 6 below) Visit facility in person (if necessary) and discuss contract to insure clear understanding and commitment	1 day per facility	The standard format for these contracts should not change too much until EP3 begins to charge for services The standard contract will be translated by the local office Contracts must be signed by both the in-country EP3 Office representative and the facility. Originals of all contracts must be sent to EP3 Core	Two copies of the signed contract (one to be sent to EP3 Core)
6. Develop Draft Statement of Work (SOW) and Schedule	Based on information collected during the initial visit and using the prototype developed by EP3 Core, develop draft SOW for procuring experts and schedule for conducting the assessment	1 day	Workplan should focus on highest opportunities in facility as described in pre-assessment information	Draft SOW that can be used to identify consultants and preliminary schedule

Step to Accomplish Activity	Description	Level of Effort	Cautions/Assumptions	Deliverables (if any)
7. Organize Local/US Participation	Check Association guides to identify industry experts Send out notices requesting consultant candidates using prototypes developed for both local and U.S experts. Draft SOW should accompany these notices. Select team members based on all information gathered about facility and information on consultants	1-2 days per facility	Pre-selecting could save time Ensure candidates have basic skills necessary (typing, computer, etc.) Get clearance for proposed team members from AID and local EP3 office	Team comprised of individuals with appropriate industry/pollution prevention expertise Biosketches for all experts BioData sheets for all experts Acceptance of team and clearance for travel
8. Collect and Summarize Pre-Assessment Data	Collect data to establish effluent and production baseline (EPB): - Overall history of facility and surroundings - Any very obvious pollution prevention options - General observations (maintained equipment, obvious problems, worker safety, level of support, structure of management, etc.), procedures governing materials handling and storage - Very basic materials flow diagram - Operational unit descriptions - Lists of chemicals used, input materials, levels of production, cost data, waste generation data, age of facility and equipment, etc.) Prepare report that summarizes data collected	1 day per facility (2 people @ 1/2 day each)	Need to link individual performing initial walkthrough (Step 3) with individual conducting this activity (if they are not the same) to exchange information Use local consultants chosen for full assessment for this task Send results to U.S. team and EP3 Core	Report summarizing plant's effluent and production baseline that experts can use to prepare for the assessment

Step to Accomplish Activity	Description	Level of Effort	Cautions/Assumptions	Deliverables (if any)
9 Finalize Arrangements with Facility (Optional)	Revisit facility in person (if necessary) Outline activities conducted to date, describe potential schedule, reaffirm commitment Confirm participation of appropriate facility personnel Provide information on U.S. experts if possible Identify additional information not found in pre-assessment to be gathered prior to arrival of assessment team	2 hours per facility	Spend sufficient time to clarify schedule, actual activities, confirm initial data, communicate what is expected/needed, review MOU	Any additional information gathered

EP3 ASSESSMENT PROCESS: Assessment Phase (6/8/94)

Step to Accomplish Activity	Description	Level of Effort	Party Responsible	Cautions/Assumptions	Deliverables (if any)
1 Brief Assessment Team in U.S. Prior to Leaving for Country	Brief U.S. participants on country, plants to be assessed Review work to be done and deliverables Brief participants on administrative items	3 days per facility (1.5 days per consultant - (includes travel)	EP3 Core Staff	May not be necessary if participants have worked for EP3 in the same country Should be done at least 2 weeks before trip (for screening purposes). However, this is often not possible Can be done through conference call	Pre-Assessment Report prepared by in-Country Office/consultants Activity Initiation Briefs (AIBs) for all participants that include Statement of Work, schedule, deliverables, and budget Signed agreements with experts (pro bono and paid consultants)
2 Brief Assessment Team in Country Prior to Beginning Assessment	Discuss roles, planned activities and schedule Answer questions on cultural issues, pre-assessment report, and any pollution prevention options identified during the pre-assessment phase	3 hours per team member (including local consultants and EP3 in-country office staff)	EP3 In-Country Office	Meeting in the same city as plants preferred Structured meeting Update on political/social travel issues Confirmation of all previous arrangements Cover translation issues Mission should be informed, but their involvement is optional	Assignments Revisions to schedule, etc Emergency contacts and phone numbers
3 Meet with Plant Manager/Owner	Meet with facility owner (or his designated representative) and plant manager (if different from above) to review goals for the assessment, present/introduce experts, confirm information/data available, and determine management concerns Reconfirm confidentiality of report and expectations for the assessment	1 hour per team member (including local consultants and EP3 in-country office staff)	EP3 In-Country Office and Assessment Team	Plant knows the team is there to work and time is limited	An assessment package for plant management -- Biosketches of consultants -- Statement of Work for assessment -- Schedule

Step to Accomplish Activity	Description	Level of Effort	Party Responsible	Cautions/Assumptions	Deliverables (if any)
4 Walk Through Facility to Review Operations at Different Phases	Inspect the entire facility's operations Observe any extremely hazardous conditions for workers and/or team After the walk-through, meet as a group to review observations and plan next steps	2-4 hours per team member (including local consultants and EP3 in-country office staff)	Assessment Team	May require 2 or 3 visits to view all manufacturing operations Don't get into details Start at the end of the process and work backwards	None. -- Visual observations only -- Notes for further investigation -- Confirm schedule - make assignments for work that needs to be done -- Prioritize
5 Obtain Detailed Information	Complete block flow diagram (inputs-outputs) and information on unit operations. Quantify to maximum extent raw materials used, energy and water consumption, waste quantities (by type) generated, product quantities generated Obtain cost information for items listed above Prioritize operations that have the greatest pollution prevention potential Meet as a group at the end of each day to review findings and discuss data gaps and to plan activities for the next day	1 day per team member (including local consultants and EP3 in-country office staff)	Assessment Team	Important to stay focused Get input from plant personnel Assumes facility has monthly raw data on costs, energy use and water use	Sections of draft report
6 Identify All Potential Pollution Prevention Opportunities	Brainstorm and list all qualitative opportunities for pollution prevention: no-cost, low cost, high cost, energy efficiency	1/2 day per team member (including local consultants and EP3 in-country office staff)	Assessment Team	Assumes information is available on manufacturing process and alternatives	A list of all opportunities

Step to Accomplish Activity	Description	Level of Effort	Party Responsible	Cautions/Assumptions	Deliverables (if any)
7. Conduct Economic/Technical Analysis to Prioritize Options	Identify process changes required and what actions will be needed to implement these changes Develop implementation schedule Quantify cost of capital required and payback period Evaluate effects of various options on needs for improving/installing treatment Discuss with plant personnel Meet as a group at the end of each day to review results and discuss data gaps	1/2 day per team member (including local consultants and EP3 in-country office staff)	Assessment Team	Plant participates in decisionmaking	Sections of draft report
8. Prepare Draft Report with Recommendations and Presentation Materials	Prepare draft report with recommendations using model supplied by EP3 Core and addressing all items specified in the SOW	1 day per team member (U.S. experts only)	Assessment Team	Goal is to have 95 percent of final report completed in-country EP3 Assessment Procedure available on computer Plant participates Computers available ant time allocated for expert to enter information Clarify how future values are calculated and who to contact with questions The in-country EP3 program Manager is responsible for seeing that the draft is acceptable before the team leaves the country	Draft report and presentation materials

Step to Accomplish Activity	Description	Level of Effort	Party Responsible	Cautions/Assumptions	Deliverables (if any)
9. Present Draft Report with Recommendations to Plant Manager/Owner	Present findings and recommendations on facility assessment to facility owner (or his designated representative) and plant manager (if different from above) Inform owner/manager that if they have any problems or concerns in implementing the Team's recommendations, they should not hesitate to contact the local EP3 Office	1/2 day per team member (including local consultants and EP3 in-country office staff)	Assessment Team	At least 1 hour should be spent emphasizing EP3's commitment to help facility implement report's recommendations. Implementation is likely to be slower if EP3's interest in providing ongoing support is not emphasized Presentation should stress that pollution prevention requires a sustained effort	Draft report (in an acceptable form) to leave with plant managers and EP3 Country Office
10 Hold Debriefing in U.S. for EP3/AID Staff	Experts report on findings of assessment and recommendations to the rest of EP3 team in Washington, D.C.	1 day per team member + 1/2 day for all Core staff participating in the debriefing	EP3 Core Staff and Assessment Team	Assumes EP3 Core/AID Staff read the report prior to the meeting Should take place within two weeks after the assessment has been completed	Oral presentation on assessment and suggested revisions and changes in draft report
11 .Finalize Report (if necessary)	Incorporate all comments from EP3 Core/AID staff and comments from EP3 Country Office	1-2 days per report (does not include translation)	EP3 Core Staff and Assessment Team	Report should be finished within two weeks following the U.S. debriefing. Translation will be done by in-country EP3 Office At later stages of the EP3 country program, the local EP3 Office will be responsible for completing these reports	Disk (Word Perfect 5.1) and hard copy of final report
12. Prepare Case Study	Prepare brief summary of the assessment report	1 day per report (does not include translation)	EP3 Core Staff	Must be cleared by facility and local EP3 Office Translation will be done by in-country EP3 Office	Disk (Word Perfect 5.1) and hard copy of 2-4 page case study
13 Prepare Sanitized Version of Report	Remove all country references and plant names from report	1 day per report (does not include translation)	EP3 Core Staff	Plant and local EP3 Office must approve sanitized report Translation will be done by in-country EP3 Office	Disk (Word Perfect 5.1) and hard copy of sanitized report

EP3 ASSESSMENT PROCESS: Post-Assessment Phase (6/8/94)

Step to Accomplish Activity	Description	Level of Effort	Party Responsible	Cautions/Assumptions	Deliverables (if any)
1. Identify Group to Work With to Disseminate Information to Rest of Industry	These could be suppliers, trade associations, other industry groups that could assist in organizing meetings and disseminating information	1/2 day	In-Country Information Specialist and Engineer	Be sure that the plant that was audited knows this will be done and has a chance to review what will be used	None
2. Conduct Minimum Monthly Local Follow-up	The first followup should take place two weeks after the audit and should be in person. Subsequent followup activities should take place monthly and can occur via phone. However, an in-person visit and plant walk-through is recommended at least every three months Followup consists of reviewing the checklist (based on exhibit and implementation schedule in the audit report). Visit the facility if warranted by information provided via phone Purpose of monthly followup is to evaluate what has been done, what is needed, and who should satisfy needs identified. Implementation schedules should be adjusted as appropriate	1 day per month per facility	In-Country Engineer	Actions identified in the report are viable and cost effective Even when actions are "finished," they can not be removed from the checklist. They need to be monitored in order to quantify whether they are having an effect (cost savings, pollution reductions achieved). Goal is to ensure that they work in the long term Specific types and level of followup should be tailored to opportunities and identified and facility's need for assistance Monthly followup continues until end of program or until followup determined to be too trivial	Status Report that describes status of actions: what is finished and what remains to be done For finished items, report should say what was achieved (quantity of waste reduced, dollar savings achieved), what problems were encountered, what was learned. These items should be transferred to followup list to ensure that they are tracked and measured over the long term For unfinished actions, report should say why unfinished, where company is in implementation schedule, and whether there is a need for assistance. If assistance is needed, what type (local EP3, local consultants, EP3 Core, US assessor)? Report format can be based on Exhibit 1 (from assessment report) and updated as appropriate

Step to Accomplish Activity	Description	Level of Effort	Party Responsible	Cautions/Assumptions	Deliverables (if any)
3 Provide Additional Help as Appropriate/Needed	Types of needs could include: - financial (analysis of alternative funding options) - technology and equipment - equipment problem - vendor needed - training in technology - employee training - management training - demonstrations of the technology and hand-holding by those who have done it First, the In-Country Engineer determines if need can be met in-country or whether US assistance is required If US assistance is needed, is Country Program willing to pay? If country is not willing to pay, is Core willing to pay to find solution? In-Country Program calls country lead at EP3/HBI Once a decision is made regarding who will pay, EP3/HBI lead works with other Core staff to find solution	1/2 day to several weeks	Could be In-Country Engineer, local consultant, US EP3, US assessor	Suggestion made that In-Country Engineer should have the option of contacting the US assessor directly rather than working through EP3/HBI. Arrangements must be made in advance for US assessor to provide responses to questions from the in-country engineer Question regarding who will pay for followup: Core or Country Program? Uncertainty regarding whether resources (Core and Country) will be adequate to ensure effective followup How to ensure timely response to implementation issues/questions raised. Should EP3 have one person who would serve as an "information broker?"	At a minimum, maintain a list of problems/issues raised and whether or not they have been resolved

Step to Accomplish Activity	Description	Level of Effort	Party Responsible	Cautions/Assumptions	Deliverables (if any)
4. Evaluate Company's Efforts Every Six Months	Conduct first evaluation six months after completion of audit and repeat/update every six months thereafter For items that have been implemented (finished), quantify cost savings (payback), environmental benefits achieved. Consider other factors/impacts, such as effects on product quality, worker health and morale, any evidence that pollution prevention has become part of the company's way of doing business Prepare/update the two-page industry case study to include new information	2 days and must include a plant visit	In-Country Engineer	At the beginning of the process (at the end of the assessment), make sure that there is a mechanism for tracking cost savings and environmental benefits on all actions May be necessary to periodically access company financial and production data Updating the case studies must be done part of this activity to keep information current	A report summarizing status of activities based on monthly reports for the period and that quantifies cost savings and environmental benefits and describes other effects on the company Updated case study describing benefits and other effects to disseminate to the industry
5. Disseminate Information to Industry and Other Audiences	Choose the information to disseminate from the "finished" list and six-month evaluation Choose the target audience. Plant managers? Owners of other companies in the same industry? Government personnel? The public? Choose the medium for communicating the information: meeting, awards ceremony, demonstration, newsletter, fact sheet Disseminate	Difficult to estimate Allow 1-2 months lead time to plan and schedule events	In-Country Engineer plus appropriate staff from the facility and local EP3 Office		Depends on the activity
6. Evaluate EP3's Efforts to Disseminate Information Every Year	Determine appropriate evaluation measures (number of facilities in the industry, industry associations) Quantify how many facilities have been reached, how many actions taken as a result of the information they received	One week	In-Country EP3 Manager		A report summarizing the Country Program's efforts to disseminate information on pollution prevention potential throughout an industrial sector and evaluating the effectiveness of these efforts: methods used, facilities reached, actions taken as a result of EP3's efforts

EP3 FACILITY CASE STUDIES

Pollution Prevention Assessment for a Manufacturer of Starting, Lighting, and Ignition (SLI) Batteries

CASE STUDY

What is EP3?

The amount of pollutants and waste generated by industrial facilities has become an increasingly costly problem for manufacturers and a significant stress on the environment. Companies, therefore, are looking for ways to reduce pollution at the source as a way of avoiding costly treatment and reducing environmental liability and compliance costs.

The United States Agency for International Development (USAID) is sponsoring the Environmental Pollution Prevention Project (EP3) to establish sustainable programs in developing countries, transfer urban and industrial pollution prevention expertise and information, and support efforts to improve environmental quality. These objectives are achieved through technical assistance to industry and urban institutions, development and delivery of training and outreach programs, and operation of an information clearinghouse.

EP3's Assessment Process

EP3 pollution prevention diagnostic assessments consist of three phases: *pre-assessment*, *assessment*, and *post-assessment*. During *pre-assessment*, EP3 in-country representatives determine a facility's suitability for a pollution prevention assessment, sign memoranda of agreement with each facility selected, and collect preliminary data. During *assessment*, a team comprised of U.S. and in-country experts in both pollution prevention and the facility's industrial processes gathers more detailed information on the sources of pollution, and identifies and analyzes opportunities for reducing this pollution. Finally, the team prepares a report for the facility's management detailing its findings and recommendations (including cost savings, implementation costs, and payback times). During *post-assessment*, the EP3 in-country representative works with the facility to implement the actions recommended in the report.

Summary

This assessment evaluated a facility that manufactures lead-acid batteries used in automobiles and trucks. The objective of the assessment was to identify actions that would: (1) reduce the quantity of toxics, raw materials, and energy used in the manufacturing process, thereby reducing pollution and worker exposure, (2) demonstrate the environmental and economic value of pollution prevention methods to the battery industry, and (3) improve operating efficiency and product quality.

The assessment was performed by an EP3 team comprised of an expert in battery production and a pollution prevention specialist.

Overall, the assessment identified nineteen pollution prevention opportunities that could save over $1,531,206 in the first 12 months for an investment of $522,500. If implemented, these changes could reduce employee exposure to lead dust, reduce energy and water use per unit output, reduce the amount of lead purchased, reduce lead-contaminated waste water, and improve product quality.

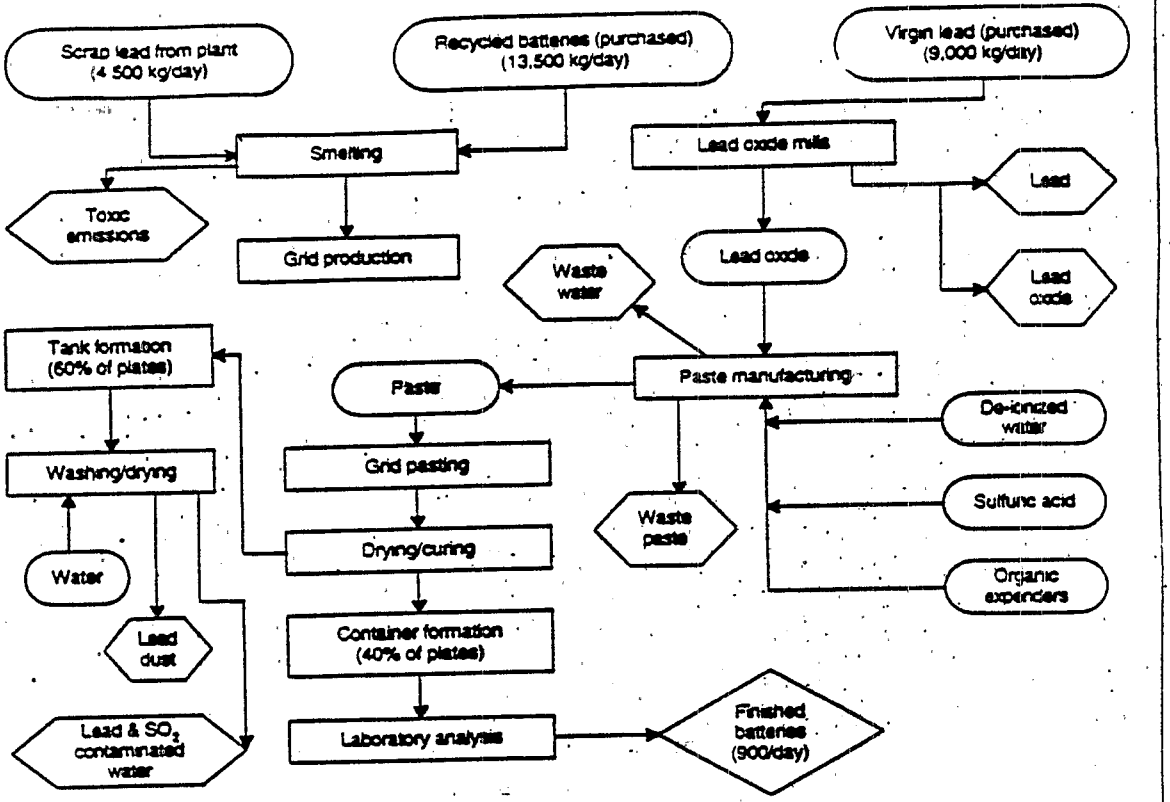
Facility Background

This facility manufactures starting, lighting, and ignition (SLI) batteries. Most of the facility's output is sold domestically, although about 20% is exported. The facility operates one, two, or three 8-hour shifts (depending upon the equipment, process, and season) and employs 220 people. In 1993, they sold 231,000 batteries.

Manufacturing Process

Facility operations can be divided into six main steps: (1) conversion of scrap lead into cast panels, (2) conversion of virgin lead into lead oxide powder and paste, (3) pasting and curing of panels, (4) container formation of batteries, (5) tank formation of batteries, and (6) laboratory analysis and process controls as shown in **Figure 1**. The battery making process begins on two parallel tracks: the facility recovers lead from used batteries that are collected and brought to the facility, scrap lead is recycled and then cast into grids, and virgin lead is mechanically

Figure 1: Overview of Facility's Battery Manufacturing Process



converted into a powdery lead oxide, which is used to make a paste. These separate feeds merge at the grid pasting machine where the paste is pressed into the grids. Pasted plates are cured and then take one of two paths to become battery elements: tank formation or container formation. These processes convert the paste into active material that will electrically charge and discharge throughout the useful life of the battery. In tank formation, this process takes place in large tanks, whereas in container formation, the cured plates are assembled and formed in the battery case itself.

To make the lead oxide paste, lead oxide powder is mixed with de-ionized water, sulfuric acid, and organic expanders. One recipe makes a positive plate, while a slightly different recipe makes a negative plate. The pasted plates then move on a conveyor belt through a drying oven. After pasting and drying, the plates move into a curing chamber for about 48 hours to convert the remaining lead into lead oxide.

In tank formation, the positive and negative plates are immersed in tanks of low specific gravity sulfuric acid, where electrodes pass a current through the plates. In the positive plates, the current converts lead sulfate from the paste into lead oxide. In the negative plates, the reaction converts the paste into sponge lead, a very porous, high surface area form of elemental lead. Container formation employs the same electrochemical process, but occurs in the plastic battery case instead of the tank. Cured plates that are not tank formed must be cut in half and assembled into battery elements, which are then placed into batteries for container formation.

After tank formation, the plates go through a washing and drying process to remove any remaining sulfuric acid. Overall, the plate washing process accounts for over 60 percent of the factory's water contaminated with lead and sulfuric acid.

Existing Pollution Problems

At the time of the assessment, there were a number of pollution problems at the facility, including: (1) waste acid from the used batteries that are cracked to recover lead is disposed of on site, (2) uncovered lead slag and dust piles, (3) excessive energy

Table 1: Summary of Recommended Pollution Prevention Opportunities

Unit Operation	Pollution Prevention Action and Environmental/Product Quality Benefit	Cost	Financial Benefits	Payback Period
Conversion of Scrap Lead into Cast Panels: Smelting	Cover slag and dust piles and clean smelting room - reduces worker exposure to lead and lead dust	$500	$3,750 per year	Less than 2 months
	Buy temperature monitoring instrument to adjust oven - reduces toxic emissions and slag, and reduces energy costs	$1,000	$1,000 per year	1 year
Casting Panels	Purchase improved design mold - reduces waste, lowers energy use, and eliminates steps in the process	$100,000	Seen in plate cutting	See plate cutting
Conversion of Virgin Lead into Lead Oxide Powder and Paste	Shovel spilled lead cylinders back into the mechanical mill rather than smelting ovens - conserves lead and energy	$0	$88,646 per year	Immediate
	Purchase a liquid lead atomization mill - improves efficiency and reduces emissions of lead oxide powder	$200,000	Quality Improvement	Not Applicable
	Sell old equipment once the liquid atomization mill is operating - recovers some of the cost of new purchase	$0	$10,000 per year	Immediate
Pasting and Curing Panels: Pasting	Shovel spilled paste back into paste hopper rather than smelting oven - reduces lead purchases, reduces volume of waste water, and saves energy	$0	$479,546 per year	Immediate
	Increase moisture content of the paste - reduces scrap and extends battery life	$0	Quality Improvement	Immediate
	Reduce the water flow to the finishing roller on paste machine - reduces water use and volume of waste water	$0	$2,000 per year	Immediate
	Buy a moisture analysis oven - makes better lead oxide and saves energy	$1,000	$500 per year	Two years
Pasting and Curing Panels: Curing	Install racks to cure larger batches - saves energy and extends battery life	$1,000	Quality Improvement	Not Applicable
	Install mist sprayers, a heater, and two fans in each curing room - improves battery quality	$4,000	Quality Improvement	Not Applicable
	Analyze the free lead content after 12 hours of curing - saves energy and extends battery life	$0	Depends on curing	Immediate
Pasting and Curing Panels: Cutting	Eliminate the cutting process - reduces scrap, and saves lead and energy	$100,000	$70,956 per year	Less than 18 months
	Recycle drops to strap casting pot rather than smelting oven - saves lead and energy	$0	$20,520 per year	Immediate
Container Formation	Immediately apply charge to batteries after filling - improves battery performance	$0	$36,288 per year	Immediate
Tank Formation of Plates	Eliminate the process - saves water and natural gas, reduces worker exposure to acid and lead dust, reduces volume of waste water, and improves battery quality	$100,000	$693,000 per year	Less than 3 months
Tank Formation: Washing and Drying of Plates	Stop washing all plates immediately - reduces waste water	$0	$125,000 per year	Immediate
Laboratory Analysis and Process Control: Laboratory Analysis	Accurately measure individual battery cell voltage - assures battery quality	$500	Quality Improvement	Not Applicable
TOTALS		$522,500	$1,531,206 per year	

use in smelting ovens, curing rooms, and the tank formation process, and (4) excessive wastewater generation in the grid pasting and washing processes. In addition, over 2,500 kilograms of lead oxide paste was spilled and fed into the smelting process each day, using virgin lead where scrap lead would suffice. Finally, several technological problems (e.g., the outdated lead oxide mill and lack of a moisture analysis oven) increased raw material use and adversely affected battery quality.

Pollution Prevention Opportunities

Overall, this assessment identified nineteen pollution prevention opportunities that could address the problems identified and produce significant economic benefits for the facility. If implemented, these opportunities could save over $1,531,206 in the first 12 months for an investment of $522,500.

The pollution prevention strategy is premised on the belief that addressing sources of waste and pollutants also improves the company's economic health by reducing operating costs and improving product quality. In this case, product quality is increased by (1) increasing the lead oxide particle size by buying a liquid atomization mill, (2) increasing the moisture content of the paste recipes, (3) increasing the curing temperature, humidity, and air circulation, (4) analyzing the moisture content of the pasted plates on-site, at the oven, (5) monitoring the smelting oven temperature and adjusting to the optimal level, (6) curing larger batches of pasted plates, and (7) utilizing cadmium sticks in the laboratory to measure cell voltage.

Table 1 lists the opportunities for pollution prevention recommended for the facility and presents the environmental and product quality benefits, implementation cost, savings, and payback time for each. Because the quantities of pollution generated by the facility and possible pollution prevention levels depend on the production level of the facility, all values should be considered in that context.

Additional Recommendation

There is an additional opportunity to prevent pollution and conserve raw materials in the battery recycling process. Before cracking the battery case, workers could pour the acid into a large plastic plating tank. The acid could be recycled (possibly through ion exchange) and returned to the production process, replacing purchases of high concentration acid.

Evaluating Performance

EP3 is developing a methodology for measuring and tracking pollution prevention performance. The approach uses simple but critical ratios to compare data among facilities in the same industrial sector.

This assessment identified four critical ratios, as shown in Table 2. The Assessment Team developed best industrial performance (BIP) values for these ratios, and found that each of this facility's current values were significantly above the BIP values. The facility should be able to reduce its ratios and come closer to the BIPs by implementing the pollution prevention options listed in Table 1.

Table 2: Critical Performance Ratios for Battery Manufacturing

Ratio	BIP	Current Ratio at Facility
Kilograms of virgin lead per battery unit	8.0	11.2
Kilograms of lead-alloy feed per battery unit	5.0	9.7
Liters of water used per battery unit	50	150
Kilowatt-hours (kwh) and cubic meters (m^3) of natural gas per battery unit	7 kwh and 5 m^3	10.7 kwh and 6.6 m^3

Implementation Status

The facility has already implemented many of the low/no cost recommendations, including covering recycled lead piles, recycling dropped virgin lead into the lead oxide mill rather than into the smelter, recycling waste paste into the hopper rather than sending it to the smelter, and maintaining optimal temperature and humidity in the curing room. In addition, the facility has begun to implement several capital intensive changes. For example, it has placed an order for boost charging equipment ($100,000) and requested price quotes for a liquid lead atomization mill ($240,000).

For Further Information

For further information on this assessment or other activities sponsored by EP3, call the EP3 Clearinghouse at (703) 351-4004, send a fax to (703) 351-6166, or on Internet at apenderg@habaco.com.

HBI-94-003-01, Pub. 10/31/94

Pollution Prevention Assessment for a Cattle Hide Tannery CASE STUDY

What is EP3?

The amount of pollutants and waste generated by industrial facilities has become an increasingly costly problem for manufacturers and a significant stress on the environment. Companies, therefore, are looking for ways to reduce pollution at the source as a way of avoiding costly treatment and reducing environmental liability and compliance costs.

The United States Agency for International Development (USAID) is sponsoring the Environmental Pollution Prevention Project (EP3) to establish sustainable programs in developing countries, transfer urban and industrial pollution prevention expertise and information, and support efforts to improve environmental quality. These objectives are achieved through technical assistance to industry and urban institutions, development and delivery of training and outreach programs, and operation of an information clearinghouse.

EP3's Assessment Process

EP3 pollution prevention diagnostic assessments consist of three phases: *pre-assessment, assessment,* and *post-assessment.* During *pre-assessment,* EP3 in-country representatives determine a facility's suitability for a pollution prevention assessment, sign memoranda of agreement with each facility selected, and collect preliminary data. During *assessment,* a team comprised of U.S. and in-country experts in both pollution prevention and the facility's industrial processes gathers more detailed information on the sources of pollution, and identifies and analyzes opportunities for reducing this pollution. Finally, the team prepares a report for the facility's management detailing its findings and recommendations (including cost savings, implementation costs, and payback times). During *post-assessment,* the EP3 in-country representative works with the facility to implement the actions recommended in the report.

Summary

This assessment evaluated a facility that tans cattle hides. The objective of the assessment was to identify actions that would: (1) reduce the quantity of toxics, raw materials, and energy used in the manufacturing process, thereby reducing pollution and worker exposure, (2) demonstrate the environmental and economic value of pollution prevention methods to the tanning industry, and (3) improve operating efficiency and product quality.

The assessment was performed by an EP3 team comprised of a US expert in leather tanning and a pollution prevention specialist.

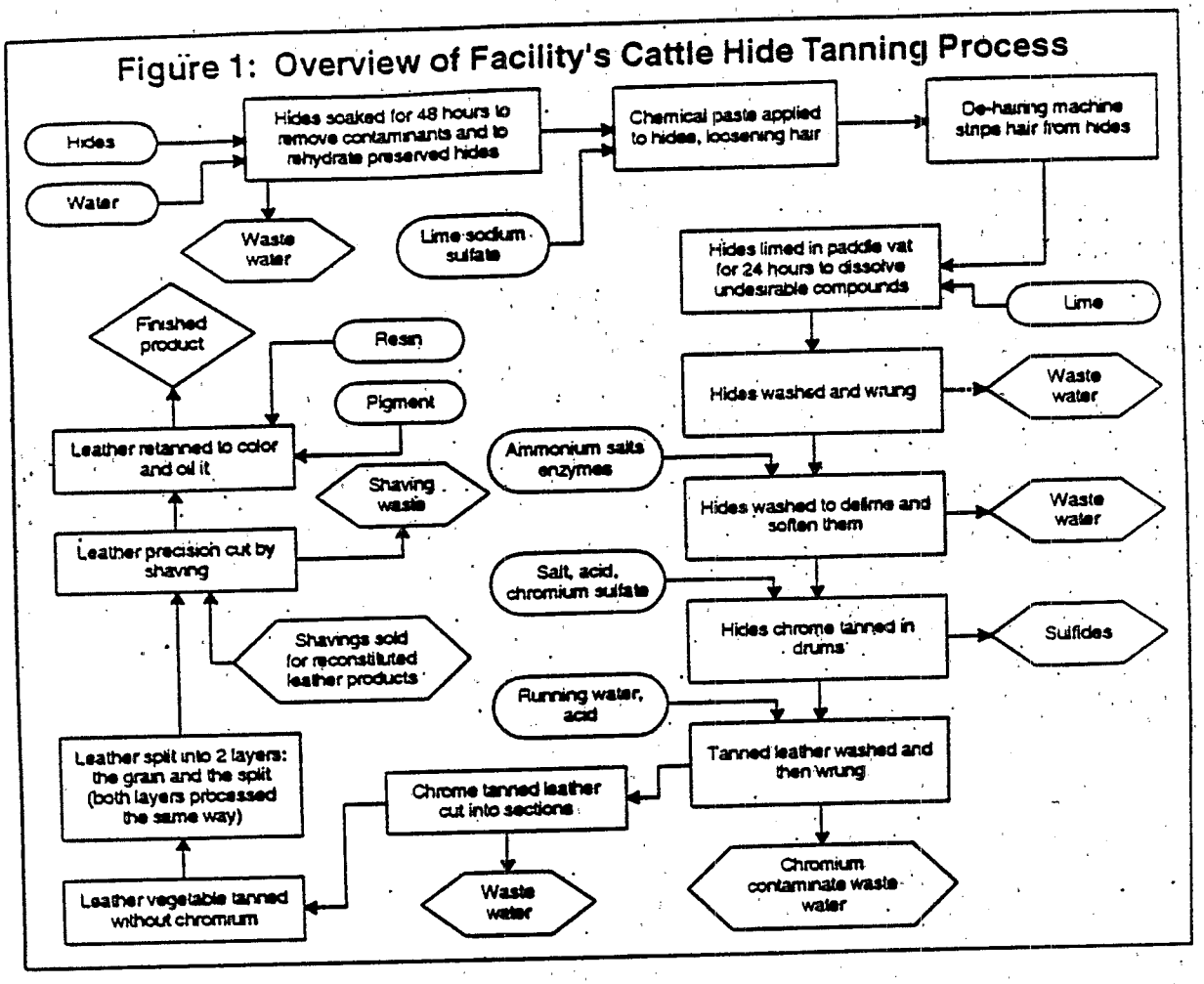
Overall, the assessment identified eight pollution prevention opportunities at this facility. Recommendations include recycling the spent chrome tanning wastes, oxidizing the sulfide containing wastes, decreasing the volatile organic discharge by changing finishing materials, decreasing water use by batch washing, and using solid wastes from the waste stream as fertilizer.

Facility Background

This facility is a cattle hide tannery producing chrome tanned shoe upper leather from salted cattle hides. The tannery has a nominal capacity of five hundred hides per day. Monthly production is 25 days at 400 hides per day, with an average hide weight of 23 kg. The total weight of hides processed per day is 9,200 kg.

The wastes generated by the tannery come from the hides and the chemicals used in the tanning process. Tannery wastes are discharged in a number of batches during the production day.

EP3 is sponsored by the U.S. Agency for International Development.



Manufacturing Process

Figure 1 outlines the process of leather production at the plant. In the production of leather from salted cattle hides, the hides must be thoroughly re-wet, and the dirt, salt and undesirable hide substances must be removed. Soaking and washing the skins is done in a series of steps to remove dirt, salt, and organic matter, and rinse the hides. The waste water is nearly neutral, and contains salt and some suspended solids.

Next, the skins are unhaired by treatment with lime and sulfides. The waste water is very alkaline, contains toxic sulfides, and is the main cause of the high BOD and suspended solids in the total waste stream.

The next step is de-liming to remove the lime in the skins and soften them by enzymatic action. The first dump of this process contains ammonium sulfate, enzymes, and some protein. The subsequent washes are very dilute, nearly neutral pH solutions.

The skins are then tanned. The chrome tanning process is standard for the industry: the solutions contain chromium as chromium sulfate salt and some free acid. About 75 percent of the chromium present combines with the hide.

Finally, the color and fatliquor steps are employed to color and oil the leather to make it as soft or firm as desired. A number of chemicals are used in these steps, and about 90 percent of the load is fixed to the leather. The spent solutions are mildly acidic, with a pH of between 4 and 6. BOD and suspended solids are relatively low.

Table 1: Summary of Recommended Pollution Prevention Opportunities

Unit Operation	Pollution Prevention Action and Environmental/ Product Quality Benefit	Cost	Payback Period
Chromium Tanning	Recycle chrome tanning - decreases Chromium to less than 3 mg/l	$20,000 (saves $60,000 per year)	4 months
Solvent Discharge	Change to water-based lacquer finish - decreases VOC discharge by 60-90 percent	None	To be determined
Water Use	Change to batch washes - decreases water usage by 20-40 percent	None	To be determined
Solid Waste	Save leather trimmings for reconstituted leather - decrease leather waste by 60-80 percent	10,000	To be determined
Sulfide Waste	Destroy sulfides by air oxidation - decreases sulfide waste by 95-98 percent	30,000	To be determined
Suspended Solids	Primary treatment - decreases suspended solids by 70-85 percent	100,000	To be determined
Sludge from Effluent	Dry sludge for land application - allows disposal of sludge as fertilizer	20,000	To be determined
Secondary Treatment	Treat primary waste - decreases BOD by 60-80 percent	$50,000 (trickling filters)	To be determined
TOTALS		$230,000 capital costs	

Existing Pollution Problems

At the time of the assessment, there were a number of pollution problems at the facility, including excessive (1) chromium discharge, (2) VOC discharge, (3) water usage, (4) leather waste, (5) sulfide waste, (6) suspended solids in effluent, (7) oil and grease in the effluent, and (8) BOD of effluent.

Pollution Prevention Opportunities

The assessment identified eight pollution prevention opportunities that could address the problems identified, with significant environmental and economic benefits to the facility (see Table 1). Two of the recommendations can be implemented with no capital investment.

The recommended actions are based on cost effective methods that have been proven in commercial applications.

Chromium recycling. This step allows the collection of the spent chrome tanning solutions, without dilution or contamination, for use in the pickle and tanning process. Since the tannery also tans splits, the spent chrome tanning solution can be used here as well. The tanning of splits results in very good fixation of chromium, so the concentration of chromium in the final effluent should meet effluent regulations. This system results in a saving of about 25 percent in the chromium chemicals used.

Solvents. The suppliers of finishing products have developed water-based lacquers with significantly lower volatile solvent contents. These materials are now widely accepted as quality products, and their use is strongly advised.

Process Water. In some hide wetting processes there is an opportunity to recycle the final rinses. The final rinse waste water in this process is compatible with fluids used for the first wetting of the hides.

Solid Waste. Elimination of solid leather waste discharges through the use of trimmings in reconstituted leather will ease the burden on landfills.

Capital Intensive Modifications. Eliminating sulfides from the effluent is very important, as they will corrode pipes, cause objectionable odors, and may cause fatal accidents. The sulfide-lime solution, and washes from this process, can be collected without contamination from other solutions. These collected wastes can be placed in a tank and the sulfides oxidized by air with a catalyst. This method is effective and can destroy the sulfide in 4-8 hours.

At this point the lime waste, with high BOD and suspended solids, can be used to neutralize the acid wastes that are being continuously discharged. The

acid and alkaline wastes from the tanning process will react to produce a co-precipitation of much of the suspended solids and BOD. This is done with a mixing tank and automatic pH control. Coagulants can also be added at this point.

The neutral streams can then flow to a primary clarifier for the removal of suspended solids as sludge. The sludge can be dewatered in a sand bed to more than 50 percent solids for disposal. Although this effluent is somewhat high in BOD, over 80 percent of the pollution load has been removed. The sludge is a good soil conditioner, and if used as such, will eliminate possible high disposal costs.

Secondary Treatment. In the future, a secondary treatment system can be added for BOD removal. The secondary system need only be as large as needed for the clarified wastes, and it may consist of a trickle filter, a secondary clarifier, and/or a filter press.

Effect on the Environment

Implementation of the suggestions will lead to a number of positive environmental benefits. Chromium recycling will decrease the chromium in the discharge by 80-90 percent. The reduction of volatile solvents will decrease VOC releases to the atmosphere by 60-75 percent. Changes to water usage patterns will decrease effluent volume by 30 percent. Elimination of solid leather waste discharges through the use of trimmings in reconstituted leather eases the burden on landfills. With primary and secondary treatment, the BOD can be reduced by 75 percent. In addition, the suspended solid reduction creates a useable by-product in the form of an organic fertilizer.

For Further Information

For further information on this assessment or other activities sponsored by EP3, call the EP3 Clearinghouse at (703) 351-4004, send a fax to (703) 351-6166, or on internet apenderg@habaco.com.

HBI-94-004-01. Pub. 10/31/94

Pollution Prevention Assessment for a Textile Dyeing Facility Serving Fabric Manufacturers

CASE STUDY

What is EP3?

The amount of pollutants and waste generated by industrial facilities has become an increasingly costly problem for manufacturers and a significant stress on the environment. Companies, therefore, are looking for ways to reduce pollution at the source as a way of avoiding costly treatment and reducing environmental liability and compliance costs.

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Summary

This assessment evaluated a dye house serving a variety of fabric manufacturers. The objective of the assessment was to identify actions that would: (1) reduce the quantity of toxics, raw materials, and energy used in the dying process, thereby reducing pollution and worker exposure, (2) demonstrate the environmental and economic value of pollution prevention methods to the dyeing industry, and (3) improve operating efficiency and product quality.

The assessment was performed by an EP3 team comprised of an expert in textile dyeing and a pollution prevention specialist.

Overall, the assessment identified 37 pollution prevention opportunities -- classified as first, second, and third priority opportunities -- that could reduce energy use at this facility and avoid the release of over 14 metric tons of air emissions each year, in addition to unquantified reductions in the release of global warming gases and heavy metals. Water use could be reduced by 125,000 cubic meters per year, and chemical releases to surface waters could also be reduced. Finally, it may be possible to avoid the disposal of 330 cubic meters of solid waste per year.

Facility Background

This facility is a dye house serving fabric manufacturers. The facility operates two eight-hour shifts, six days per week, employing seventy shift workers and twenty technical and administrative employees. In 1992, the facility processed 350,000 kg of cotton and 360,000 kg of wool fabric.

Manufacturing Process

In general, cotton dyeing involves two procedures, desizing and bleaching, and dyeing. Each procedure involves a number of steps that must be carried out in proper sequence and under optimal conditions. For detailed depictions of these processes, see Figure 1. Wool dyeing also involves several procedures: (1) washing, (2) podding (heating thin wool fabrics in

Figure 1: Cotton and Polyester Processing

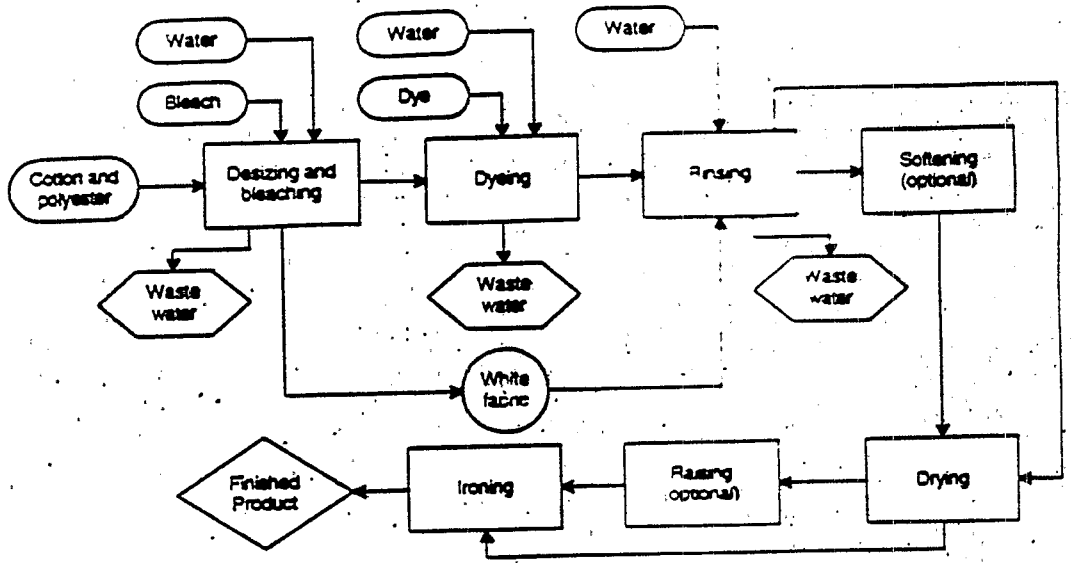
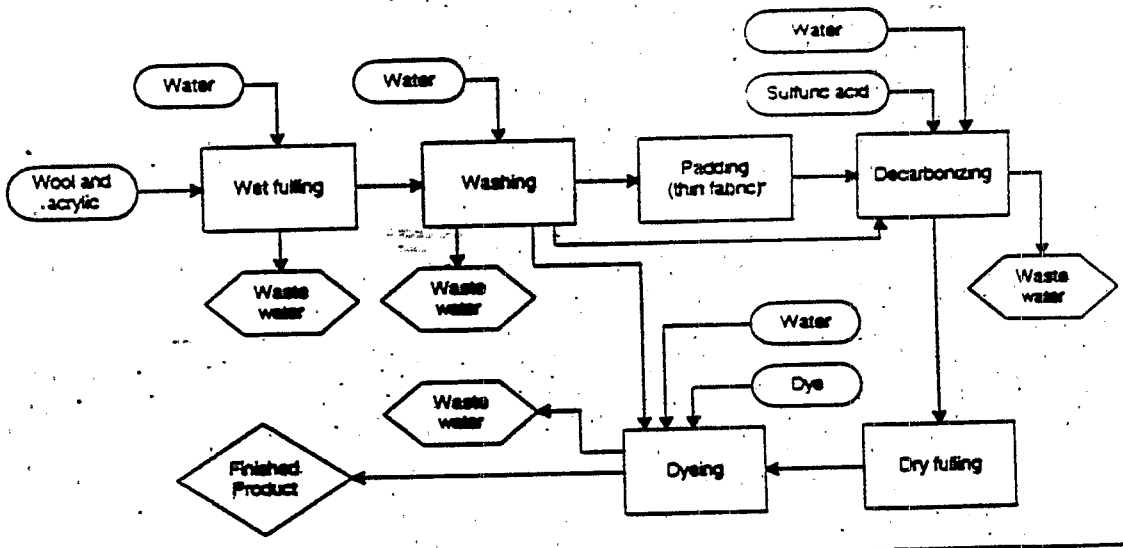


Figure 2: Wool and Acrylic Processing



boiling water to improve appearance and brightness); and (3) dyeing. For detailed depictions of these processes, see Figure 2.

- White fabric is desized and bleached in becks, with nominal capacities of 500 liters, 1,000 liters, and 1,500 liters of water. Fabrics to be dyed are desized and then dyed in jets.

Existing Pollution Problems

At the time of the assessment, there were a number of pollution problems at the facility, including (1) excessive loss of water, chemicals, and heat energy from the becks, (2) excessive use of water in the rinsing process due to residual solution left at bottom of the beck, (3) excessive suspended solids, primarily

Table 1: Summary of Recommended Pollution Prevention Opportunities

Unit Operation	Pollution Prevention Action and Environmental/ Product Quality Benefit	Cost	Financial Benefit	Payback Period
First Priority Opportunities				
Steam Traps	Repair leaking traps - reduces air emissions and fuel costs.	$700 to replace traps.	$47,000 per year	1 week
Steam System	Evaluate steam system components and layout and add at least two steam traps - reduces energy use prolongs life of components and reduces bath and boiler water contamination.	$120 for insulation;$500 for traps.	To be determined	To be determined
Steam Traps	Improve knowledge of steam trap selection - reduces energy use and avoids purchase and repair of traps.	None	To be determined	Immediate
Steam Traps	Purchase and use steam leak detector - reduces fuel consumption.	$1100 for instrument	To be determined	To be determined
Dyeing Becks	Modify rinsing procedures and becks - reduces water costs.	$400 for 16 valves - flow restrictors and siphon piping.	$45,000 per year	Less than 1 week
Dye Baths	Replace sodium sulfate with sodium chloride - reduces sulfate emissions below effluent standards and reduces chemical costs.	None	$7,500 per year	Immediate
Wool Laundries	Repair leaks - reduces water and energy use.	$50 for screens and valve.	$3,700 per year	Less than 1 week
Zonco Washer	Repair leaks and maintain drain valves - reduces water and energy use.	None	$2,200 per year	Immediate
Sulfuric Acid Decarbonizing	Filter acid continuously - reduces release of sulfuric acid to sewer system.	$700 for in-tank filter.	$300 per year	2.5 years
Floor Drains	Install and maintain screens to prevent lint from entering drains - reduces suspended solids sedimentable solids and sulfide in effluent.	$10 for screens.	To be determined	To be determined
Beck Number 10	Relocate steam coil to prevent boil-over - reduces loss of chemicals and energy to drains.	None	To be determined	Immediate
All Becks	Repair and maintain steam coils - reduces fuel consumption and prevents contamination of dye baths and boiler water.	None	To be determined	Immediate
Boiler	Purchase and install combustion controls - reduces emissions and fuel use.	Unquantified	To be determined	Immediate
Jet Dyers	Monitor dye bath temperature to detect out-of-control condition - avoids chemical loss to sewer and reduces energy use.	$25 for thermometers.	To be determined	To be determined
Dyeing Process	Use Datacolor instrument to control process - reduces chemical use.	None	To be determined	Immediate
EMOS Water Supply	Test plant water distribution system for leaks - reduces water use.	None	To be determined	Immediate
Green Dryer	Re-balance internal air flow - reduces emissions of H_2SO_4 mist and energy use.	None	To be determined	Immediate
Green Dryer	Install exhaust fan after re-balancing dryer - avoids worker exposure to sulfuric acid mist and future medical costs.	$700 (est.)	To be determined	To be determined
Sewer Effluent	Determine nitrogen and hydrocarbon concentrations - assures compliance with effluent standards and helps set reduction priorities.	$200 for testing.	To be determined	To be determined
TOTALS		$4,500	At least $105,700 per year	

int washed off fabric, (4) leakage of detergent-laden water from the wool washing machines, (5) excessive pH of effluent from the decarbonizing acid bath, (6) excessively hot effluent, (7) excessive oil and grease and sulfate concentrations in effluent, (8) leakage from steam coils, (9) hydrogen sulfide generation at the wool laundry sump, (10) disposal of dry wool, cotton combings and shavings, and sodium sulfate bags (materials that could be recycled), (11) excessive air emissions of particulates, and (12) lint and sulfuric acid mist in the wool laundry room.

This facility uses about twice as much water as the average commission batch dyer its size; thus, many of the recommendations focus on reducing water consumption and the energy required to heat it for various dyeing processes.

Pollution Prevention Opportunities

The assessment identified almost 40 pollution prevention opportunities that could address the problems identified, with significant environmental and economic benefits to the facility. The assessment team prioritized these opportunities based on pollution prevented and implementation cost. Table 1 lists the high priority opportunities recommended for the facility and presents the environmental benefits, savings and implementation costs, and estimated payback period for each (a complete list of recommendations is available from the EP3 Clearinghouse). Many of the recommendations can be implemented with no capital investment. Further, many can be implemented almost immediately and most are not dependent upon other projects for their initiation.

Of the 19 high priority opportunities recommended, the savings possible from implementing six have been quantified. These six recommendations will reduce operating costs by almost $106,000 per year for an initial investment of $1,900. The simple payback period for these changes is one week. Another $2,600 in investments is required to implement other changes whose savings potential cannot be quantified without further research.

Effect on the Environment

Implementation of the recommended actions will produce positive environmental impacts in three areas: reduced air emissions, lower water and chemical use, and reduced generation of solid waste.

Air Emissions. Many of the proposed changes will reduce steam consumption and lower fuel use, thereby reducing air emissions. Repairing all traps should reduce fuel consumption by 36 percent, or 454 metric tons of number 6 residual oil per year. The expected reductions in air emissions from this change total over 14 metric tons per year. In addition, this change will result in reduced carbon dioxide and heavy metal emissions.

Water and Chemical Use. When all rinsing changes have been implemented, the facility should consume half the water it currently does. The yearly reduction in water use will be about 125,000 cubic meters. Chemical use will decline due to a number of changes. Sulfate in the effluent will be reduced by more than 70,000 kg/year by changing to sodium chloride and filtering the decarbonizing acid bath.

Releases to the sewer of other chemicals such as dye, dye stabilizers, de-foamers, detergents, sodium hydrosulfite, bleach, optical brighteners, acetic acid, equalizers, and boiler treatment chemicals will be reduced as a result of the recommended changes. Among the changes that will affect chemical releases are: (1) better process controls, (2) screening drains and cleaning sumps regularly to prevent sulfide generation, (3) preventing beck boil-over, (4) repairing coil steam leaks that contaminate boiler feed water and process baths, (5) using a lower-foaming jet-dye detergent, (6) calibrating and shimming becks, (7) repairing and modifying becks and wool laundries, and (8) determining sizing formulae. Until these changes are made, it is not possible to calculate the degree to which releases will be reduced.

Solid Waste. Solid waste discarded by the facility consists mainly of sulfate chemical bags and shavings and combings from fabric finishing. Assuming that the eight sulfate bags generated per day fill one large (0.1 cubic meter) garbage bag and that the combings fill ten bags per day, the yearly un-compressed volume of these solid wastes is 330 cubic meters. If both wastes are recycled, this volume of waste can be reused at least once before being discarded.

For Further Information

For further information on this assessment or other activities sponsored by EP3, call the EP3 Clearinghouse at (703) 351-4004, send a fax to (703) 351-6166, or on Internet apenderg@habaco.com.

HBI-94-006-02, Pub. 10/31/94

Pollution Prevention Assessment for an Electroplating Facility
CASE STUDY

What is EP3?

The amount of pollutants and waste generated by industrial facilities has become an increasingly costly problem for manufacturers and a significant stress on the environment. Companies; therefore, are looking for ways to reduce pollution at the source as a way of avoiding costly treatment and reducing environmental liability and compliance costs.

The United States Agency for International Development (USAID) is sponsoring the Environmental Pollution Prevention Project (EP3) to establish sustainable programs in developing countries, transfer urban and industrial pollution prevention expertise and information, and support efforts to improve environmental quality. These objectives are achieved through technical assistance to industry and urban institutions, development and delivery of training and outreach programs, and operation of an information clearinghouse.

EP3's Assessment Process

EP3 pollution prevention diagnostic assessments consist of three phases: *pre-assessment*, *assessment*, and *post-assessment*. During *pre-assessment*, EP3 in-country representatives determine a facility's suitability for a pollution prevention assessment, sign memoranda of agreement with each facility selected, and collect preliminary data. During *assessment*, a team comprised of U.S. and in-country experts in both pollution prevention and the facility's industrial processes gathers more detailed information on the sources of pollution, and identifies and analyzes opportunities for reducing this pollution. Finally, the team prepares a report for the facility's management detailing its findings and recommendations (including cost savings, implementation costs, and payback times). During *post-assessment*, the EP3 in-country representative works with the facility to implement the actions recommended in the report.

Summary

This assessment evaluated an electroplating facility. The objective of the assessment was to propose a program of pollution prevention that would: (1) reduce the quantity of toxics, raw materials, and energy used in the manufacturing process, thereby reducing pollution and worker exposure, (2) demonstrate the environmental and economic value of pollution prevention methods to the electroplating industry, and improve operating efficiency and product quality.

The assessment was performed by an EP3 team comprised of an expert in electroplating and a pollution prevention specialist.

Overall, the assessment identified 18 pollution prevention opportunities at this facility. Recommendations for pollution prevention include replacing the solvent degreaser with an alkaline cleaner, improving process solution monitoring, and capturing and returning 100 percent of chromium dragout to the process solution.

Facility Background

This facility is an electroplater that performs zinc, nickel, brass, and chrome plating. Seventy percent of production is comprised of brass articles. The facility operates with 23 workers who work in a single 8-hour shift, 300 days a year. Approximately 15 m^2 of metal surface is finished per day.

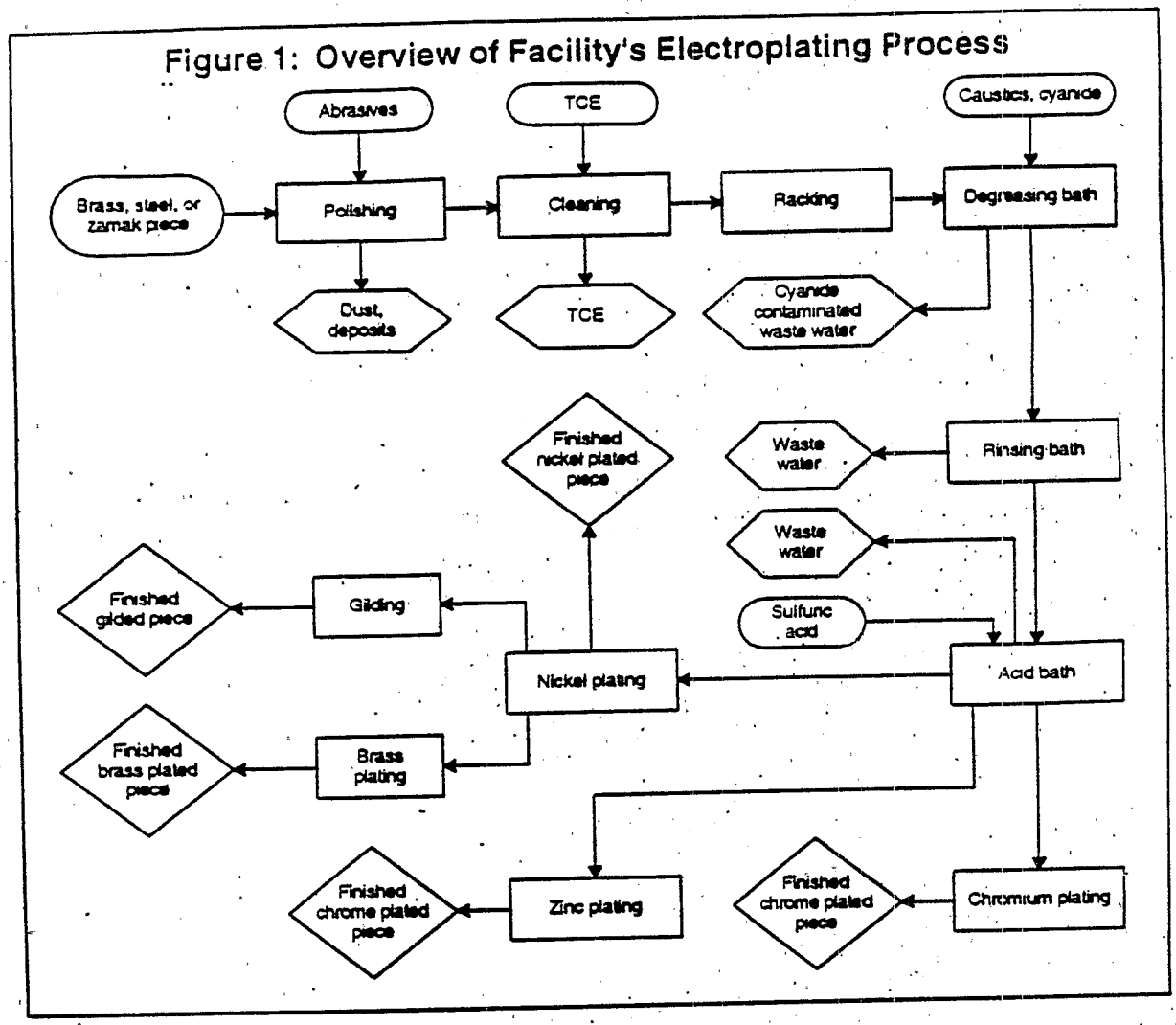
Manufacturing Process

Facility operations can be divided into five main steps: (1) polishing, (2) cleaning, (3) racking, (4) electroplating, and (5) gilding as shown in **Figure 1**.

Parts are first polished. Polishing paste is applied to stationary belt sanders to provide the necessary abrasion. The parts are then polished with the sanders. Dust generated by the polishing process is collected by vacuums connected to each machine.

EP3 is sponsored by the U.S. Agency for International Development.

Figure 1: Overview of Facility's Electroplating Process



Prior to electroplating, many parts are cleaned in a vapor degreaser that uses trichloroethylene (TCE) to remove grease and other impurities. Parts removed from the degreaser are dried with paper towels.

The facility electroplates many different kinds of parts. Several parts are hung on special racks that are constructed specifically to handle the part. Other pieces are plated in baskets that are placed directly in the solutions.

The electroplating line consists of washing tanks, rinsing tanks, and nickel and chrome plating and recuperation baths. A copper cyanide bath is located across from the line and is used to plate zamak before it is plated to nickel and chrome. All plating is manual. Times are not exact, and there is considerable variation in soaking times among different parts and different workers.

Before gilding, parts are rinsed in special rinse baths. They are then immersed in gilding solution for less than a minute.

Existing Pollution Problems

At the time of the assessment, there were a number of pollution problems including (1) polishing debris, (2) the use of organic solvents for degreasing, (3) acid dip contamination, (4) inefficient cyanide electroplating, (5) unnecessary chrome and nickel waste, and (6) excessive water use.

Table 1: Summary of Recommended Pollution Prevention Opportunities

Unit Operation	Pollution Prevention Action and Environmental/ Product Quality Benefit	Cost	Financial Benefit	Payback Period
Polishing -- Option #1	Reduce time between buffing and cleaning	$0	Savings in costs of degreasing	N/A
Polishing -- Option #2	Replace polishing compound with one compatible with aqueous alkaline cleaners	$0	Savings in costs of degreasing	N/A
Polishing -- Option #3	Improve operator performance by purchasing fixtures and jigs; provide training	Undetermined	Savings in costs of degreasing	N/A
Polishing -- Option #4	Reduce compound and wheel use through proper operator practice	$0	$150 - $300 per year	Immediate
Solvent degreasing	Replace this process step with aqueous alkaline cleaner	$5,000	$11,134 per year	< 6 months
Alkaline cleaning -- Option #1	Eliminate cyanide use in cleaning	$0	$895 per year	Immediate
Alkaline cleaning -- Option #2	Improved process control and solution monitoring	< $100	$930	Immediate
Acid Dip – 10% sulfuric	Isolate acids for steel and brass	$0	Quality improvement	N/A
Acid Dip – 10% sulfuric	Improved process control and solution monitoring	$0	$144	Immediate
Acid Dip -- Depassivation of nickel	Eliminate this process step; cleaner is adequate	$0	$672	Immediate
Acid Dip -- Mixed acid stripper	Replace with solutions in smaller tanks; practice segregation and recovery	Undetermined	Reduced treatment	N/A
Copper cyanide	Improved process control and solution monitoring	< $100	Quality improvement	N/A
Cyanide brass electroplating	Improved process control and solution monitoring	< $100	Quality improvement	N/A
Nickel electroplating -- Option #1	Improved process control and solution monitoring	< $100	Quality improvement; reduced solution loss	N/A
Nickel electroplating -- Option #2	Less frequent purification	Already incurred in other options	$4,130 to $5,875 per year	Immediate
Chrome electroplating -- Option #1	Capture and return 100% of dragout to the process solution	$0	Reduced need for treatment	N/A
Chrome electroplating -- Option #2	Improved process control and solution monitoring; porous pot	$500 to $1,000	Could eliminate need to invest in treatment	1 - 2 years
Rinsing -- Effectiveness	Add agitation and sprays; control water use; reduce water use	< $100	$1,728 per year	< 3 months
TOTALS		$5,500 to $6,500	At least $19,783 per year	

Pollution Prevention Opportunities

The assessment identified 18 pollution prevention opportunities that could address the problems identified above, with significant environmental and economic benefits to the facility. Table 1 lists the recommended opportunities for the facility, and presents the environmental benefits and implementation costs for each.

Polishing Debris. As currently performed, the polishing process leaves considerable debris (consisting of a mixture of polishing compound and solids from the polishing wheel) inside the pieces. These deposits cannot be removed by scraping or wiping.

To alleviate this problem, the facility can take several steps. Reducing the amount of polishing compounds used will reduce the amount of debris. Removing visible residue will allow less debris to harden on the pieces. Reducing the time between buffing and cleaning will also allow less debris to harden on the pieces. Lastly, employing a polishing compound that is compatible with alkaline cleansers will improve the efficiency of the cleaning process (along with recommendations outlined in the next section).

Degreasing. The facility currently employs the chlorinated solvent TCE to degrease parts. TCE is highly toxic and chemically reactive, and has been linked to liver cancer and ozone depletion. Parts can be cleaned equally well, or better, through the use of aqueous alkaline cleaners. Thus, the facility can greatly reduce its environmental impact *and* improve product quality by implementing an alkaline cleaning system. Further, the alkaline system is more cost effective than the TCE system. A $5,000 investment will yield savings (from eliminated solvent purchases) of $12,000 per year.

Acid Dips. In this facility's plating process, an acid dip (usually 10 percent sulfuric acid) is used to remove any oxides that may have developed on the brass or steel surface. With time, copper and organic contamination accumulates in the acid bath. If more than 300 mg/l of copper is present in the acid dip, the bath can cause adhesion problems for the steel substrate. Further, copper contamination also impacts the nickel electroplating solution. While the facility utilizes nickel depassivation to remove the copper contamination, it is not efficient, wasting nickel, brightener, and energy.

Separate acid dips for steel and brass substrates will improve the quality of both the steel substrate cleaning, and the nickel electroplating solution, and hence reduce the number of rejects the facility produces. Additionally, by employing tighter process control over the acid dips, the facility will save $816 a year in reduced solution cost.

Inefficient Cyanide Electroplating. Cyanide electroplating cannot be eliminated at this facility because the known non-cyanide alkaline alternatives do not function well in this application. However, improved process control and solution monitoring could enhance product quality, and hence reduce the number of rejects the facility produces.

Unnecessary Nickel and Chrome Waste. Currently, the facility purifies the nickel bath six times per year. By improving process control and purifying the nickel bath only once per year, the facility should save between $4,100 and $5,900 a year from recovered nickel solution.

The lost chrome solution is only valued at $180 per year. However, if 100 percent of this chrome could be captured, the facility would not have to install expensive chrome waste treatment required by the facility's government. A porous pot purification system (priced between $500 and $1,000) is capable of removing the chromium from the waste water. While the expected costs of meeting chromium discharge limits have not been determined, they are sure to be greater than the cost of the purification system.

Excessive Water Use. Waste water is generated in significant volumes from the facility's rinse steps. Some fairly simple changes can be made that will reduce water use by 25 percent. The use of air or solution agitation would increase the efficiency of the rinses, and reduce the frequency of changes. Spray rinses would also be more efficient than the current practice. Lastly, water inputs should be installed with switches that turn off the inputs after a set period of inactivity. For an investment of less than $100, the facility should save $1,728 a year from reduced water usage.

For Further Information

For further information on this assessment or other activities sponsored by EP3, call the EP3 Clearinghouse at (703) 351-4004, send a fax to (703) 351-6166, or on Internet apenderg@habaco.com.

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Pollution Prevention Assessment for an Oil Extraction and Soap Manufacturing Facility

CASE STUDY

What is EP3?

The amount of pollutants and waste generated by industrial facilities has become an increasingly costly problem for manufacturers and a significant stress on the environment. Companies, therefore, are looking for ways to reduce pollution at the source as a way of avoiding costly treatment and reducing environmental liability and compliance costs.

The United States Agency for International Development (USAID) is sponsoring the Environmental Pollution Prevention Project (EP3) to establish sustainable programs in developing countries, transfer urban and industrial pollution prevention expertise and information, and support efforts to improve environmental quality. These objectives are achieved through technical assistance to industry and urban institutions, development and delivery of training and outreach programs, and operation of an information clearinghouse.

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Summary

This assessment evaluated a facility that extracts and refines olive oil and manufactures domestic soap from resulting side products. The objective of the assessment was to identify actions that would: (1) reduce the quantity of toxics, raw materials, and energy used in the manufacturing process, thereby reducing pollution and worker exposure, (2) demonstrate the environmental and economic value of pollution prevention methods to the soap industry, and (3) improve operating efficiency and product quality.

The assessment was performed by an EP3 team comprised of an expert in oil extraction and soap manufacturing and a pollution prevention expert.

Overall, the assessment identified 13 pollution prevention opportunities that could provide first year savings of $420,000 for a one-time investment of $236,000. If implemented, these changes could reduce energy and water use per unit output, reduce contaminated wastewater, and improve product quality.

Facility Background

This facility extracts and refines oil from spent olive oil pressing waste (grignon) for sale as consumable oil. Any oils that cannot be used for consumption are used in the manufacture of soap. The facility operates three eight-hour shifts, employing eighty permanent workers and eighty seasonal workers. Sales exceeded $2.6 million during the 1992-1993 operating season.

The facility is the only company in the area that extracts olive oil from grignon. It represents approximately 30 percent of the national market for oil seed refining and sells about 15 percent of the nation's bar soap used primarily for clothes laundering.

Manufacturing Process

The plant has five main unit operations: grignon drying, oil extraction, recovery of hexane, oil refining, and soap making as shown in Figure 1.

Figure 1: Overview of Facility's Oil Extraction and Soap Manufacturing Process

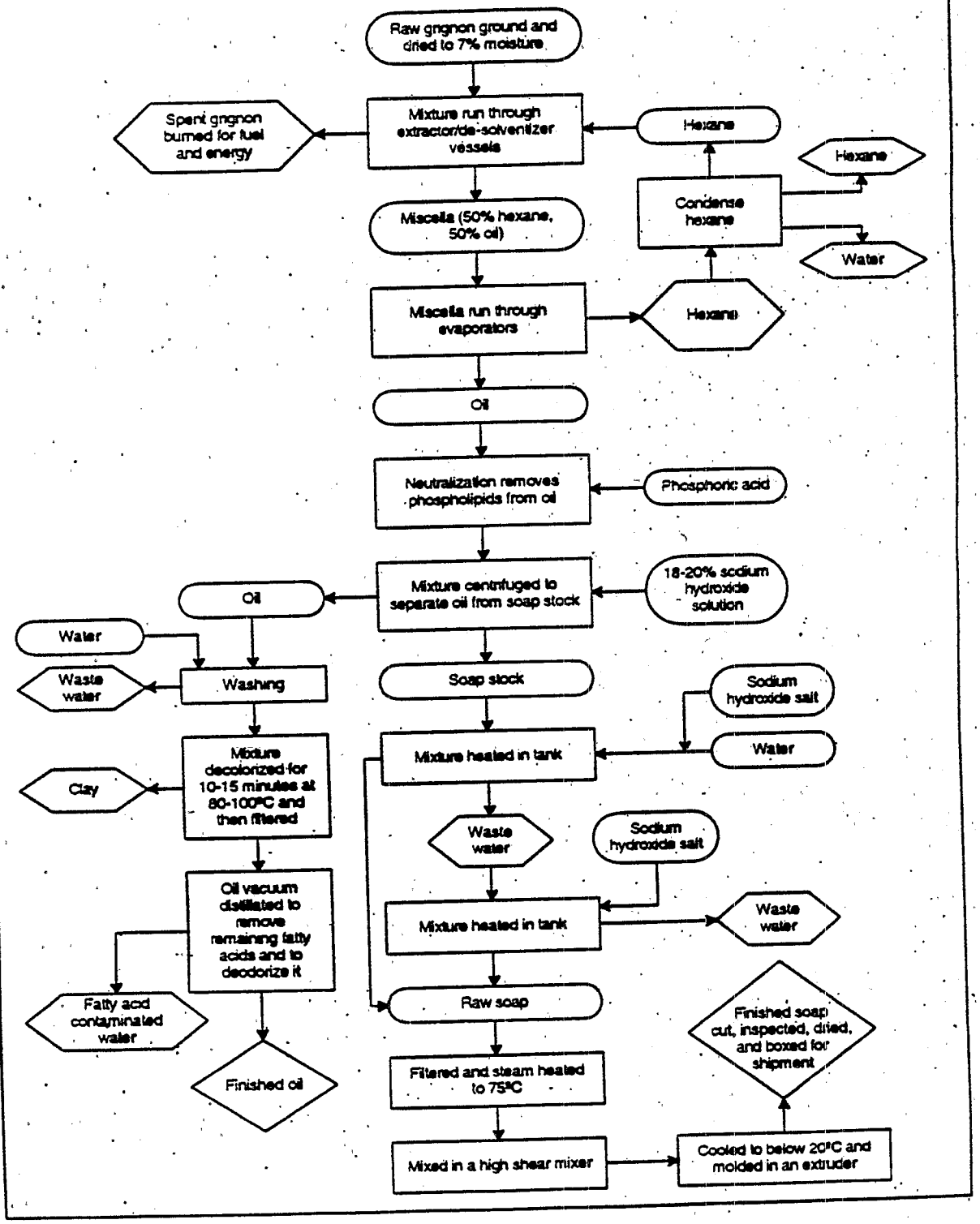

Table 1: Summary of Recommended Pollution Prevention Opportunities

Unit Operation	Pollution Prevention Action and Environmental/ Product Quality Benefit	Cost	Financial Benefit	Payback Period
Grignon Drying	Leave 12 percent residual moisture instead of the current 7 percent - reduces hexane emissions from extraction and particulate and NOx emissions from boilers.	$0	Not directly quantifiable	Not Applicable
Oil Extraction: Hexane Washing	Purchase and install a heat exchanger to pre-heat the grignon and hexane to 60 degrees C - reduces hexane emissions.	$12,000	$213,000 combined	3 months
Oil Extraction: Hexane Distribution	Design, build, and install a hexane distribution manifold for each extractor - reduces hexane emissions.	$24,000	$213,000 combined	3 months
Oil Extraction: Control Hexane Feed Rate	Purchase and install flow meters for each extractor - reduces hexane emissions.	$14,500	$213,000 combined	3 months
Oil Extraction: Vapor Vent Condensing	Purchase a shell and tube condenser to maintain a negative pressure (vacuum) on the system - reduces hexane emissions.	$7,000	$213,000 combined	3 months
De-Solventizing Grignon: Steam Measuring	Purchase and install flow meters and pressure gauges - reduces hexane emissions.	$15,500	$21,000 combined	1.5 years combined
Miscella Distillation: Hexane Evaporation	Purchase and install a heat exchanger to pre-heat the miscella with the hot oil exiting the stripper - reduces hexane air emissions; reduces by 95 percent the volume of hexane contaminated waste water (equivalent to 91,200 kg of hexane and 96,000 cubic meters of water per year).	$8,000	$162,000 combined	About 1 year
Miscella Distillation: Water Cooling	Purchase and install an efficient cooling tower with a fan - same as above.	$58,000	$162,000 combined	About 1 year
Miscella Distillation: Hexane Vent Recovery	Purchase and install a mineral oil absorber - same as above.	$58,000	$162,000 combined	About 1 year
Refining Oil: Neutralization Wash Water Centrifuge	Purchase and install wash water flow controller and meter - reduces waste water volume.	$4,000	$6,000	9 months
Decolonzation	Purchase and install a shell and tube heat exchanger to cool oil before storage - reduces loading on decolorizing system and reduces waste volume.	$7,000	$18,000 combined	Less than 5 months
	Increase the holding time in the bleacher from 15 minutes to 30 minutes - reduces operating wastes and costs in decolorization.	None	$18,000 combined	Immediate
Deodorization	Purchase and install two shell and tube vacuum condensers - reduces fatty acids dumped into the sea.	$29,000	$6,000	5 years
TOTALS		$236,000	$426,000	

Each day, raw grignon is ground and dried in three large hot air rotary dryers to 7 percent moisture before the extraction process begins. The plant operates two systems of six 13-ton extractor/de-solventizer vessels. Each system uses three tanks at a time in series for oil extraction. The grignon is placed in the tanks, and an un-metered amount of hexane is added through the top of the first tank. It extracts oil as it percolates through the grignon. The mixture of hexane and olive oil (called miscella) flows to fill the second tank, overflows, and then fills the third before going to temporary storage to await separation.

The miscella drains from the extractors and is pumped to the evaporators. The evaporators use non-contact steam to evaporate the hexane from the mixture.

The neutralization process separates the oil from the waste, called "soap stock." The neutralized oil is then decolorized and deodorized. The refined oil is sold for consumption.

Oil of insufficient quality for refining and the soap stock from the neutralizing step in refining are used as feed for soap making. In large, steam-heated cylindrical tanks, oil and/or soap stock mix with sodium hydroxide, salt, and a variable amount of water, reacting to form a soap that floats on top of the tank. The wet soap is filtered, steam heated, and vacuum-dried. The soap next passes through a high-shear mixing machine to an extruder where it is cooled and molded into a continuous rectangular solid. The soap bar is cut, inspected, dried, and boxed for shipment.

Existing Pollution Problems

At the time of the assessment, there were a number of pollution problems at the facility, including: (1) excessive hexane emissions during oil extraction, (2) particulate and NO_x emissions from boilers, (3) fire hazard from dried grignon, (4) excessive waste water from hexane evaporation, (5) oil loss to the water stream, and (6) excessive fatty acids dumped directly into the sea.

Pollution Prevention Opportunities

Overall, the assessment identified 13 pollution prevention opportunities that could provide first year savings of $426,000 for a one-time investment of $236,000.

The predicted savings could rise dramatically by including the avoided capital costs for a waste water pre-treatment station designed for pre-assessment operating conditions. Table 1 presents the pollution prevention opportunities in order of unit operation processes.

A number of the recommendations can help the facility produce superior oil for consumption, including (1) cooling the oil from the oil/hexane stripper, (2) adding process flow meters and controls in the refining stage, and (3) upgrading equipment in the deodorizing process. In addition, several of the recommendations will reduce waste water volume by nearly 50 percent, and lower the COD level, hydrocarbon loading, and the amount of solids in the waste water. These changes could help the facility improve its competitiveness in the domestic and export markets.

If implemented these pollution prevention improvements will reduce hexane emissions to the atmosphere and to waste water by over 160,000 kilograms; reduce waste water volume by 96,000 cubic meters per year, reduce particulate and NO_x emissions, and reduce the risk of fire or explosion from hexane.

Implementation Status

The facility has appointed a follow-up team that is working under the supervision of the local EP3 office and a specialized local consultant in order to implement the assessment's recommendations. After setting priorities relative to the implementation plan, actual execution began. The follow-up team is conducting experiments to determine the most suitable way of obtaining 12 percent moisture in the dried grignon and whether such a moisture level yields the desired results, for both oil extraction and combustion purposes. Two shell-and-tube heat exchangers have been purchased to pre-heat hexane (before extraction) to 60 degrees C and are scheduled for installation by the end of September 1994. The follow-up team is screening the market for appropriate flow meters and pressure gauges to ensure better measurement and control of its production operations. The facility has also purchased two NIAGARA filters to reduce the volume of waste water and hexane losses in its deodorizing operation effluents.

For Further Information

For further information on this assessment or other activities sponsored by EP3, call the EP3 Clearinghouse at (703) 351-4004, send a fax to (703) 351-6166, or on internet at apenderg@habaco.com.

CHAPTER 4
FINANCIAL CONSIDERATIONS[1]

4.1 INTRODUCTION

As companies incorporate pollution prevention approaches in their strategic planning, capital investment priorities, and process design decisions, it is vital that they understand both the quantitative and qualitative dimensions of assessing pollution prevention projects. These projects tend to reduce or eliminate costs that may not be captured in cursory financial analyses due to the way the costs are categorized and allocated by conventional management accounting systems. Additionally, pollution prevention projects often have impacts on a broad range of issues, such as market share and public impact, that are difficult to quantify but that can be of strategic importance. Identifying and analyzing all costs and less tangible items is an important step in an evaluation of the potential benefits of a pollution prevention project.

The process for assessing pollution prevention projects, particularly the financial analysis component, fits with the framework of the standard capital budgeting model. However, the process described here, referred to as ***capital budgeting for pollution prevention projects*** expands on and broadens the way capital budgeting is often practiced.[2] The approach described here attempts to address this tendency of financial analyses to omit environmentally-related costs, which typically are lumped into overhead accounts, allocated to products, or overlooked in the cost identification process. This chapter also focuses relatively greater attention on the more qualitative impacts of projects. While this is not the only way to evaluate a project, it does provide an accurate method for ensuring that important benefits and potential impacts are included in the analysis.

Section 4.2 provides an overview of capital budgeting and the key concepts and factors used to perform a financial analysis of a pollution prevention project. Section 4.3 describes how to establish a cost baseline, a necessary first step in any evaluation of pollution prevention projects. Section 4.4 presents a process for evaluating projects against the baseline. Section

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1. This chapter is derived from the United States Environmental Protection Agency document "A Primer for Financial Analysis of Pollution Prevention Projects".

2. The standard capital budgeting model in theory incorporates all changes in operating and administrative costs; anecdotal evidence, however, suggests that in practice many "indirect costs" are excluded.

4.5 introduces the various intangible qualitative costs to be considered in conjunction with a financial analysis to determine the real impact of a proposed project.

4.2 KEY CONCEPTS IN CAPITAL BUDGETING

Pollution prevention can take many forms -- from simple "housekeeping" improvements, which cost little to carry out, to the installation of expensive capital equipment. Although many pollution prevention projects, such as material substitution or process redesign, do not require large outlays for the purchase of equipment, they may require significant engineering expense, create incremental costs or savings, or may require extensive qualitative assessment related to such issues as product quality or employee health and safety. The analytical tools described in this section are applicable to the assessment of most pollution prevention initiatives that fit under the umbrella of the capital budgeting process.

Pollution prevention projects are a recent addition to the list of typical capital budgeting projects and generally include:

- New manufacturing equipment;
- Replacement equipment; and
- Plant expansion and construction.

Capital budgeting is a process of evaluating capital investment options based on a company's needs and analyzing the impact of an investment on a company's cash flow over time. Pollution prevention and other capital projects are justified by showing how the project will increase revenue and how the added revenue will not only recover costs, but substantially increase the company's earnings as well. Financial tools demonstrate the importance of the pollution prevention investment on a life cycle or total cost basis; in terms of revenues, expenses, and profits. Key concepts and factors used in capital budgeting are described below:

Life cycle costing: Also referred to as Total Cost Accounting, this method analyzes the costs and benefits associated with a piece of equipment or a procedure over the entire time the equipment or procedure is to be used. The concept was first applied to the purchase of weapons systems for the U.S. military. Experience showed initial purchase price was a poor indicator of the total cost: costs such as those associated with maintainability, reliability, disposal/salvage value, and training/education needed to be considered in the financial decision making process. Similarly, in justifying pollution prevention, all benefits and costs must be spelled out in the most concrete terms possible over the life of each option.

Present worth: The importance of present worth, or present value, lies in the fact that time is money. The preference between a dollar now or a dollar a year from now is driven by the fact that the dollar in-hand can earn interest. Mathematically, this relationship is as follows:

$$PresentValue = \frac{Future\ Value}{(1 + interest)^{Number\ of\ years}} \qquad P = \frac{F}{(1+r)^n}$$

where P is the present worth or present value, F is the future value, r is the interest or discount rate, and n is number of periods. In the above example $1 in one year at 5% interest compounded annually would have a computed present value of:

$$P = \frac{\$1.00}{(1 + .05)^1} = \$.95$$

Because money can "work," at 5% interest, there is no difference between $.95 now and $1.00 in one year because they both have the same value at the present time. Similarly, if the $1 was to be received in 3 years, the present value would be:

$$P = \frac{\$1.00}{(1 + .05)^2} = \$.86$$

In considering either multiple payments or case into and out of a firm, the present values are additive. For example, at 5% interest, the present value of receiving both $1 in one year and $1 in 3 years would be $.95 + $.86 = $1.81. Similarly, if one was to receive $1 in one year, and pay $1 in 3 years, the present value would be $.95 - $.86 = $.09. As a result, present worth calculations allow both costs and benefits which are expended or earned in the future to be expressed as a single lump sum at their current or present value.

Comparative factors for financial analysis: The more common methods for comparing investment options all utilize the present value equation presented earlier. Generally, one of the following four factors is used:

- ***Payback period:*** This factor measures how long it takes to return the initial investment capital. Conceptually, the project with the quickest return is the best investment.

- ***Internal rate of return:*** This factor is also called "return on investment" or ROI. It is the interest rate that would produce a return on the invested capital

equivalent to the project's return. For example, a pollution prevention project with an internal rate of return of 23% would indicate that pursuing the project would be equivalent to investing the money in a bank and receiving 23% interest.

- ***Benefits cost ratio:*** This factor is a ratio determined by taking the total present value of all financial benefits of a pollution prevention project and dividing by the total present value of all costs of the project. If the ratio is greater than 1.0, the benefits outweigh the costs and the project is economically worthwhile to undertake.

- ***Present value of net benefits***: This factor shows the worth of a pollution prevention project as a present value sum. It is determined by calculating the present values of all benefits, doing the same for all costs and subtracting the two totals. The new result would be an amount of money that would represent the tangible value of undertaking the project.

While firms can use any of these factors, the importance of life cycle costing or total cost analysis makes the present value of net benefits the preferred method.

4.3 ESTABLISHING A BASELINE

The first step in determining the cost of a project is to establish a baseline for the analysis. The "do-nothing" or "status quo" alternative is generally used as a baseline. Then any changes in material use, utility expense, etc., for other options being considered are measured as either more or less expensive than the baseline.

McHugh[3] outlines four tiers of potential costs that should be examined relative to pollution prevention projects:

- Tier 0: Usual costs such as direct labor (wages and benefits, including vacation, holidays, etc.), raw materials used in the production process, and equipment used for production;

- Tier 1: Hidden costs such as monitoring expenses, reporting and record keeping, and permit requirements.

3 McHugh, R.T., "The Economics of Waste Minimization," Hazardous Waste Minimization, McGraw-Hill, 1990.

- Tier 2: Future liability costs such as costs to respond to or clean up accidental releases of contaminants or other incidents, personal injury, property damage, etc.

- Tier 3: Less tangible costs such as consumer response, employee relations, and corporate image.

McHugh's Tier 0 and Tier 1 costs cover typical direct and indirect costs such as engineering, materials, labor, construction, utilities, depreciation, recordkeeping, etc., as well as waste collection and transportation services, raw material consumption (increase or decrease) and production costs. Conventional cost accounting schemes tend to spread Tier 2 costs indiscriminately over all activities, regardless of actual use. Full cost accounting seeks to uncover these costs and properly assign them to specific activities. Often such determinations require an estimate of the amount of a resource that is consumed in the production process (e.g., the amount of electricity used by a piece of equipment).

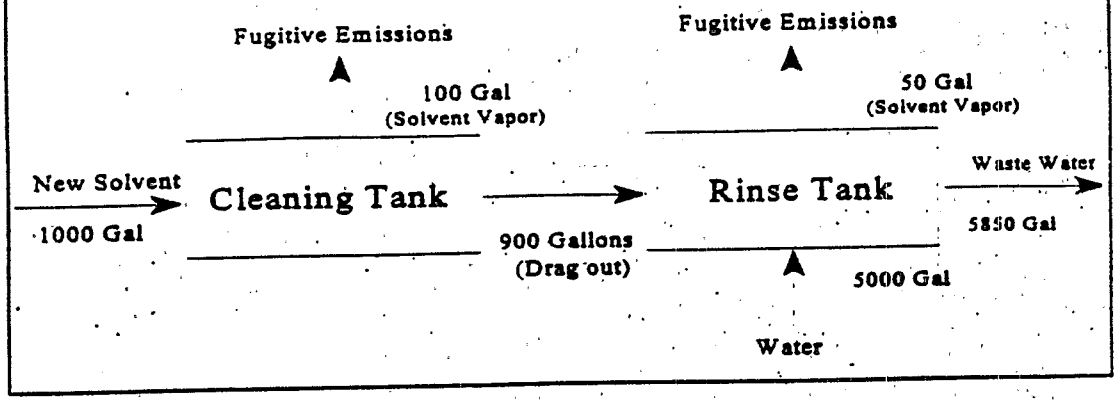
Tier 2 and Tier 3 represent intangible costs, which are more difficult to define and include liabilities that could arise from third party lawsuits for personal or property damages, and benefits of improved safety and work environments. Although it is difficult to accurately account for these intangible costs, they can be most important. Section 4.5 provides additional information on these costs and their role in any analysis of potential pollution prevention projects.

4.3.1 Measuring Baseline Costs

The simplest way to establish a baseline cost is to add up the relevant input and output materials for the process and then compute their appropriate dollar value. This is done by first completing a material balance for the process (see chapter 4 for a discussion on preparing a material balance). **Exhibit 4-1** shows an example material balance.

Once the material balance is completed, determining the baseline cost becomes a simple matter of pricing each input and output and multiplying their volumes by the appropriate unit.

Exhibit 4-1: Annual Material Balance for the Hazardous Solvent



An example using a small electronics firm illustrates how to compute baseline costs. The firm cleans metal parts with a chlorinated solvent that is hazardous to workers. In addition,the wastewater that results from rinsing the parts must be treated before it can be discharged to the environment. For these reasons, the company is considering ways to reduce the volume of wastewater generated. The firm's current costs for parts cleaning are provided in **Exhibit 4-2.**

Exhibit 4-2
Current Costs for Parts Cleaning

Item	*Cost/Unit*	*# Units*	*Cost/Year*
Solvent	$3.25/gal	1,000 gal	$ 3,250.00
Water	$2.10/1,000 gal	5,000 gal	$10.50
Waste Treatment	$2.50/gal	5,850	$14,625.00
		Total Annual Cost	**$17,885.50**

Although the next step would be to examine expected business changes such as business expansions, new accounts, rising prices, etc., for simplicity, the **Exhibit 4-2** costs and volumes are assumed to be constant. This means that the current annual costs will be same in the out-years except for one very important aspect, the time value of money.

Due to the assumptions made regarding constant cost, the $17,885 annual cost shown in **Exhibit 4-2** can be assumed to repeat each year. The present value calculations shown earlier in the chapter enable this annual expenditure to be expressed as a single sum which includes the effects of interest. The first year's cost, assuming the bills are paid at the end of the year, would be the amount of money that would have to be banked starting today, to pay a $17,885 bill in one year. Using a 10% interest rate, the calculation is as follows:

$$P = \frac{\$17,885}{(1+10)^1} = \$16,260$$

This means that if $16,260 is banked at 10% interest, it would provide enough money to pay the $17,885 bill at the end of the year. Similarly, the second, third, fourth, etc., years expenditures can also be expressed in present value. This is done in Exhibit 4.3.

Exhibit 4-3
Present Value Calculations For The Electronics Firm

Year	*Expenditure*	*Present Value*
1	$17,885	$16,260
2	$17,885	$14,781
3	$17,885	$13,437
4	$17,885	$12,216
5	$17,885	$11,105
6	$17,885	$10,096
7	$17,885	$9,178
8	$17,885	$8,343
9	$17,885	$7,585
10	$17,885	$6,895
Total		$109,896

The bottom line to the analysis is that the total cost of the current cleaning system over the next 10 years, given a 10% interest rate, is $109,896 in present value terms. In other words,

$110,000[4] invested today at 10% interest would be sufficient to pay the entire material and disposal costs for the parts cleaning operation for the next 10 years. Hence, any changes to the operation of the firm can now be compared to this $110,000 baseline. Any change which would result in a lower 10 year cost would be a benefit because it would save money; any option with a higher cost would be more expensive and should not be adopted from a financial or economic standpoint.

Simple pollution prevention projects often require little more financial justification than the savings related to Tier 0 or possible Tier 1 costs. However, as a firm gets more sophisticated, the less tangible Tier 2 and 3 costs are likely to become more important. Even if these costs cannot be accurately predicted, in cases where two investment options appear to be financially equivalent, if one is a pollution prevention project, the Tier 2 and 3 consideration can favor that option.

4.3.2 The Effect of Pollution Prevention Projects on Revenues and Expenses

With few exceptions, the goal of most business endeavors is to make a profit. As a result, the costs and benefits cash flows for each option can be related to the basic profit equation:

Revenues - Expenses = Profit

The most important aspect is that profits can be increased by either an increase in revenues or a decrease in expenses. A benefit of pollution prevention is often lowered expenditures and increase profit. The remainder of this section examines the different categories of pollution prevention revenues and expenses.

Revenues: In its simples definition, revenue is money coming into the firm; from sales of goods or services, rental fees, interest income, etc. From the profit equation, it can be seen that a revenue increase leads to a direct increase in profit and vice versa if all other revenues and expenses are held constant.[5]

Because a pollution prevention project can either increase or decrease production rates, it is important to examine the project's effects on revenues. For example, often firms can cut wastewater treatment costs if water use (and in turn the resulting wastewater flows) is

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4 Given the number of assumptions regarding costs, growth, etc., that must be made in these calculations, rounding the calculated values to 2 significant figures is generally wise.

5 The condition of other expenses/revenue being held constant is assumed throughout this chapter.

regulated to non-peak times at the wastewater treatment plant. However this limitation on water use could hamper production.

Consequently, even though the firm's actions to regulate water use could reduce wastewater charges, unless alternative methods are found to maintain total production, revenue could also be decreased.

Conversely, a change in production procedure as a result of a pollution prevention project could increase revenue. For example, a process change such as moving from liquid to dry paint stripping can not only reduce water consumption, but also affect production output. Since cleanup time from dry paint stripping operations (such as bead blasting) is generally much shorter than from using a hazardous, liquid based stripper, it could mean not only the elimination of the liquid waste stream (the direct objectives of the pollution prevention project), but less employee time spent in the cleanup operation. Hence, production, and in turn revenues, could be enhanced through pollution prevention.

Although less common, one more potential revenue effect is the generation of marketable byproducts as a result of pollution prevention efforts. Hence, pollution prevention has the potential to either increase or decrease revenue and profits.

Expenses: Expenses are moneys leaving the firm to cover the costs of operations, maintenance, insurance, etc. The major cost categories for pollution prevention investment consideration and their effects on total expenses are outlined below.

- ***Depreciation expense:*** If the pollution prevention project involves the purchase of capital equipment with a limited life (such as storage tanks, recycle or recovery equipment, new solvent bath systems, etc.), the entire cost is not charged against the current year. Instead a system of depreciation spreads that expense over time. Depreciation expense calculations allocate the equipment's procurement costs (including delivery charges, installation, start up expenses, etc.) by taking a percentage of the cost each year over the life of the equipment.

  For example, if a piece of equipment was to last 10 years, an accounting expense of 10% of the procurement cost for the equipment would be charged each year.[6]

[6] This method is called straight-line depreciation. Although there are other methods available since straight-line depreciation is easy to compute, it is the method of choice in the chapter. Investment projects under consideration at any given time should use the same depreciation method to allow for accurate comparisons of expense and revenue impacts between the alternatives.

- ***Interest expense:*** Pollution prevention investment implies that one of two things must occur; either a firm must pay for the project out of its own cash, or it must finance the cost by borrowing money from a bank, seeking funds from private sources, etc. In the case where a firm pays for a pollution prevention project out of its own cash reserves, the action is sometimes called an opportunity cost, which is discussed later. If cash for the project must be borrowed, there is an interest charge connected with using someone else's money.

- ***Labor expense:*** In most cases, the firm's labor requirements will change due to the pollution prevention project. As pointed out in the dry paint stripping example, this could be a positive effect that increases available productive time, or, if extra man hours are required to run new equipment, perform preventive maintenance, etc., there could be a decrease in employees' productive time.

  When computing labor expenses, the Tier 1 costs could be significant. For example, if a material substitution project eliminated a hazardous input material which eliminated a hazardous waste, there could be a significant decrease in labor required to handle and store the waste in a safe manner. Hence, both direct, Tier 0, expenses and secondary, Tier 1, expenses (e.g., hours per week for preventive maintenance on equipment) can have an effect on manpower costs.

- ***Training expense:*** Pollution prevention may also involve the purchase of equipment or new, non-hazardous input materials which require additional operator training. In computing the total training costs, both the direct costs and the man hours spent in training must be considered as an expense. In addition, any other costs for refresher training or training for new employees, which is above the level currently needed, must be included in the analysis.

- ***Floor space expense:*** As with any opportunity costs, the floor space cost must be based on the value of alternative uses. For example, multiple rinse tanks have long been used to reduce water use in electroplating. If a single dip rinse tank of 50 square feet is replaced with a cascade rinse system of 65 square feet, then the floor space expense would be the financial worth of the extra 15 square feet and must be included as an expense in the financial analysis for the pollution prevention project. Unfortunately, computing this floor space opportunity cost is not always as straightforward as it is with the case of training costs. In instances where little square footage is required, there may be no other use for the floor space which implies a zero cost. In other cases, if the area is currently only being used for storage of extra parts, bench stock,

feed materials, etc., the costs may involve determining the worth of having a drum of chemical or an extra part closer to the operator.

- ***Insurance expense:*** Depending on the pollution prevention project, insurance expense could either increase or decrease. For example, if a heat recovery still was added to a process operation, fire insurance premiums could increase. Or if the use of a hazardous material is eliminated, health insurance costs for employees could go down. Depending upon the premium change (if any), expenses, and in turn, profits could increase or decrease as a result of the pollution prevention project.

Other factors that could affect the decision whether to implement a pollution prevention project include cash flow and opportunity cost. Although cash flow does not have a direct effect on the firm's revenues or expenses, the concept must be considered before undertaking any pollution prevention project, If the project involves procurement costs, they often must be paid upon delivery of the equipment. Conversely, cash recovery could take years. Hence, three things can affect a firm's available cash. First, cash is used at the time of purchase. Second, it takes time to realize financial returns from the project through enhanced revenues or decreased expenses. Finally, depreciation expense is calculated at a much slower rate than the initial cash is spent. As a result of the investment, a firm could find itself cash poor.

Opportunity cost is also important because to the extent a firm uses its cash to purchase equipment for a project, it forgoes the opportunity to use that cash for other investments. As a result, revenues that could have been generated by the cash (e.g., interest resulting from saving the money) should be treated as an expense and reduce the value of the pollution prevention project.

Although it is true that the cash will not be available for other investments, opportunity cost should not be considered as an expense. The opportunity lost by using the cash is considered when the pollution prevention project competes for the firm's funds and is expressed by one of the financial analysis factors discussed earlier (e.g., net value of present worth, pay back period, etc.). It is this competition for a firm's limited funds that encompasses opportunity cost, and opportunity cost should not be accounted directly against the project's benefits.

A minimum rate of return or hurdle rate is often used to express this opportunity cost competition between investments. For example, if a firm can draw 10% interest on cash in the bank, then 10% would be a valid choice for the hurdle rate as it represents the firm's cash opportunity cost. Then in analyzing investment options under a return on investment criteria, not only would the highest returns be selected, but any project which pays the firm a return less than the 10% hurdle rate would not be considered.

Pollution prevention has good investment potential. In reducing or eliminating waste generation and the related disposal/treatment expenses, pollution prevention can have a significant impact on the firm's bottom line. Even in cases where revenues are not generated, reducing the expenses and liabilities associated with managing wastes represents a substantial reduction in overall expenses and an increase in profit.

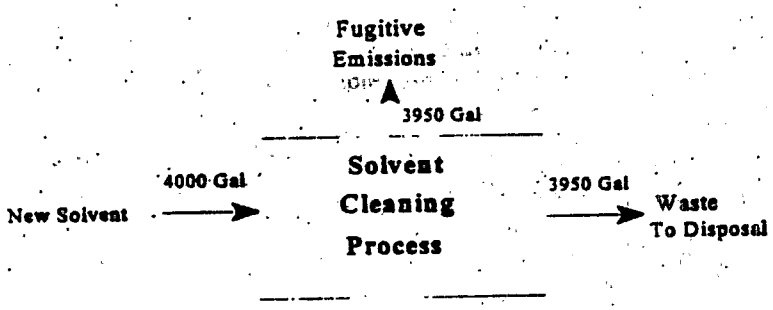
4.4 EVALUATING POLLUTION PREVENTION OPPORTUNITIES

This section describes how to analyze a pollution prevention project. The hypothetical firm introduced in the previous section takes in used parts, cleans them in a dip tank using a hazardous solvent, and applies a new finish. The financial analysis will compare the current solvent cleaning operation with two pollution prevention alternatives: a solvent recycle system and non-hazardous material substitution.

4.4.1 Establishing the Baseline

As indicated in Section 4.3, the first step is to define the baseline cost. Once this is done, it is possible to evaluate the financial effects of any change to business as usual. **Exhibit 4-4** shows the material balance for the current system.

Exhibit 4-4: Baseline Material Balance



Based on the material balance, annual costs can be assigned for the process. The resulting cash flow is shown in **Exhibit 4-5.**

Exhibit 4-5
Baseline Costs

Element	*Rate*	*Annualized Costs*
Procurement Expenses		None
Operations Expenses		
-- Utilities		N/A[7]
-- Operating Expense		N/A
-- Maintenance/Spare Parts		N/A
-- Input Solvent	$3.50/gal	$14,000
-- Waste Disposal	$2.50/gal	$9,875

To express these annual costs in present value terms, a time reference must be selected so that each option can be considered over the same length of time. Since the recycle equipment has an expected life of 10 years, the baseline and both options will be examined over this time period.

For the purpose of illustration, the firm's discount rate (the firm's internal interest or "hurdle" rate) is assumed to be 15%, and the inflation rate is assumed constant at 5% per year. Since the discount rate and inflation rate work against each other (i.e., interest makes your money more valuable over time and inflation makes it less valuable over time), they can be combined. However, for simplicity, they are treated separately in this analysis. All present value computations are made using 15% interest and all expenses are increased at an inflationary rate of 5% per year.

To account for prices that rise faster than inflation, annual real price increases (in excess of inflation) of 1% of the cost of solvent and 4% of the cost of disposal are assumed. In these cases, the cost of solvent increases 6% per year (5% inflation + 1% real price increase) and waste disposal increases 9% per year. Given these assumptions, the baseline expenses for the next 10 years are shown in **Exhibit 4-6**.

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7 These expenses are not applicable for the baseline because it is only necessary to consider increases/decreases when analyzing the options.

Exhibit 4-6

Ten Year Baseline Costs

	Annual Cost		
Year	Item	w/o Recycle	Annual Total
1	New Solvent	$14,000	
	Waste Disposal	$9,875	
			$23,875
2	New Solvent	$14,840	
	Waste Disposal	$10,764	
			$25,604
3	New Solvent	$15,730	
	Waste Disposal	$11,732	
			$27,462
4	New Solvent	$16,674	
	Waste Disposal	$12,788	
			$29,462
5	New Solvent	$17,674	
	Waste Disposal	$13,939	
			$31,613
6	New Solvent	$18,734	
	Waste Disposal	$15,194	
			$33,928
7	New Solvent	$19,859	
	Waste Disposal	$16,561	
			$36,420

Ten Year Baseline Costs			
8	New Solvent	$21,050	
	Waste Disposal	$18,051	
			$39,101
9	New Solvent	$22,313	
	Waste Disposal	$19,676	
			$41,989
10	New Solvent	$23,652	
	Waste Disposal	$21,477	
			$45,099

In many cases, firms simplify these calculations by assuming costs will be constant over the life of the project. If this is the case, then all outyear costs would be same as was done with the **Exhibit 4-5** example.

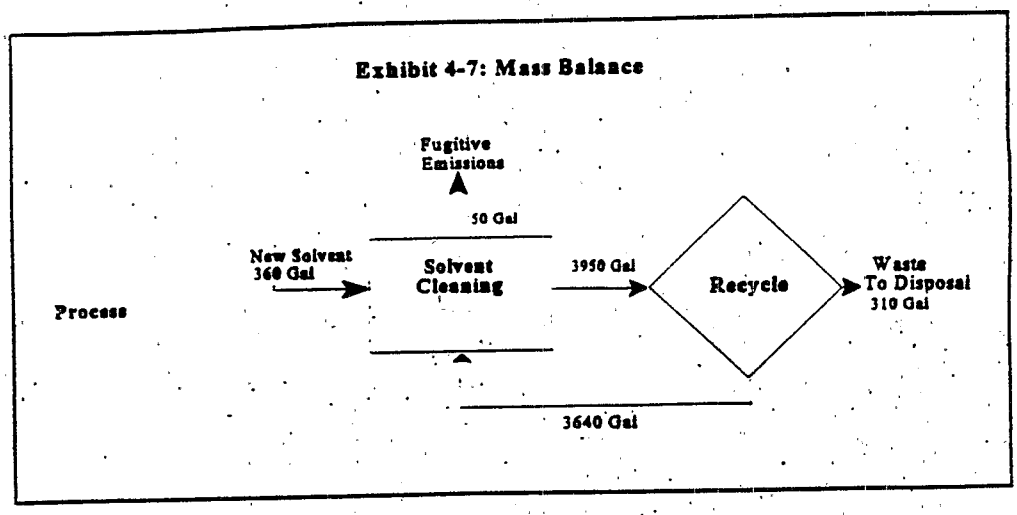
The intermediate step in the financial analysis will be to compare the annual costs of the two pollution prevention options with the annual costs of the baseline process. Then the present value of the annual cost savings (or cost increase) of the options can be calculated. This will be done for the base line and both options simultaneously at the end of the analysis.

The final step will be to sum the present values from each year to obtain the net present value. The net present value represents the quantifiable worth of the project.

4.4.2 Examining The Recycle Option

As before, the first step will be establish the mass balance, as shown in **Exhibit 4-7**. As is the case with many recycle options, a salable by-product is generated (the recycled solvent), but instead of offering the solvent for sale, the firm is using it as an input to offset the cost of new solvent so there is no revenue impact. Further, since the actual cleaning operation has not changed, there should be no change in production rate as result of this option. As a result, there are no revenue impacts to consider.

Exhibit 4-7: Mass Balance



This material balance is converted to a cash flow in **Exhibit 4-8.** As mentioned earlier, the recovery equipment has a life of 10 years. Further, there is no salvage value; the solvent must be chemically treated at the end of year 5 to retain its effectiveness at a cost of $1000; and no additional permits are required to operate or install the equipment.

Exhibit 4-8
Costs for Solvent Recycling

Element	*Rate*	*Base Year Costs*
Procurement Expenses		
Recycle Equipment:		
Tanks, Pumps, Mixers, etc.		$40,500
Installation; Design, Piping, Labor; etc.		$20,000
Contingency (@10%)		$6,000
	Total:	$66,500
Operations Expenses		
Recovery System		
Utilities		$240

Element	*Rate*	*Base Year Costs*
Operating Expense	1hr/day@$20/hr	$5,000
Maintenance/Spare Parts	5% of Capital Cost	$3,325
Input Solvent	$3.50/gal	$1,260
Waste Disposal	$2.50/gal	$775

Other expenses to consider include:

- Depreciation. It is assumed to be straight line, with the procurement costs expense at 10% each year for 10 years.
- Interest. The firm borrowed the capital costs, will make annual payments for 3 years, and must pay 12% interest annually. Note: the principle ($66,500) will be repaid in three equal installments. The interest expense is calculated for each year based upon the current balance. (The actual monies borrowed, or repaid, are neither revenues nor expenses and do not appear in the financial analysis).
- Labor. The equipment requires 1 hour of maintenance per day. This expense ($20/hour) is included in the operations expenses listed above. For simplicity, the wage rate is assumed constant except for cost of living increases due to inflation.
- Training. Training was supplied by the recycle equipment supplier with training on site so there are no direct costs. Three operators must spend 2 hours each learning the operations. Their wage costs are also taken as $20/hour.
- Floor Space. The equipment is relatively compact, will be installed integral to the process, and carries a zero floor space expense.

As done with the baseline, annual costs for the recycling option must also be spread over time as they will actually occur. **Exhibit 4-9** shows the costs, by year, for the 10 year life of the recycle equipment.

Exhibit 4-9
Ten Year Costs for Recycle Option

Year	*Item*	*w/Recycle*	*Total*
1	Interest Expense ($66,500 x 12%)	$7,980	
	Depreciation Expense	$6,600	
	Initial Training	$ 120	
	Operating Expenses		
	(Labor, Utilities, Maintenance)	$8,565	
	New Solvent	$1,260	
	Waste Disposal	$ 775	
			$25,300
2	Interest Expense ($44,333 x 12%)	$5,320	
	Depreciation Expense	$6,600	
	Operating Expenses (5%/yr. increase)	$8,993	
	New Solvent (6%/yr. increase) (360 gal.)	$1,336	
	Waste Disposal (9%/yr. increase)	$845	
			$23,094
3	Interest Expense ($22,166 x 12%)	$2,660	
	Depreciation Expense	$6,600	
	Operating Expenses	$9,442	
	New Solvent	$1,416	
	Waste Disposal	$921	
			$21,039
4.	Depreciation Expense	$6,600	
	Operation Expenses	$9,915	
	New Solvent	$1,501	
	Waste Disposal	1,004	
			$19,020
5	Depreciation Expense	$6,600	
	Operating Expenses	$11,410[9]	
	New Solvent	$1,591	
	Waste Disposal	$1,094	

Year	*Item*	*w/Recycle*	*Total*
			$20,695
6	Depreciation Expense	$6,600	
	Operating Expenses	$10,931	
	New Solvent	$1,686	
	Waste Disposal	$1,192	
			$20,409
7	Depreciation Expense	$6,600	
	Operating Expenses	$11,477	
	New Solvent	$1,787	
	Waste Disposal	$1,300	
			$21,164
8	Depreciation Expense	$6,600	
	Operating Expenses	$12,051	
	New Solvent	$1,895	
	Waste Disposal	$1,417	
			$21,963
9	Depreciation Expense	$6,600	
	Operating Expenses	$12,654	
	New Solvent	$2,008	
	Waste Disposal	$1,544	
			$23,806
10	Depreciation Expense	$6,600	
	Operating Expenses	$13,287	
	New Solvent	$2,129	
	Waste Disposal	$1,683	
			$23,699

Again, these annual costs will be compared to the baseline after all cash flows for the options have been computed.

4.4.3 Evaluating Material Substitution

This option consists of replacing the hazardous solvent used for cleaning in the baseline case with a non-hazardous cleaner which is used in the same manner. The firm has been fortunate to find a cleaning solution which is sewerable and does not require disposal as a hazardous waste. The cost of sewering the 3,950 gallons is assumed to be negligible.

In pollution prevention projects that involve substituting a non-hazardous material for a hazardous material, part of the analysis must consider how well the new product or process works in relation to the current practice. In this example, it is assumed no operational changes are required so production levels can be maintained. However, the cost of the new cleaner is nearly 25 percent higher: $4.60/gal. The first-year costs for implementing this option are shown in **Exhibit 4-10.**

Exhibit 4-10
First Year Costs for the Material Substitution Alternative

Element	*Rate*	*Annualized Costs*
Procurement Expenses		None
Operations Expenses:		
Operating Expense		N/A
Maintenance/Spare Parts		N/A
Input Solvent	$4.60/gal	$18,400
Waste Disposal		$ 00
Training		$120

Other expenses to consider include:

- Depreciation. Since there is no capital expenditure, there is no equipment to depreciate.
- Interest. The company has the cash to absorb the additional cleaner cost without borrowing any additional capital. Hence, there is no interest expense.
- Labor. There is no additional equipment maintenance requirement and the wage rate is again constant except for cost of living increases due to inflation.

- Training. As before, it is assumed that the vendor provides the training and 3 operators spend 2 hours learning how to handle, test, and maintain the new cleaner. Their wage rate is taken as $20/hour (from the previous example).

- Floor space considerations. The current solvent storage capacity for the firm is adequate for the new material.

With the same assumptions regarding cost increases, the annual costs for switching to the non-hazardous cleaner, over the ten year period, are shown in **Exhibit 4-11**.

Exhibit 4-11
Ten Year Material Substitution Costs (5%/Yr. Increases)

Year	*Item*	*Annual Cost*
1	New Cleaner	$18,520
2	New Cleaner	$19,320
3	New Cleaner	$20,286
4	New Cleaner	$21,300
5	New Cleaner	$22,365
6	New Cleaner	$23,484
7	New Cleaner	$24,658
8	New Cleaner	$25,891
9	New Cleaner	$27,185
10	New Cleaner	$28,544

4.4.4 Making the Financial Comparison

With all the annual costs computed, the final comparisons can be made. **Exhibit 4-12** shows the annual baseline costs (from **Exhibit 4-6**) in the first column; columns 2 and 3 show the annual costs for recycle (from **Exhibit 4-9**) and the increase or decrease from the baseline; and finally, columns 4 and 5 show the annual costs for material substitution (from **Exhibit 4-11**) and their associated change from the baseline.

Exhibit 4-12
Annual Cost Comparison

Year	*Baseline*	*Recycle*	*Savings*	*Material Substitution*	*Savings*
1	23,875	25,300	(1,425)	18,520	5,355
2	25,604	23,094	2,510	19,320	6,284
3	27,462	21,039	6,423	20,286	7,176
4	29,462	19,020	10,442	21,300	8,162
5	31,613	20,695	10,916	22,365	9,248
6	33,928	20,409	13,519	23,484	10,444
7	36,420	21,164	15,256	24,658	11,762
8	39,101	21,963	17,138	25,891	13,210
9	41,989	23,806	18,183	27,185	14,804
10	45,099	23,699	21,400	28,544	16,555

If an option's annual costs are less than the baseline, the difference is considered a benefit. Conversely, if the option's annual costs are higher than the baseline (indicated by parenthesis), the difference is considered a cost. So that the two options can be compared, the final steps are to bring each option's costs and benefits back to present value, compute the net difference, and make the financial decision. These calculations are shown in **Exhibit 4-13**. The present value calculation uses the formula from page __ with the interest rate set at 15%. (Recall that 15% was set as the example firm's "hurdle" rate or acceptable internal interest rate).

$$P = \frac{F}{(1+r)^n}$$

Exhibit 4-13
Present Values of the Costs and Benefits

	Recycle Option		*Material Substitution*	
Year	*Difference*	*Present Value*	*Difference*	*Present Value*
1	(1,425)	(1,239)	5,355	4,657
2	2,510	1,898	6,284	4,752
3	6,423	4,223	7,176	4,718
4	10,442	5,970	8,162	4,666
5	10,916	5,427	9,248	4,598
6	13,519	5,844	10,444	4,515
7	15,256	5,735	11,762	4,422
8	17,138	5,602	13,210	4,318
9	18,183	5,169	14,804	4,208
10	21,400	5,290	16,555	4,092
NET PRESENT VALUE		**$43,919**		**$44,946**

4.4.5 Making the Final Decision

In this example, both options display a positive effect on profitability. The two proposals each generate a new benefit compared to the baseline. Likewise, the proposals also meet the firm's internal hurdle rate (15%), because their present values are positive when calculated using a 15% discount rate.

The final task is to select between the two options. In that they have the same present worth of new benefits, they are equivalent under the financial criteria. However, as previously discussed, when projects appear financially equivalent, consideration of other tier costs can swing favor toward a particular option. The above analysis considered only Tier 0 and Tier 1 costs. Eliminating the use of hazardous solvent limits the potential intangible Tier 2 and 3 costs for cleanup, lawsuits, etc. Given these considerations, and the fact that material substitution is higher on the pollution prevention hierarchy, the material substitution option is clearly the most beneficial option.

4.5 THE IMPORTANCE OF CONSIDERING INTANGIBLE COSTS

As stated earlier, Tiers 2 and 3 include less tangible considerations such as effects on product quality, productivity, public image, market share, stakeholder relations employee health and safety, and financial liability which, while very important, are more difficult to account for. This section provides some guidance on addressing these factors and highlights their significance. Some of these issues, such as public impact, tend to be straightforward. The impact of a pollution prevention project is presumed to be positive, and the question is "to what extent and how quickly". Other issues, such as product quality, arise as (possibly) unintended consequences of the effort to reduce waste. In these cases, pollution prevention changes may have either a positive or negative impact. After determining the nature of the impact, it is important to consider ways to restructure the project to minimize unwanted consequences.

Product Quality. Customers are increasingly demanding environmentally-friendly products yet are rarely willing to surrender price or quality to achieve their demands. A pollution prevention project that is detrimental to product quality (e.g., through inferior material substitution or process changes that fail to meet design specifications) will rapidly translate into lost sales or into increased costs of rework and downtime. Alternatively, a pollution prevention initiative may improve quality and/or enable a product to be marketed as "green," a benefit that may engender greater market acceptance and boost sales. Concerns about impacts on quality need to be addressed up-front by:

- Conducting sufficient engineering review and testing before specifying equipment or changing a product or process;
- Securing guarantees from the vendor;
- Planning for incremental ramp-up of production using the new process or new material; and/or
- Securing customer feedback to determine what impact changes may have on consumer acceptance.

A project proposal should include a section on product quality that outlines possible concerns and describes in detail the measures that have been taken to anticipate, address, and resolve these concerns. Almost nothing can kill a project faster than the fear that it may harm product quality, and the justification package must allay those fears as much as possible.

Impact on productivity/capacity: Process changes resulting from implementing a pollution prevention project could potentially increase or decrease the productivity and/or effective

capacity of a plant. For example, an aqueous degreaser may reduce solvent use but may require a longer cycle time to remove contaminants effectively, thereby increasing throughput time and lowering productivity. On the other hand, installing new equipment to add a parallel process line might both reduce solvent use required for product changeovers and increase productive capacity. As with determining effects on product quality, engineering review of new process specifications is crucial to assess a project's effect on production. Thorough review should enable the impact on productivity/capacity to be estimated with sufficient accuracy to permit its inclusion in the financial analysis. If this is not possible, the potential impacts should be explored and described qualitatively, perhaps using sensitivity analysis to quantify their effect.

Public image. Having an "environmentally-correct" image continues to become more important. Many companies now tout their "green" credentials. For example, Sun Oil Company recently launched a major ad campaign to publicize its signing of the CERES (formerly Valdez) principles, the first Fortune 500 company to do so. While a good public image is important for its own intangible reasons, its value is increasing as the link between a company's public image and market acceptance of its products becomes stronger. Image can be especially important to a company that has suffered a poor environmental reputation. For example, Polaroid, which had received a lot of negative publicity for its toxic discharges, now promotes its pro-active strategies of pollution prevention and recycling. The company has received widespread recognition for many of its innovative environmental programs.

Although almost any pollution prevention project can bolster the environmental record of a business, one that directly addresses publicly-recognized problems can be especially valuable. If a proposed pollution prevention project eliminates a source of bad publicity, such as the discharge of effluent that discolors a waterway, the public relations benefits of the project should be strongly emphasized in the justification package.

Market share (i.e., consumer acceptance). Numerous surveys have documented the trend of green consumerism, and companies have responded by emphasizing environmental attributes in new product development. The growing inclination of consumers to buy "green" refers to purchases of products or services that are environmentally-benign or that are offered by companies with good environmental records. A pollution prevention project that "creates" a green process or product may have a significant impact on sales, depending upon customer demand. A project justification proposal could promote the value of this factor by including survey data related to the particular industry or product type. Additionally the report could show how a specific product or company, in a similar situation or industry, either gained market share after emphasizing its green qualities or lost market share due to a poor environmental record. To further demonstrate the significance of this issue, developing computer-generated scenarios based on experiences of similar companies could be valuable in demonstrating how even small impacts on market share can generate large returns on the bottom line.

Stakeholder relations. The term "stakeholders" can broadly include almost any person, group or organization with which a business has contact: employees, stockholders, lending institutions, customers, suppliers, surrounding communities, and others. Though small, privately-held firms may not be as susceptible to shareholder pressure as large corporations, they may be equally or more sensitive to the interests of such other stakeholders as the surrounding community and employees. For businesses in small towns where they are one of the major employers, many of these interests overlap. Benefits of a pollution prevention project may affect relationships with these groups in different ways, as detailed in some of the other issues (public image, employee health and safety, market share). Generally, most firms place importance on the value of being recognized as a good neighbor.

Employee health and safety. Improving working conditions can have substantial short and long-term benefits, including lower worker compensation rates due to safer conditions, lower health care payments, increased productivity, and reduced absenteeism.

Pro-active environmental strategy. Environmental regulations in Egypt and elsewhere show a clear trend toward increasingly stringent limitations for contaminations in air emissions, wastewater, and solid waste. Companies that incorporate these anticipated tougher levels in their strategic planning will have advantages over those companies that continue to avoid the requirements. Pollution prevention projects have the ability to position a company to meet or surpass projected future toxic use and discharge limits. A strong argument for a pollution prevention project is its capacity to alleviate such unknown factors as purchase price, waste disposal costs, or new health issues, that accompany the use of substances known to be environmentally damaging.

Financial liability. Financial liability can be associated with storage, transportation, and disposal of wastes; property damage associated with the misuse of wastes or materials; civil actions; or fines or penalties imposed by government entities. Although reducing liability can be one of the most significant advantages of a pollution prevention project, this benefit is usually difficult to characterize and thus may be "underweighted" in a project assessment.

Companies, environmental consultants, the academic community, and others have developed a variety of methods that attempt to characterize potential liability risk. These range from precise projections of financial exposure based on historical data of actual occurrences to current efforts to use fuzzy logic to translate managers' qualitative responses into quantitative assessments. As no method has gained wide acceptance and many are complex and require considerable time and expertise to employ, it is beyond the scope of this chapter to describe their design or use in detail.

4.6 CONCLUSION

The key point to remember is that firms are in business to make a profit, and pollution prevention can be critical to profitability. In the past, environmental expenditures were seen as pure cost sinks with no payback potential. It is becoming apparent that in the realm of pollution prevention there are a number of areas where expenditures can be cut significantly. One study of waste reduction projects showed that in 29 cases that included data on payback period, over 80% had payback periods of less than 3 years.

There is no doubt that environmental management can make a difference in reducing accompany's expenses. The task becomes one of selling improvements in the expense side of the profit equation. Reducing an expense is as effective as increasing revenues when it comes to profit.

The final considerations in justifying pollution prevention investments are the Tier 2 and 3 intangible costs. Many types of projects can affect revenues, expenses, and/or cash flow, but pollution prevention projects are relatively unique in their additional positive effects. Although difficult to express in concrete financial terms, both environmental compliance and pollution prevention can have far ranging benefits in terms of reduced long term liability, customer relations, public goodwill, and employee morale. While these factors may not serve to justify the investment in a project by themselves, they must enter into the analysis.

This chapter has introduced the basic financial tools and described a preference for using Net Present Value as an appropriate method of financial comparison. Suggestions were made on what types of costs should be considered in evaluating pollution prevention projects, and how those costs should be calculated over the project lifetime. An example case study using an industrial process and two pollution prevention options illustrated the key concepts presented in the chapter. Finally, the financial results of the case study were evaluated and the meaning of those results was discussed.

In conclusion, this chapter presents financial tools and a suggestion of other less tangible benefits which can be used to justify pollution prevention projects on an equal basis with other funding requests.

CHAPTER 5
IMPLEMENTATION[1]

5.1 INTRODUCTION

If pollution prevention is such a great thing, why doesn't it just happen? Plenty of case studies show it is beneficial to industry, environment, and people. However, not all companies have found pollution prevention cheap or easy.

Pollution prevention is a complex subject ranging from small changes in operating practices to massive, research-driven endeavors to create new products and processes. For the purposes of this manual, implementation of pollution prevention will mean incremental changes to existing technology. In this context, incremental change means the substitution of one or two steps in a production process; it may also mean changes in the relationships between production steps. Examples of this type of pollution prevention implementation might include changes in a washing step or redesigning the process to eliminate the need for washing altogether. Eliminating chlorofluorocarbons and saving energy by replacing a refrigeration process with a heat exchanger that can exploit waste cooling from another part of the process would likewise be an incremental change.

For these incremental changes, three decision-making stages are critical:

- Identifying a pollution prevention opportunity;
- Finding a solution appropriate to that opportunity; and
- Implementing that solution.

The first two stages above have been addressed in chapters 4 and 5. Implementation, more than the other stages, is a function of organizational elements. It is useful to examine how three important aspects of an organization - its culture, its ability to process information, and its politics - affects implementation. This chapter highlights the importance of thinking of pollution prevention as a social, rather than simply a technical activity.

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1 This chapter is derived from "Corporate Obstacles to Pollution Prevention", by Peter Cebon.

5.2 POLLUTION PREVENTION: INSIDE THE ORGANIZATION

What makes pollution prevention difficult in practice? The question can best be answered by first considering a second question, "How is pollution prevention different form end-of-pipe pollution control?" A key difference between the two is that pollution prevention opportunities are embedded deep within the plant and are tied to very specific physical locations. To determine whether a particular solution is feasible, people need a very thorough understanding of the way the plant works. This kind of understanding does not come from design drawings but from the uses and working idiosyncracies of the individual pieces of equipment.

Pollution control devices, on the other hand, are physically quite separate from the rest of the production process. All that is necessary to understand them is the composition of the material coming out the pipe. Because that tends to be the same from one plant to another, the solutions can be relatively independent of the process. One example: Despite different makes and ages of conventional boilers, different control systems, different histories, and different operating strategies, a scrubber is always a viable emissions control strategy for high-sulfur, coal-fired power stations.

5.2.1 How An Organization's Culture Affects Implementation of Pollution Prevention Opportunities

Organizations tend to recruit people who think in a way compatible with the organization's view of the world, or else socialize them to think that way. They train, reward, and punish employees to reinforce the organization's beliefs, and they allocate resources in accordance with those beliefs.

If an organization makes a cultural assumption that technical expertise is the only really valid form of knowledge and, therefore, that knowledge built from hands-on experience has very little value outside of day-to-day operations, people in such a company are likely to make at least two kinds of errors. First, engineers who are reasonably - but not intimately - familiar with the process may conclude that there are no pollution prevention opportunities because they can't see them. Second, the company may call on technical experts to identify opportunities comparable to those found in many case studies. Not surprisingly, the team may not find many conclude that they don't exist (the Ford Case presented in section 4.4 provides an example of company engineers outperforming the technical experts in identifying pollution prevention opportunities).

5.2.2 How an Organization's Ability to Process Information Affects Implementation of Pollution Prevention Opportunities

Other important cultural beliefs also affect companies' behavior regarding pollution prevention. Consider the way people conceptualize the production process. Do they think of it in terms of technology or people? How do they see their jobs and the jobs of others? Do they look for opportunities to improve things or wait for things to go wrong? Finally do they see unusual events as problems to be solved or opportunities to get even deeper insights into the way things work?

Pollution prevention presents a different information processing problem because it requires people to understand more than the intimate details of the production process; they must also understand the technical possibilities. Such specialized information is generally carried into the organization by technical specialists or vendors. Such information is, for the most part, accessible only to people with the skills and communications links to get and understand it.

Pollution prevention solutions, then, require a nexus between two very dissimilar types of information: contextual and technical. The organizational problem lies in bringing the two together. This is notoriously difficult because they tend to be held by different actors in the organizational cast. As mentioned above, the engineers and technical consultants are unlikely to find opportunities and solutions.

Instead of looking to individuals, combinations of personnel can provide the organizational answer. The production operators -- the people who turn the knobs and run the process -- and production engineers the people who help solve technical problems and design and implement changes in the production technology -- could work together to find solutions. While the operators know exactly where the possibilities are, they rarely have the skills to realize them or knowledge of the variety of available solutions. Together with production engineers, however, they have all the information. And, sometimes, the production engineers have good enough relationships with the operators to find the problems and the skills and contacts to get the technical information to determine solutions.

Suppose, then, that a pollution prevention manager wants to get engineers and operators working together. This can be intensely political because of competition from numerous other managers. Production engineers and operators generally report to production supervision, and most of their time is taken up with immediate production issues. The engineers must understand and remedy the day-to-day crises, ensure the product is up to standards, deal with the latest spill, make sure people work safely, and do a myriad other jobs. Operators spend most of their time actually running the plant. The pollution prevention manager competes for their remaining time along with the safety, diversity, energy, quality, and training managers. All these managers have top management's endorsement, but that generally amounts to permission to compete, not to succeed.

5.2.3 How an Organization's Political Structure Affects Implementation of Pollution Prevention Opportunities

The pollution prevention manager's solution requires the engineers and operators to work together. For that to happen, both groups must be amenable. In many American plants, engineers have been young, they have lacked the interpersonal skills to solicit and obtain good help from operators, and they have not fully appreciated the operators' skills and knowledge. The operators, on the other hand, have been older and are not necessarily willing to share information with the newest young engineer.

Even when the pollution prevention solutions are identified, resources such as capital and people are allocated by intensely political processes. Largely because pollution prevention projects are so often deeply embedded in the technology of the plant, assessing the return on a pollution prevention investment may be difficult. This is important because, in many companies, discretionary capital is scarce and money for new projects is hard to come by. Unless the true costs and potential profitability of pollution prevention opportunities can be properly assessed, these projects are at a disadvantage in competition with other projects for discretionary resources.

In sum, rather than being simple, as many case studies might lead one to believe, pollution prevention is often quite difficult to put into practice. But these barriers are not insurmountable. There are many encouraging case studies. A number of companies have managed to overcome existing barriers and find cost-effective pollution prevention solutions to their environmental problems. The case study presented in section 5.3 illustrates how Ford Motor Company has overcome many of these problems.

5.3 CASE STUDY: POLLUTION PREVENTION AS CONTINUOUS IMPROVEMENT AT FORD MOTOR COMPANY

5.3.1 Introduction

Seeing the benefits of preventing waste at the source, Phil Lawrence of Ford's Plant Engineering Office decided to develop a pollution prevention[2] program that could be implemented at Ford plants worldwide. To achieve this, measurables had to be defined, a

[2] Many terms exist for pollution prevention. They include waste minimization, waste reduction, and total quality environmental management (TQEM). Because the intent of these various programs is the same (only the way of affecting it is different), the term pollution prevention will be used in this case for clarity. TQEM can be viewed as the employment of TQM tools to pollution prevention issues.

pollution prevention methodology had to be developed, and importantly, senior management had to understand the need for and benefits of such a program.

Lawrence knew that waste prevention programs could result in the following:

1. Reduced operating costs. These arise from the more efficient use of resources and raw materials, reduced maintenance requests, and reduced waste hauling and disposal costs.

2. Improvement in the environment. The environmental impact caused by plant operations will be lessened, and an "environmentally conscious" production process may be an important requirement for many customers.

3. Improved quality. This is a natural outcome of an analysis of the manufacturing process. As the process becomes better understood, it is easier to identify opportunities.

4. Safer workplaces. While this is especially true if any of the waste materials are potentially toxic, it is also important for astute management of other materials such as oils, detergents, and packaging products. Improvements in worker safety result in a better work environment.

5. Compliance with regulations. As federal and local regulations dealing with pollution and worker safety become continually more strict, the company should aim not only to meet or exceed these regulations, but to develop and implement processes and procedures that reduce their implications within Ford plants.

With these benefits in mind, Lawrence set out to develop an aggressive pollution prevention program.

5.3.2 Background

In 1990, Ford's corporate Waste Minimization Directive was revised to focus primarily on pollution prevention. Workshops, seminars, and an action plan for implementing the program had been provided to all manufacturing operations throughout the company. Major issues surfaced at manufacturing plants, however, that inhibited implementation of the program. These were the time required to acquire data on process information, and a reluctance to authorize "up-front" money and/or human resources for "potential" opportunities. To acquire management buy-in and demonstrate the efficacy of a pollution prevention program (both in waste reduced and dollars saved), Lawrence saw the need to develop a pilot project. The results of this project along with the procedures developed would be used to structure a

quality-oriented company-wide pollution prevention program. To assist in the initial "pollution prevention opportunity assessment" and reduce the inhibitors to the program, Lawrence contracted a pollution prevention consultant.

The Livonia Transmission Plant was selected for the study, and funding for the project was provided by Ford's Research Staff. Lawrence hoped that Ford personnel would learn the data collection and evaluation techniques from the consultant, and then apply them to other plants. The Livonia Assessment Team (LAT) was established with representatives from the consultant and various levels of Ford (see **Exhibit 5-1**).

The Livonia Transmission plant is located in Livonia, Michigan, west of Detroit. Livonia's production in 1991 was over 1 million transmissions. Two types of transmissions details the plant layout. Upon completion, these transmissions are sent to Ford assembly plants where the AODE goes into Broncos, F-150s, E-150s, Crown Victorias/Grand Marquis, Thunderbirds, Cougars, and Mustangs, while the AXOD is installed into Tauruses, Sables, and Lincolns. The transmission plant is part of the Transmission and Chassis (T&C) Division of Ford. T&C is in turn part of Powertrain Operations. Staff support is provided by members of the Environmental and Safety Engineering Staff's Environmental Quality Office.[3] Additional support comes from the Research Staff.

5.3.3 The Livonia Project

The pollution prevention opportunity assessment took place between October 1991 and February 1992. Livonia Plant representative, John Connor, coordinated the Livonia Assessment Team's work in the plant. A large part of the team's efforts were spent identifying and gathering relevant data. Unlike production and/or product quality data which are often very detailed and easily available, data pertaining to wastes are widely dispersed about the plant, and often unavailable to the level of detail needed for study. For example, the purchasing department is responsible for material input data, the waste water treatment plant handles waste water data and the environmental engineer (in this case, John Connor) handles manifested toxic waste.[4] Because specific departments are not responsible for information on the quantity of wastes leaving their management area, some data is not routinely gathered. As a result, assumptions and extrapolations are a necessary part of the assessment. **Exhibit 5-2** shows an example calculation.

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3 As of this writing, the Plant Engineering Office's personnel and responsibilities have shifted to the Environmental Quality Office.

4 United States environmental regulations require toxic wastes to be manifested (or documented) upon removal from the site. The paperwork involved represents a large part of the environmental engineer's responsibility.

After five months of data collection and detailed plant and process evaluation, the team provided initial waste prevention opportunities of 4,000,000 lbs. with an annualized value of $1.2 million. These wastes included solid and water waste as well as toxic waste. **Exhibit 5-3** provides a list of these initial recommendations. These results quickly came to the attention of the plant management and an internal Livonia Transmission team was developed to verify the results and make the warranted process improvements. The plant personnel discovered several opportunities beyond those realized by the initial team (20,000,000 lbs/year, saving $8.2 million/year). **Exhibit 5-4** displays a summary of the ongoing recommendations.[5] The specifics of these opportunities will be discussed in the next section.

5.3.4 · Waste Prevention Opportunity Examples

Listed below are the thirteen waste prevention opportunities identified by the consultant and Ford personnel. In some instances, the Ford engineers improved upon the consultants suggestions, in other they came up with innovative solutions of their own. In still other cases, they simply demanded more of outside contractors or demanded more of their own operations personnel.

5 As of December 1992, several of the projects are still under management review.

1. OPPORTUNITY:	**Collect fluids on AODE test stands**
WASTE GENERATED:	Transmission fluid
WASTE PREVENTED / YEAR:	20,000,000 lbs.
SAVINGS / YEAR:	$4,000,000
IMPLEMENTATION COST:	Not applicable[6]
IMPLEMENTATION TIME:	3 months
PREVIOUS PROCESS:	**Faulty reclaim**

Departments 306 and 307 both test AODE transmissions. These Departments access a Central System for transmission fluids. Large quantities of "red" fluid were showing up at the waste water treatment facility, and a root cause analysis pointed to Departments 306 and 307. First, there was considerable leakage in the reclaim system's piping. Secondly, degraded screens and filters caused the fluid to overflow the system.

PROCESS IMPROVEMENT: **Repairs and maintenance**

The leaks were repaired, and the screens and filters were repaired or replaced. Further, screens and filters were put on a maintenance schedule to prevent future overflows. These adjustments are expected to save Livonia $4,000,000 per year in reclaimed transmission fluids.

2. OPPORTUNITY:	**Collect fluids on Test Stands**
WASTE GENERATED:	Transmission fluid in water
WASTE PREVENTED / YEAR:	20,000,000 lbs.
SAVINGS / YEAR:	$4,000,000
IMPLEMENTATION COST:	$288,500
IMPLEMENTATION TIME:	4 months

[6] Implementation costs relate to additional funding related to completing the project. As the process improvement can be made within the existing budget, there is no implementation cost associated with this opportunity.

CURRENT PROCESS: **Trans fluids to waste treatment**

It has been estimated that at least 270,000 lbs. of torque oil from Department 454 alone and 11,000,000 lbs. of transmission fluid from Department 406 alone are lost to waste treatment each year. Some departments are set up to reclaim and recycle fluids; however, equipment does not always work as specified. For example, in Department 406, oils collected from the floor drainage system are pumped through a Hilco Oil Reclaimer. However, this reclaimer cannot provide continuous treatment of oil with high levels of water in it. It is estimated that inefficient oil reclamation costs Department 454 $175,425 per year.

PROCESS IMPROVEMENT: **Portable oil reclamation system**

In Department 406, the apparent solution was to "Activate AXOD reclaim unit." This involved replacing the float control valve and installing water removing filters on the reclaim unit. Upon further investigation, it was determined that the reclaimer was obsolete — its outdated design made it impossible to repair.

The present proposal, which is under evaluation, calls for an automatic, portable oil reclamation system that can be used in several departments. The system requires holding tanks in the various departments to maintain the oil until the reclaimer is available. The oil can then be processed through the reclaimer which will remove water, dirt, dissolved gases, and volatile impurities.

For Department 406, the reclaiming system is expected to save $167,054 per year in recycled transmission fluid, waste treatment deterred, maintenance, and filters. Extrapolated to the whole plant, the reclaiming system should save Livonia $4,000,000 a year.

3. OPPORTUNITY:	**Capture carry-off oil**
WASTE GENERATED:	Transmission fluid in water
WASTE PREVENTED / YEAR:	4,000,000 lbs.
SAVINGS / YEAR:	$1,000,000
IMPLEMENTATION COST:	$7,000 (prototype)
	$600,000 (plant wide)
IMPLEMENTATION TIME:	1 month

CURRENT PROCESS: **Dump to waste treatment**

Departments 306 and 307 contain transmission test stands. Currently, test transmission fluid is dumped to a subterranean trench where it goes to a sump that directs it to the plant's waste water treatment facility. It is estimated that up to a gallon (7.5 lbs.) of fluid per transmission tested ends up in waste water treatment.

PROCESS IMPROVEMENT: **Pump back to Central System 330**

A procedure change would be implemented to collect the carry off oil that drips from the test transmissions. First, the oils would be drained from the collection pan on the transmission carrier. The oil would then be pumped through a treatment system that will dehydrate the substance. Lastly, the oil would be pumped back through Central System #330 for reuse. The capture system would be prototyped in Departments 306 and 307 with successful performance resulting in a plant-wide implementation. Savings in reclaimed transmission fluid in Departments 306 and 307 is expected to approach $1,000,000 per year.

Among the issues affecting the implementation of this process improvement is the use of reclaimed transmission fluid in transmissions shipped as product from the facility. At question is the public impression of buying new transmissions containing reclaimed oil.

4. OPPORTUNITY:	**Implement oil tracking system**
WASTE GENERATED:	Hydraulic oil
WASTE PREVENTED / YEAR:	2,467,213 lbs.
SAVINGS / YEAR:	$880,000
IMPLEMENTATION COST:	To be determined
IMPLEMENTATION TIME:	3 months

CURRENT PROCESS: **Tracking number of oil adds to a machine**

Using PFIS (Plant Floor Information System), it is currently possible to report when oil is added to a process machine. However, several limitations result from the current process:

-Some oilers do not record oil adds in PFIS.
-Only oilers report oil adds to PFIS (not operators).
-The amount of oil can not be recorded in PFIS (it must be estimated).
-Run time is not recorded in PFIS (does the machine leak only when operating or all the time?).
-Oil usage by department is very difficult to determine.
-Direct piped tanks do not have automatic shutoffs (if technicians are pulled to another job they overflow).
-Most drops and oilers' trucks do not have meters to determine amount of oil added, and many of the meters that do exist are non-functional. With the current reporting mechanism it is extremely difficult to track wasted oil let alone minimize it.

PROCESS IMPROVEMENT: **Tracking amount of oil added to a machine**

Rectifying the limitations identified above will enable Livonia to better track and thus minimize waste hydraulic oil. A preliminary pareto chart of the 21 top dollar hydraulic oil users pointed to a yearly oil usage of 287,664 gallons of oil for those 21 machines alone. Roughly 2/3 of this amount is considered excessive. Thus the Livonia engineer sees a savings close to $200,000 for these 21 machines alone. Extrapolated to the entire plant, the Livonia engineer thinks the $880,000 figure is attainable.

To achieve this, functionality must be added to PFIS that allows all oil adds and the amount of those adds, along with the time of the add to provide the necessary tracking information.

Reporting functionality that tracks oil usage by department will also be beneficial. To determine the amount of oil added, meters must be installed on both the oilers' trucks and on direct drops. The installation of automatic shutoff mechanisms will immediately reduce some wasted hydraulic oil. And lastly, with the functionally robust reporting procedures in place, Livonia engineers will be able to effectively identify and rank the largest oil users. With this information, they will be able to repair those machines that provide the largest cost savings for the plant.

5. OPPORTUNITY:	**Reclaim rinse water in Anodizer room**
WASTE GENERATED:	Rinse water
WASTE PREVENTED / YEAR:	192,720,000 lbs.
SAVINGS / YEAR:	$539,419
IMPLEMENTATION COST:	$278,500
IMPLEMENTATION TIME:	3 months

CURRENT PROCESS: **Rinse water to waste treatment**

Currently, all rinse water systems in Department 469 are supplied by city water. Acids used in process along with this water are dumped to waste treatment.

PROCESS IMPROVEMENT: **Recycle rinse water**

A reverse osmosis recycling system has been specified by plant engineering that will recycle city and process water continuously at 50 gallons per minute. This will reduce city water in the rinse process by 98%, and reduce the rate of waste water by 90%. The system will enable 100% recycling of acids back to the plating bath.

The cost savings associated with the rinse water reclaim are made up of several components:

Savings = recycled process city water + wastewater treatment deterred
+ recycled chemicals + reduced maintenance + reduced scrap
+ reduced sewer maintenance (due to acid reduction)

These savings translate to $539,419 per year.

As the system recycles rinse water, it eliminates all suspended contamination. This reduced contamination can only effect product quality in a positive way.

6. OPPORTUNITY:	**Install heat-exchanger for cooling mill water and replace city water**
WASTE GENERATED:	City water
WASTE PREVENTED / YEAR:	175,564,800 lbs.
SAVINGS / YEAR:	$240,734
IMPLEMENTATION COST:	$ 60,000
IMPLEMENTATION TIME:	2 months

CURRENT PROCESS: **Niagara cooling tower using city water**

Department 294 performs a deburring operation that requires part cooling as part of its process. Presently, the equipment used to perform this cooling function is a Niagara cooling tower that employs city water at a rate of 60 gallons per minute. The water is then dumped to waste treatment.

PROCESS IMPROVEMENT: **Heat exchanger using mill water**

A heat exchanger with a self cleaning system can be utilized to achieve the necessary cooling without employing city water. The self cleaning system allows the use of mill water that can be totally recycled without waste treatment. This self-cleaning component of the heat exchanger system has been uniquely developed by the Livonia engineer.

This reduction in city water usage is calculated at 21,945,600 gallons. At $.01 per gallon, this translates to a $219,456 savings per year in city water alone. Reductions in electricity usage translate to another $12,070 per year. Additionally, the heat exchanger is easier to maintain — maintenance savings are projected at $9208 per year. Total expected savings from this process improvement: $240,734 per year.

7. OPPORTUNITY:	**Manage and track soluble oil**
WASTE GENERATED:	Soluble oil
WASTE PREVENTED / YEAR:	375,000 lbs.
SAVINGS / YEAR:	$192.234
IMPLEMENTATION COST:	within supplier contract
IMPLEMENTATION TIME:	<1 month

PREVIOUS PROCESS: **Modern Treatment Services**

A water soluble cutting oil is used on machining tools throughout the plant. Often, the coolant for several machines is supplied by one central coolant system. Modern Treatment was responsible for assessing the central systems' performance standards and reporting their condition to engineering.

PROCESS IMPROVEMENT: **Modern Treatment continuous improvement**

The Livonia engineer developed a new contract that holds Modern Treatment more accountable for the performance of the central coolant systems, and requires them to show continuous improvement in the reduction of waste cutting fluid. Modern Treatment is allocated a blanket 10,000 gallons per month to dispense throughout the plant. This means that oil not used in one piece of equipment can be carried over to one that does need it. If oil usage exceeds 10,000 gallons, however, maintenance pays for the excessive oil. Modern Treatment has developed control charts for each central system, and Modern Treatment reports monthly oil usage and reasons for discrepancies on these charts. Additionally, Modern Treatment is writing fund requirements for implementing engineering solutions discovered as a result of process control practices.

It is estimated that this new relationship with Modern Treatment will result in a 50,000 gallon per year reduction ($192,234) in the use of soluble oil in Livonia. Modern Treatment is obligated, through its contract, to reduce waste cutting fluid by 15 percent a year. Modern Treatment understands that to continue doing business with Livonia Transmission, it must continue to reduce its waste cutting fluid. The Livonia engineer sees further ways to reduce cutting fluid waste. Reducing hydraulic oil contamination and system pump downs for maintenance repair would reduce wasted oil.

8. OPPORTUNITY:	**Install media rewinders**
WASTE GENERATED:	Aluminum & cast iron media
WASTE PREVENTED / YEAR:	1,500,000 lbs.
SAVINGS / YEAR:	$165,545
IMPLEMENTATION COST:	$30,000 per rewinder
IMPLEMENTATION TIME:	

CURRENT PROCESS: **Filter media in scrap hoppers**

There are several chip separation systems throughout the plant that use rolls of filter media to filter metal chips from cutting fluids. On ten of these systems, the media is deposited in the hopper with the salvageable chips. This aluminum/paper mix has a salvage value $0.11 per pound less than straight aluminum. With 1,518,760 lbs produced a year, this translates to an opportunity of $165,545 per year for aluminum. Cast iron and steel contribute an extra $49,125 in cost savings potential per year. Together, this accounts for a potential cost savings of $230,748 per year.

PROCESS IMPROVEMENT: **Install media rewinders**

Media rewinders will rewind the filter media and deposit only the chips in the hopper. This will allow the plant to receive the highest price (without the $0.11 penalty for filter contamination) for its scrap aluminum. This value will show the plant $165,545 per year in cost savings. Since the cast iron and steel cost savings potential is not much more than the rewinder cost ($30,000 + labor), reclaiming these metals without the filter paper is not cost effective.

Among the issues affecting the implementation of this process improvement is the question of project funding. While the plant would be saddled with the project's implementation and maintenance costs, any cost savings resulting from improved scrap value reverts to a corporate fund. Thus, the plant has difficulty justifying such expenditures. Additionally, use of rewinders has proven infeasible at some scrap locations in the past (due to process layout, and equipment unreliability), and may not prove feasible for future use.

9. OPPORTUNITY:	**Install new conductivity meters on parts washers**
WASTE GENERATED:	Washer chemicals
WASTE PREVENTED / YEAR:	263,560 lbs.
SAVINGS / YEAR:	$91,525
IMPLEMENTATION COST:	$49,500
IMPLEMENTATION TIME:	To be determined

CURRENT PROCESS: **Defective conductivity meters**

Washers are located throughout the Plant to wash dirt, oil, and metal chips off transmission. Parts. After operating for a period of time, these washers become contaminated with tramp oil, chips, and dirt. A cleaning schedule is maintained whereby the solution tank is dumped to waste treatment, and replaced with a fresh chemical water solution (usually 2%). Because a washer is in operation, the chemical concentration decreases due to solution carry-off on the parts. The washers have conductivity meters to measure concentration and control the addition of washing chemical from adjacent drums. However, the meters do not work properly, become fouled, and the chemical drum is either emptied or underutilized. In many areas, chemicals are added manually. The cost differential on washer chemical usage attributed to the faulty meters is $91,525.

PROCESS IMPROVEMENT: **New meters, different chemical**

The installation of new conductivity meters would greatly reduce the variation chemical usage and would also improve product quality. Meters free of fouling problems are available at the cost of $500 ($49,500 for plant-wide implementation). With the introduction of new meters, the maintenance of the washers is critical to their success.

While new meters will reduce concentration variance (thus better insuring product quality), their effect on the amount of chemical used needs to be verified. It might well be that, with the introduction of meters, more chemical will be used in the aggregate.

Additional investigations are underway to determine the effect of using smaller washers (with less waste per recharge) at certain locations. Also, alternatives to the chemical ATF-571 are being evaluated. ATF-571 is not compatible with conductivity meters, is expensive, and is not waste treatable.

10. OPPORTUNITY:	**Implement oil analysis plant-wide**
WASTE GENERATED:	Hydraulic Spindle Oil
WASTE PREVENTED / YEAR:	102,490 lbs.
SAVINGS / YEAR:	$34,720
IMPLEMENTATION COST:	Not applicable
IMPLEMENTATION TIME:	<1 month

CURRENT PROCESS: **Periodic oil change**

Preventative maintenance requires the periodic change of hydraulic spindle oil in process machines throughout the plant. This change is performed whether the oil quality is still within specification or not. While this form of preventative maintenance prevents machine wear and assures a smooth running process, it also generates a significant amount of waste oil.

PROCESS IMPROVEMENT: **Oil analysis before change**

Maintenance area 1-South is analyzing the oil before changing it on a test basis. If the oil is still within specification, no oil change is performed, thereby saving oil and labor. An economic analysis of this operation resulted in the following conclusions:

- Oil analysis has deterred the disposal of 52,920 lbs./year of clean oil in Area 1-5. The rest of the plant uses about as much oil again as area 1-South. Using the double size estimation factor, if oil analysis was employed throughout the entire plant, 102,490 lbs. of clean oil would be spared early disposal each year.

- The cost savings associated with oil analysis are made up of several components:
  Savings =
  oil saved + wastewater treatment deterred
  +oil disposal deterred + oil change labor saved
  -lab fee - sampling labor.
  The savings for Area 1-5 was $12,165 per year.

Those machines that undergo several samples before requiring a change provide the greatest opportunity for savings. Conversely, some machines require a change almost every time they are tested. It is not economical to test these machines before changing hydraulic oil. By eliminating testing of those machines that do not demonstrate cost savings, Area 1-5 would save $17,928. On a plant-wide basis this results in an optimized savings of $34,720 per year.

11. OPPORTUNITY:	**Install shield in Central System 111**
WASTE GENERATED:	Cutting fluid
WASTE PREVENTED / YEAR:	614,250 lbs.
SAVINGS / YEAR:	$17,035
IMPLEMENTATION COST:	Not applicable
IMPLEMENTATION TIME:	<1 month

PREVIOUS PROCESS: **Unshielded turnings conveyor**

System 111 had a problem with oil foam being carried out of the system on the chip conveyor. Observations showed that 50 gallons of cutting fluid were lost per hopper. With seven hoppers generated each day, central system 111 lost 350 gallons of cutting fluid per day. For the year, 91,000 gallons (614,250 lbs) of cutting fluid were lost from central system 111. At 8% oil, 7280 gallons of oil at $2.34 a gallon were lost. Annually, the cost of lost oil was $17,035.

Additionally, environmental concerns arose from this waste oil. When hoppers were dumped to railroad cars, the oil eventually leaked onto the railbed.

PROCESS IMPROVEMENT: **Change soluble oil supplier**

The only place that the oil foam contacts the conveyor is at the interface between the conveyor and the cutting oil surface. Originally, it was thought that a "shield" could be placed around the conveyor at the point where it is in contact with the surface of the cutting fluid thereby keeping the foam off the conveyor. This solution, however, proved infeasible. To effectively restrict the foam, the shield would also restrict the larger turnings. Another solution was sought.

The solution was to eliminate the foam chemically rather than mechanically. A new soluble oil supplier — Fuchs — was contracted. Fuchs' soluble oil proved to foam much less than the soluble oil used previously. Further investigation showed that foam could not account for all the oil loss in Central System 111. A root cause analysis showed that the system's liquid level control was faulty. As a result the systems discharge valve was on, thus pumping oil to waste treatment when it should have been recycling through the system. The level control problem will be corrected, with a significant reduction in lost oil expected as a result.

12. OPPORTUNITY:	**Eliminate non-operational part cleaners**
WASTE GENERATED:	Safety Kleen
WASTE PREVENTED / YEAR:	12,000 lbs.
SAVINGS / YEAR.	$12,000
IMPLEMENTATION COST:	within supplier contract
IMPLEMENTATION TIME:	<1 month

PREVIOUS PROCESS: **Safety Kleen services**

Part cleaners are drums filled with solvent with a removable sink basin on top. Part cleaners provided by Safety Kleen are used throughout the plant. The plant is charged a fee each time the solvent is changed. The waste solvent leaves the plant as a manifested hazardous waste.

Previously, the Livonia engineer tracked the waste generated by these parts cleaners, and assigned cost/year and cost/department figures. Safety Kleen was responsible for assessing washer performance standards.

PROCESS IMPROVEMENT: **Safety been continuous improvement**

The Livonia engineer developed a new contract that holds Safety Kleen more accountable for the performance of their parts cleaners, and requires them to show continuous improvement in the reduction of waste solvent. Safety Kleen was instructed to evaluate usage of each part cleaner. From this evaluation, they identified cleaners that were not used or used so infrequently as to merit consolidation with other cleaners. They also developed a servicing schedule more in tune with actual usage. The Livonia engineer also created a new inspection form that demands a more comprehensive inspection from Safety Keen representatives.

This new relationship with Safety Keen has resulted in an estimated 12,000 lb. reduction in the hazardous solvent waste, at a yearly savings of $12,000 to the plant. Further, Safety Keen is obligated, through its contract, to reduce waste solvent by 15 percent a year. Safety Keen understands that, to continue doing business with Livonia Transmission, it must continue to reduce its waste solvent.

13. OPPORTUNITY:	**Install baffle on Central System 111**
WASTE GENERATED:	Cutting fluid
WASTE PREVENTED / YEAR:	357,563 lbs.
SAVINGS / YEAR.	$10,397
IMPLEMENTATION COST:	$1000
IMPLEMENTATION TIME:	<1 month

CURRENT PROCESS: **Overflow of vacuum filter**

Central System 111 has a problem with turnings clogging up the port to the vacuum filter. This flow restriction causes the cutting fluid level to back up and overflow the weir. The fluid falls into the trench and is dumped to waste treatment. It is estimated that 25 percent (or 3814 gallons per year) of the waste oil generated by system 111 can be attributed to such overflows. The waste cutting fluid (at 8 percent oil) is then estimated at 47,675 gallons (357,563 lbs) per year. This translates to $10,397 per year in lost cutting fluid due to overflow.

PROCESS IMPROVEMENT: **Install baffle**

To eliminate the cutting fluid overflow, turnings have to be kept free of the port to the vacuum filter. To address this, a baffle will be installed at the inlet to the fluid tank. This baffle will direct chips away from the vacuum filter outlet and towards the front of the conveyor. The baffle will consist of sheet metal elbows at the ends of the inlet trenches. It should take less than a week for members of Ford trades to perform this fix. Without turnings clogging the outlet, the controlled flow of cutting fluid will be maintained in Central System 111.

5.3.5 Developing a Pollution Prevention Program

The success of the Livonia Transmission Plant Waste Prevention Opportunity Analysis gave Phil Lawrence the proof he needed to demonstrate that waste prevention was a viable and fruitful activity. The next step was to formalize the waste prevention procedures so that they could be disseminated to Ford plants worldwide. To accomplish this, Bill Schneider, who had been actively involved in the Livonia Assessment Team was requested to head an ad hoc team. With members of the LAT and other environmental and process personnel, Schneider reviewed the Livonia findings along with pertinent material from other corporations and the United States Environmental Protection Agency. While many publications exist on pollution prevention, a priority objective was to develop procedures that would be extensions of Ford's existing quality program. The resulting guidebook, "Roadmap to an Effective Waste Minimization Program," has been distributed to other Ford plants. A summary of the guidebook's main ideas follows:

1. A plant-wide team should be set up to coordinate waste reduction efforts. The team can be an existing plant team, or a pollution prevention team created for this project. This team should be made up of representatives from all the departments in the plant, workers, and environmental experts. It is essential that both senior management and line workers be a part of the drive to reduce waste.

2. The most effective way to eliminate a specific waste at each level of plant operations would be to create teams at each segment of the manufacturing process. These teams would be made up of people who already work on the process and would include a member who has been trained in the specifics of pollution prevention.

3. The coordinating team for the plant would begin the pollution prevention process by setting goals and carrying out a macroscopic analysis of plant operations focusing on waste streams (steps A and B below). The teams specific to the particular waste or area of the plant could then take over the planning and implementation of the pollution prevention plans selected.

The steps to be followed in implementing a pollution prevention program are:

A. Identify Waste Streams
B. Establish Pollution prevention Priorities
C. Focus On Waste Sources
D. Develop Solutions
E. Verify Results

A. Identify Waste Streams

The coordinating team should start by identifying the process streams leading into and out of the manufacturing plant. The streams that do not contribute to the final product are waste streams. The quantity of waste material produced by the plant must be measured so that the cost of each waste stream can be estimated. The costs of waste arising from each unit of a particular product, whether defective or not, should also be estimated. These costs can be used as factors in the production planning and costs analysis for the products made.

B. Establish Pollution Prevention Priorities

After determining what the waste streams are, it is essential to establish pollution prevention priorities on a plant-wide basis. The factors that will affect this prioritization may include raw material cost, amount produced, and environmental effects, among others. The priorities will be specific to the plant and the overall pollution prevention objectives will be set by the coordinating team. Once the priorities have been set, it is also necessary to establish realistic goals and timelines for achieving them. As with all process improvement programs, pollution prevention requires a sustained, incremental effort if lasting change is to be achieved.

C. Focus On Waste Sources

After the macroscopic analysis of the waste streams has been done and appropriate goals have been set, a more detailed analysis of each targeted waste stream is required. The source of each waste stream should be located. This will require extensive coordination within the plant, especially if the same waste material comes from several operations in the plant. Specialized teams that will deal with each targeted waste should be formed at this time to carry out the detailed analyses. The waste quantities should be measured and compared to the goals set for pollution prevention. This process should begin on a plant-wide basis and steadily get more focused, culminating in measuring waste from individual machines or parts of machines.

D. Develop Solutions

Once the targeted waste streams have been identified, options for reducing each stream have to be developed and screened. The options must deal with the waste directly rather than just switching to alternate means of disposal. The aim is to reduce as much of the waste as possible. Materials should be captured and reused where feasible. Only when waste is unavoidable should it be disposed of safely.

An action plan should be developed from each option that is selected. The action plan should fulfill the goals set for the plant and must itself have verifiable goals. The plan should be implemented as soon as it has been approved by the coordinating team.

E. Verify Results

The efficacy of the pollution prevention program can be evaluated only if measurables have been used throughout the planning and implementation process. When it is time to verify the results, the goals can be compared to what has actually been achieved. Having a quantitative basis for evaluation will also be helpful in calculating the monetary gains from the success of such plans.

After evaluation, the plans that have been implemented should be adjusted as indicated by the results. A reevaluation of the process may reveal new insight that will prove to be beneficial for the overall system. This will enable the company to apply the plan to other facilities. The plans should be continued and enhanced after each evaluation. Following the "Plan, Do, Check, Act" method of Total Quality Management (TQM), the overall pollution prevention process should then return to the analysis phase.

Total Quality Management employs continuous improvement to strive for the goal of zero defects. While some defects are inevitable, the goals of TQM drive companies to improvements they might not otherwise seek. Similarly, pollution prevention is a process of continuous improvement and assessment that should not be considered complete until all wastes have been eliminated from the plant.

Exhibit 5-1
Livonia Assessment Team

John Connor	Livonia Plant
Alan Amberg	Environmental Quality Office
Ron Burns	Transmission and Chassis Division
David Chock	Research Staff
Phil Lawrence	Plant Engineering Office
Jack Murray	Plant Engineering/Environmental Quality Offices
Mark Panetta	Truck and Chassis Division
Bill Schneider	Research Staff
Two consultants	Outside consulting firm

Exhibit 5-2

Waste Calculation

System 111 has a problem with oil foam being carried out of the system on the chip conveyor. Observations showed that 50 gallons of cutting fluid were lost per hopper. The system has been generating seven hoppers per day. Waste costs for the first six months of 1991 were calculated as follows:

7 hoppers/day X 50 gallon/hopper = 350 gallons/day

350 gallons/day X 130 days/6months = 45,500 gallons/6 months

45,500 gallons X 8% oil in cutting fluid lost = 3,640 gallons of oil wasted

Projected waste oil for one year: 2 X 3,640 = 7,280 gallons of oil

7,280 gallons of oil X $2.60/gallon = $18,928 per year

Exhibit 5-3
Initial Recommendations

Waste Prevention Opportunities	Type of Waste Generated	Pounds/Year Prevented	$ Savings/Year
Activate AXOD reclaim unit	Transmission fluid	1,885,295	560,807
Oil tracking system	Hydraulic & spindle oil	307,470	104,160
Eliminate no-operational parts cleaners	Naphtha	26,055	18,760
Install media rewinders	Scrap metal & filter paper	1,360,100	230,748
Reduce rubbish contamination	Scrap metal	N/A	109,911
Install shield on Central System 111	Cutting fluid	614,250	17,035
Install Baffle on Central System 111	Cutting fluid	357,563	10,397
Install new conductivity meters on washers	Washer chemicals	263,560	91,525
Update PFIS oil tracking	Oil	Unknown	Unknown
Needle bearing grease accountability	Greases	5,000	5,000
	Total	4,819,293	1,148,343

Exhibit 5-4
Ongoing Recommendations

Waste Prevention Opportunities	Type of Waste Generated	Pounds/Year Prevented	$ Savings/year
Activate AXOD reclaim unit	Transmission Fluid	11,000,000	1,287,000
Collect fluids on test stands	Transmission Fluid	20,000,000	4,000,000
Capture carry-off oil	Transmission Fluid	4,000,000	1,000,000
Oil tracking system	Hydraulic &spindle oil	307,470	104,160
Eliminate no-operational parts cleaners	Naphtha	12,000	12,000
Install media rewinders	Scrap metal & Filter paper	1,360,100	335,692
Reduce rubbish contamination	Scrap metal	N/A	109,911
Install shield on Central System 111	Cutting fluid	614,250	17,035
Install baffle on Central System 111	Cutting fluid	357,563	10,397
Install new conductivity meters on washers	Washer chemicals	263,560	91,525
Update PFIS oil tracking	Oil	Unknown	Unknown
Reclaim Anodizer rinse water	Rinse water	192,720,000	291,343
Install heat exchanger to cool mill water	City water	48,000,000	120,000
Reclaim cutting oils, broach oil, mineral oils	Misc. oils	592,000	80,300
	Total	272,200,000	9,000,000

QUESTIONS

1) What are the benefits to Ford of reducing waste?

2) How do total quality management principles relate to pollution prevention?

3) What data management techniques would improve the waste assessment process?

4) The case presented only improvements to *existing* processes. From a TQM standpoint, what might be done to design processes with the intent to prevent pollution?

CHAPTER 6
ADDITIONAL CASE STUDIES IN POLLUTION PREVENTION

Office of Technical Assistance
Executive Office of Environmental Affairs
Commonwealth of Massachusetts

Toxics Use Reduction Case Study

ALCOHOL FREE FOUNTAIN SOLUTIONS AT AMERICRAFT CARTON, INC.

SUMMARY

Americraft Carton was using large quantities of isopropyl alcohol (IPA) in the fountain solution for the offset printing presses used to print the paperboard cartons for its client's products — food, health and beauty and children's products. Concern for the health and safety of its employees and the environmental concerns of its clients required Americraft to change its process. Introduction of a $108,000 new fountain solution delivery system has resulted in the elimination of IPA, cost savings that will yield full payback (in materials costs alone) in less than two-and-one-half years, and a likely end to toxics use reporting.

BACKGROUND

Americraft Carton, Inc., in Lowell, Massachusetts, is a $30 million a year folding carton manufacturer and printer. Health and safety issues and environmental concerns of Americraft clients — makers of health and beauty products, children's toys and games, and food products — influenced Americraft's efforts to introduce less toxic printing materials.

Until August 1991, Americraft mixed fountain solution for its presses in the traditional manner — a solution of 15-25% isopropyl alcohol (IPA), tap water, and etch material was measured by hand into a drum and stirred with a wooden paddle. Americraft received bulk deliveries of IPA every two to three weeks and up to six 55 gallon drums of waste solution were generated monthly by the company's four sheetfed offset presses.

There are significant economic, health and safety, and environmental drawbacks to this method of producing and using fountain solution. Inconsistency in the solution can cause press downtime; it increases labor and material costs, and it can require disposal of inadequate, unused, or waste solution at a cost of more than $2 per gallon. Inhalation of alcohol-laden vapors present health and safety concerns for employees. And IPA, an ozone producing volatile organic compound (VOC), increases the cost and complexity of air emission permitting and reporting.

TUR PLANNING

Americraft Manufacturing Manager Jim Klecak knew that inconsistency in fountain solution formulation as well as air emission concerns needed to be resolved. Jim moved quickly to research the available options and, in April 1991, to purchase and install a *Prisco Aquamix Central System* at a cost of $108,000. News of the change was initially received with some trepidation by management because of the expense. Now, because the system has proven cost-effective and efficient, implementation of similar systems is underway at two other Americraft plants, in Memphis, Tennessee, and St. Paul Minnesota. St. Paul utilizes a modified version of the mixing system and is pleased with early results. In Memphis, "black-box" technology that irradiates the water for the dampening system, enables operation with plain water and fountain concentrate, completely eliminating IPA and its

substitutes. In Lowell, when Jim began introducing no-IPA solution, he even had to prove to his pressmen that high standard printing is possible without IPA — he locked the IPA storage area and installed a drum, visible through the storeroom window, labeled IPA but filled with water with a hose leading to the presses. Ten days later, Jim told the pressmen that the system was operating without IPA.

TUR MODIFICATIONS

Americraft installed the Prisco system and (because water quality could vary even from hour to hour) reverse osmosis equipment to filter incoming water and automatically adjust pH and conductivity. These changes made it possible to use IPA substitutes, which are less tolerant to variations in water quality and parameters than is IPA. The reverse osmosis filtration system has five micron carbon prefilters, a reverse osmosis membrane, and a storage and distribution tank. Americraft first replaced IPA with Hi-Tech solution and Alkaless R, a fountain concentrate with 20 percent monoglycol ether, a VOC. Release of VOCs was greatly reduced by using a closed loop system, but introduction of the glycol ethers required reporting under SARA (Title III, section 313) and TURA. Prisco Q-11, a new substitute introduced in April 1993, has nearly eliminated VOCs and will likely end the required reporting.

The Prisco system is a closed loop recycling system connected to all the presses, which can release solution at up to 15 gallons per minute (gpm). Recharging of the solution (made up of water obtained by reverse osmosis, IPA substitute, and used fountain solution) is computer-controlled to ensure that pH, temperature, and conductivity are all precisely maintained. From the press, the solution goes to a return tank where it is chilled and filtered to 25 microns (contaminants are ink, paper, dust, and paperboard stock). The solution is then returned to the main system for filtering to 10 microns and for further chilling as well as solution recharging. The chiller is a holding tank with a 250 gallon capacity to ensure adequate quantities at all times.

RESULTS

Reductions Achieved: Americraft used high volumes of IPA in the last full year before introduction of the Prisco system. Replacement of IPA with Alkaless R, which contains 20 percent VOCs, and the substitution of Q-11 for the Hi-Tech fountain concentrate Presulted in an 88 percent reduction in VOC emissions from the operation. Recirculation also eliminated VOCs from the air in the plant and the substitute had reduced flammability as well (flash point of 110 F versus 72). The system ran for 11 months before spent fountain solution required disposal; waste solution was reduced 50 percent.

Supplies	8/90-7/91 *(old system)*	8/91-7/92 *(new system)*	8/92-7/93 *(Q-11, 8 months)*	7/93 to 7/94* *(Q-11, full year)*
Isopropyl (IPA)	$23,025	-0-	-0-	-0-
Alkaless R	1,292	$5,816	$17,146	$3,877
Fountain Solution, Hi-Tech , Q-11	44,907	23,188	10,986	14,610
Total	$69,224	29,004	28,132	18,488
Savings		$40,220	$41,092	$50,736

*PROJECTED

NOTE: Total Materials Purchase Savings = $132,048 in three years. These calculations do not include substantial additional savings estimated at about $35,000 per year from decreased paperboard waste on startups, a capacity increase due to reduced down time for system maintenance, reduced hazardous waste disposal costs for spent fountain solution, and finally, no, or substantially reduced permit fees as a result of the chemical substitutions and process changes.

Installation of the *Prisco Aquamix Central System* automatically and accurately mixes fountain solution in a closed loop and has resulted in:

- The end of losses and costs associated with hand mixed solution — the cost and disposal cost of unacceptable solution that also sometimes caused press downtime;
- Reduced costs for waste removal by internal recycling of the solution and from converting from weekly solution disposal and pan maintenance to an annual schedule, and
- Significantly reduced use of VOCs and VOC emissions through the replacement of IPA. The introduction in April 1993 of Prisco Q-11, which contains 0 percent VOCs will result in nearly complete elimination of VOCs.

Economics: Americraft invested $108,000 in the new equipment required to reduce the VOC emissions from its offset printing operations. Payback resulting solely from the reduced cost for materials will occur about 30 months after introduction of the new system — there are substantial additional savings from increased press efficiency, reduced wastes, and reduced and eliminated permit costs. Americraft has also found that alcohol substitutes cause the need to maintain and/or replace rollers at a higher rate, but also require lower durometer meaning they may last longer.

The cost of the alcohol replacement (Alkaless R) is 5 times greater than IPA; the cost of Q-11 is comparable to that of the Hi Tech concentrate which it replaces. However, because of the improved efficiency of the mixing system and the new chemistry, a reduction of about 75% in Alkaless R use is projected to occur this year, producing the savings (from materials costs alone) shown in the table above.

OTHER POLLUTION PREVENTION ACTIVITIES

Americraft has introduced other pollution prevention changes. Approximately 85 percent of its products are made from *recycled paperboard*. Printing on recycled board is technically more difficult, but the introduction of a consistent fountain solution greatly facilitates printing on recycled material. Americraft also uses *water-based coatings*, instead of UV-based coatings which may make paper non-recyclable; and Americraft recently switched from petroleum-based ink to *soy-based ink*. Soy-based inks produce a higher quality print and result in substantial further VOC reductions. Finally, Americraft is exploring ways in which to cleanse and recycle its cloth filter bags to reduce its overall waste load and improve disposal methods of the filtered-out hazardous material.

This Case Study is one of a series of such documents prepared by the Office of Technical Assistance for Toxics Use Reduction (OTA), a branch of the Massachusetts Executive Office of Environmental Affairs whose mission is to assist industry in reducing the use of toxic chemicals and/or the generation of toxic manufacturing byproducts. OTA's non-regulatory services are available at no charge to Massachusetts businesses and institutions that use toxic chemicals. For further information about this or other case studies, or about OTA's technical services, contact: Office of Technical Assistance, Executive Office of Environmental Affairs, Suite 2109, 100 Cambridge Street, Boston, Massachusetts 02202, (617) 727-3260, Fax - (617) 727-3827. - C101-3, 9/93

Office of Technical Assistance
Executive Office of Environmental Affairs
Commonwealth of Massachusetts

Toxics Use Reduction Case Study

WATER AND INK WASTE REDUCTION AT F.C. MEYER COMPANY

SUMMARY

F.C. Meyer Company, a Lawrence, Massachusetts cardboard box manufacturer and printer, has trained its employees in "good housekeeping" practices and significantly reduced ink wastes and wastewater generated when cleaning the printing presses. The improved washing practices include draining and scraping as much ink as possible before washing and minimizing the amount of water used. Most of the ink wash water is now used to dilute concentrated virgin black ink. The decrease in wash water and the reuse of ink wastewater have resulted in a 90 percent savings in waste disposal as well as reduced costs for raw materials.

BACKGROUND

F.C. Meyer employs 200 people and has eight printing presses and operates three shifts a day, five days a week. The company uses a flexographic printing process with rubber printing plates.

In 1989, F.C. Meyer switched from solvent-based inks to water-based inks, and reduced its VOC emissions from 280 tons per year to less than 1,000 pounds per year. Performance quality was unchanged and the regulatory workload was reduced substantially. In 1992, F.C. Meyer began to seek further waste reduction opportunities and looked at the press cleaning procedures. Presses must be cleaned every time the ink is changed. The bulk of the ink contained in the bins and on other parts of the press is poured back into the ink container. The remaining ink was washed off with water-soaked rags and the waste water was put in 55 gallon drums and, before the ink change, taken away by a hazardous waste contractor at $100 per drum. Before implementation of the waste reduction program the company generated 10 drums of hazardous waste a week, now it generates one to two drums a week of nonhazardous waste.

WASTE REDUCTION ACTIVITIES

F.C. Meyer decided that reduction of the volume of water used in cleaning process could be achieved by training workers to use the least amount of water possible. The new washing procedures include draining as much ink as possible back into the containers and thorough scraping of excess ink off the press parts before any water is added, and then using as little water as possible.

In addition to reducing the volume of wash water used, the company asked its supplier to deliver black ink with 10% reduced water content. Wastewater is added to the black ink with no apparent effect on the color quality of the ink. The wastewater can also be added to other colors, such as grey, in smaller amounts than when added to black ink.

RESULTS

Reductions Achieved: Modifying the press cleanup procedure reduced the solids in spent washwater from more than 30 percent to 13 percent. The volume of water used also has decreased by 35 percent. Approximately one pint of water is now used each time a press is washed.

By reusing most of the washwater, the amount of waste which had to be disposed has decreased from ten to one to two 55-gallon drums per week.

Economics: The 55 gallon drums of waste cost approximately $100 each to dispose. Implementing the reuse of ink wastewater has reduced the yearly cost of waste disposal from about $52,000 to $5,200.

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- C101-2, 8/93

Case Study: Prepared by the Vermont Agency of Natural Resources, Pollution Prevention Division

Pollution Prevention Efforts at the Journal Press, Inc.

Executive Summary:

As a commercial job shop, the Journal Press, Inc. prints a variety of products including posters, college catalogs, and financial reports. The president of the company, Charles Colvin, has been directly involved in keeping hazardous material usage and waste generation to a minimum. As an employer, Mr. Colvin is concerned about the health of his employees and the impact that his business has on the community. As a small business owner he is also concerned about reducing costs - and reducing waste reduces operating costs. In particular the successes at the Journal Press have included recovery of silver from spent photo processing solutions, a 99.9% elimination of isopropyl alcohol from printing operations, and reductions in the volume and toxicity of the ink used.

Background

The Journal Press, Inc. is a small commercial offset lithographic printing business. The company has been a fixture in downtown Poultney, Vermont since the 1860's. Originally the company published a local newspaper. Newspaper publishing ended in the 1930's, however, the business has continued to thrive as a commercial job shop. The business is currently owned by Charles and Katherine Colvin who purchased it from his parents.

Production activities at the company include photo processing, plate making, printing and book binding. The company presently employs thirteen people on a full time basis and five additional people on a part time basis.

Hazardous Materials Usage and Waste Generation

The four major production activities mentioned above all use hazardous materials or generate solid or hazardous waste. Mr. Colvin has worked hard to minimize the use of hazardous materials and prevent the generation of hazardous waste. He has also tried to find recycling outlets for the solid waste streams which his company generates, including successfully locating a means of recycling the waste paper generated in the bindery. There are two main reasons behind these efforts. First, Mr. Colvin is concerned about the health of his employees and the community at large. This has led him to seek out those chemicals available to the printing industry which are the least toxic. Secondly, as a small business owner, Mr. Colvin has to keep a close eye on the bottom line. Waste generation is viewed as lost profit. In light of this, all personnel at the facility are encouraged to try very hard to conserve the materials which they use and prevent waste from being generated in each area of production.

Plate Making and Photo Processing

Fixer from photo processing operations is generated as a waste. The silver content in the spent fixer makes it a hazardous waste. Silver is removed from the spent fixer by means of a simple ion exchange unit. This device removes silver to a level that is less than 5 ppm. After the silver has been removed, the spent fixer is no longer considered to be hazardous waste and may be discharged to the local POTW [1]. The silver recovery canister is shipped to Boston Recovery Company in Canton, Massachusetts. This company pays the Journal Press for the value of the silver which they recover from the ion exchange cartridges. Approximately 5 gallons of de-silvered fixer are discharged to the local POTW on a weekly basis.

A similar quantity of spent photographic developer and a much lower quantity of spent plate making chemicals are also discharged to the local POTW. Mr. Colvin has contacted both the Agency of Natural Resources and the local POTW to ensure that discharge of these wastes meet with their approval. He has also apprised these organizations of any changes in the chemistry of these waste streams which have occurred when the company purchase new products.

Waste water is also generated from cleaning the photo processors. This is also discharged to the local POTW. Many photo processors are cleaned with a solution which contains small amounts of sodium dichromate. The Journal Press recently replaced their photo processing equipment and found that the new equipment could be cleaned with detergent and water, thus eliminating the use of a toxic chemical common to the printing industry.

Solid wastes generated from plate making and photo processing activities include used plates, used film, and dimensionally stable mylar. The used plates and film are sold to Munger Scrap Metal in Rutland, Vermont where they are eventually resold for their scrap metal value. Due to the relatively small amount of spent film generated by the company it has not been considered economically feasible to segregate film based on its silver content. This has been done by some of the larger printing companies in Vermont in order to get a higher price for used film that has a higher solver content. No recycling outlet has been located for the mylar waste stream.

Printing

Printing activities use most of the hazardous chemicals required at the Journal Press and generate hazardous waste which is required to be shipped off-site for disposal. Fountain solution, blanket wash and ink make up the bulk of the hazardous materials used by this printer as well as most other printing establishments. The Journal Press has located low

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[1] POTW means publicly owned treatment works.

Success Story FACT SHEET

NYSDEC

Number 5

July 1990

Hazardous Waste Reduction

Spence Engineering Company, Inc.
150 Coldenham Road
P.O. Box 230, Walden, NY 12586
Contact: (914) 778-5566

By changing a parts cleaning process, an engineering firm has eliminated toxic air emissions and reduced costs.

Background:

Spence Engineering Company, a manufacturer of automatic fluid controls, used the solvent trichloroethylene (TCE) to clean components in a vapor degreasing process. TCE, a toxic chemical compound, is listed by EPA as a priority pollutant. Stack emissions of trichloroethylene averaged 9200 pounds a year.

Improved process:

The company replaced the vapor degreasing system in 1989 with an efficient parts washing system that uses a waterbased, nontoxic detergent cleaner instead of trichloroethylene.

Results:

As soon as it was put into operation, the new process eliminated stack emissions of trichloroethylene.

Benefits:

- Elimination of solvent emissions
- Elimination of all related sludge and fluid waste streams
- Maintenance and operating costs reduced
- Parts cleaning time reduced
- Improvement in employee safety

New York State Department of Environmental Conservation
Mario M. Cuomo, *Governor* Thomas C. Jorling, *Commissioner*

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Technical assistance

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For more information

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  Bureau of Pollution Prevention
  NYSDEC
  50 Wolf Road
  Albany, NY 12233-7253
  (518) 457-6072

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  Industrial Materials Recycling Program
  NYS Environmental Facilities Corporation
  50 Wolf Road
  Albany, NY 12205
  (518) 457-4138

Division of Hazardous Substances Regulation

Success Story

NYSDEC

FACT SHEET

Number 9

October 1990

Hazardous Waste Reduction

Atochem North America, Inc.
Organic Peroxides Division
P.O. Box 188
Geneseo, N.Y. 14454
Contact Environmental Manager (716) 243-0330

By installing a collection and recovery system for suspended solids, Atochem increased product yield and saved money.

Background:

During the drying of a solid product, fine particles are lost to the circulating air stream and scrubbing water. In the past; this slurry was pretreated to convert it to a soluble biodegradable substance for subsequent processing at the on-site waste treatment facility.

Improved Process:

The company installed a collection and recovery system consisting of piping, lined circulating tank, pumps and mixers. The scrubbing water containing the suspended solids is transferred to a mixing tank through a coarse magnetic screen. The solids are isolated from the slurred material by a basket centrifuge and used in the manufacture of a paste product.

Cost Savings:

More than $50,000 per year, payback in nine months on investment.

Benefits:

- On-site treatment cost reduced.
- Material recovered yields at least 8 percent more usable product.
- The recovered fine solids provide an improved, less grainy paste product.

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Division of Hazardous Substances Regulation

Success Story

NYSDEC

FACT SHEET

Number 10

October 1990

Hazardous Waste Reduction

Atochem North America, Inc.
Organic Peroxides Division
P.O. Box 188
Geneseo, N.Y. 14454
Contact Environmental Manager (716) 243-0330

By recycling and reusing a solvent, Atochem North America reduces waste by 90% and reduced raw material costs.

Background:

The production of a semi-solid organic peroxide required that the solvent be extracted, after which the product was recrystalized to achieve the necessary purity. In the past, the filtrate (a mixture of by-products and solvent) was discarded.

Improved Process:

The solvent is recycled approximately 15 times, The spent solvent is then stripped and the recrystalized product is blended into regular production material. Both the quantity of solvent needed and the amount of waste have been reduced by 90 percent.

Cost Savings:

Operating cost reduced by approximately $50,000 per year.
Payback time on investment—six months.

Benefits:

- **90% reduction in waste.**
- **Raw material costs reduced, production capacity increased.**

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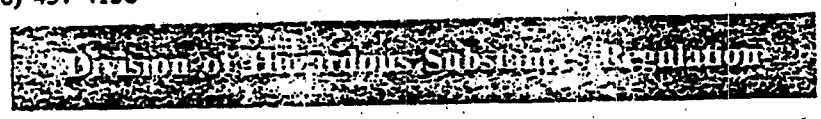

Success Story

NYSDEC

FACT SHEET

Number 15

March 1991

Hazardous Waste Reduction

Ayerst Laboratories, Inc.
(a.k.a. Wyeth-Ayerst Laboratories)
64 Maple Street
Rouses Point, NY 12979
Contact Environmental & Safety Engineer (518) 297-8714

Ayerst Laboratories has redesigned a manufacturing process to reduce air emissions by 96 percent and a solvent waste by 89 percent.

Background:

Ayerst Laboratories manufactures spheroids for its long-acting beta-blocking drug INDERAL LA, which is used in the management of hypertension, angina pectoris and migraine headaches. The manufacturing process produced large quantities of solvent-based waste from a coating solution. The waste was incinerated at an approved facility.

Improved Process:

The manufacturing process was modified using larger equipment with a fluid bed dryer and a highly efficient air emissions control system. The emissions are condensed in a closed loop system at -40 degrees Fahrenheit to recover clean solvents which are then reused. The improved process reduced the solvent-based coating solution waste stream from 17,200 pounds per year to 1,900 pounds per year and reduced the amount of virgin solvent required from 160,600 pounds per year to 4,400 pounds per year.

Benefits:

- 89 percent waste reduction.
- 97 percent reduction in the amount of solvent required.
- Improved process control.

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Division of Hazardous Substances Regulation

Office of Technical Assistance
Executive Office of Environmental Affairs
Commonwealth of Massachusetts

Toxics Use Reduction Case Study

MONOMER STORAGE AND HANDLING IMPROVEMENTS AT NOVACOR CHEMICALS INC.

SUMMARY

The U.S.-based polystyrene division of Novacor Chemicals, Inc. updated the equipment of their monomer storage and handling facility in order to demonstrate the company's environmental awareness and to reduce overall potential liability. This project eliminated the volatile hydrocarbon emissions that previously emanated from the monomer storage tanks, spelling a 50% reduction in the facility's overall emissions. The change also reduced the risks of fire and groundwater contamination, while eliminating the potential liability associated with collapse of the aged tanks previously in use.

BACKGROUND

Novacor is a Canadian corporation whose polystyrene division is based in Leominster, MA, with plants in Springfield, MA, Decatur, AL and Montreal, Quebec, Canada. The 55-employee facility at Indian Orchard in Springfield manufactures plastic pellets which are used to produce molded plastic parts for a wide variety of applications.

TOXICS USE REDUCTION PLANNING

Before 1990, the firm stored monomer - a raw material used in the manufacture of certain plastics - in three 100,000 gallon tanks that had been designed and constructed in 1946. These tanks were not fitted with up-to-date equipment for spill containment and fire protection. The lines into which a flame-retardant foam could be injected in the event of fire were positioned over the top of each tank and had become clogged with polymer formed from hydrocarbon vapors. They had also begun to show signs of declining structural integrity. Earthen dikes protected against gross surface contamination by funneling spills into the soil and groundwater. Lacking the ability to recapture fumes displaced by tank refilling, the tanks emitted approximately 8,800 pounds per year of volatile hydrocarbons. This was more than 50% of the facility's total hydrocarbon emissions.

TOXICS USE REDUCTION MODIFICATIONS

Novacor's insurance company had recommended that the firm update its monomer storage and handling system in order to tighten control over fire and groundwater contamination risks. The firm was further motivated to update these storage tanks because managers believed that such action was consistent with membership in the Chemical Manufacturers Association's Responsible Care Program. As part of the program's codes, pollution prevention is stressed as a means of improving the environment and public health. Managers state that the success of the program has created enthusiasm at corporate headquarters for similar projects which employ equipment

upgrades as a compliance strategy, instead of traditional pollution control.

Novacor's managers considered three alternatives. The first, continuing with the status quo, was rejected because managers concluded that this option was "contrary to corporate environmental and risk management standards." The second option, upgrading the existing storage facility, would have resulted in only marginal improvements in fire protection and spill containment capabilities at a cost of $700,000. The managers elected to replace all three existing tanks with a single 375,000 gallon tank fitted with up-to-date safeguards against fires and spills and with modern equipment for recovering hydrocarbon vapors. Novacor decided that this $995,000 investment was justified because it fit the corporation's environmental policy and risk management standards and because it promised to reduce the firm's potential liability for groundwater and soil contamination.

The new facility has a cooling system which condenses vapors. These vapors are returned to the tank through a vapor recovery return line. Additionally, there is a nitrogen gas blanket which protects the tank and fills the head space of the tank, preventing the monomer from volatilizing.

RESULTS

Reductions Achieved: By providing for the recovery of hydrocarbon vapors in the tank's headspace, the project eliminated hydrocarbon emissions from Novacor's monomer storage system. Novacor now emits 8,800 pounds less per year of hydrocarbon vapors, a reduction of 50% of the facility's total annual hydrocarbon emissions.

Economics: The new system represents a $995,000 capital investment. This investment will not lead to direct and quantifiable reductions in operating costs. However, Novacor's management judged the project worthwhile in part because of other economic effects that are difficult to quantify. In particular, the project promises to reduce Novacor's exposure to liability for soil and groundwater contamination. Moreover, the project anticipates regulatory requirements by taking into account the emissions reduction goals of the Massachusetts Toxics Use Reduction Act.

Advantages: The new storage and handling facility has four major advantages over the old system. Most importantly, hydrocarbon emissions are eliminated. Second, the new tanks offer improved fire and spill protection. The foam injection system is located at the tank bottom and is thus protected from clogging. A concrete dike contains spills while still protecting against soil and groundwater contamination. A false bottom and collection pit in the sub-floor further reduce leak risks. Third, replacing the old tanks has greatly reduced the threat of tank collapse due to lack of structural integrity. And finally, these upgrades place Novacor in a better position to meet future air regulations.

The Office of Technical Assistance (OTA) in the Massachusetts Executive Office of Environmental Affairs facilitates the reduction of toxic chemical use and hazardous waste generation. the Office evaluates statewide needs for toxic use reduction and provides technical information and assistance to users of toxic materials. For further information on this case study and toxics use reduction in general, contact: Office of Technical Assistance, Suite 1904, 100 Cambridge Street, Boston, Massachusetts 02202, (617) 727-3260.

Success Story

NYSDEC

FACT SHEET

Number 6

July 1990

Hazardous Waste Reduction

By installing a computer monitoring system and replacing a pump, a manufacturer has reduced hazardous wastes by 90 percent and saved $45,000 a year.

RIM Division
Chardon Rubber Company
6 Apollo Drive
Batavia, NY 14020
Contact: Randy Cooke, Facility Coordinator, (716) 344-1221

Background:

The Chardon Rubber Company, RIM Division, manufactures sliding rear windows for the automotive industry. The company encases the window units in a polyurethane molding that is fabricated from a mixture of polyether polyol and aromatic isocyanate prepolymer.

The molding process requires precise control of the component chemical compounds. In the past, workers determined the amount of material needed by manual weighing. Excess materials were discarded as hazardous waste.

Another aspect of the process requires transferring isocyanate from drums to a day tank. In the past, workers had to flush the drum pump with dioctyl phthalate (DOP) to prevent pump failure, because contact with air crystalizes the isocyanate.

Improved process:

By installing an in-line computer system, workers are now able to monitor the system and obtain precise chemical measurements at all times. The process eliminates waste chemicals.

By installing a diaphragm pump, the company has prevented isocyanate from contacting the air and forming crystals. Consequently, DOP is no longer needed as a flushing agent.

Results:

Improvements to the molding process and the pumping system have reduced hazardous wastes by 90 percent and saved more than $45,000 annually in raw material and waste disposal costs. As the division grows, managers plan to incorporate similar improvements into future production designs. The company is working actively to reduce waste and improve processes by eliminating as many hazardous chemicals as possible.

Benefits:

- reduced costs of raw materials and maintenance
- hazardous wastes reduced 90 percent
- reduced waste disposal costs
- improved worker safety
- quick payback on capital expenses

New York State Department of Environmental Conservation
Mario M. Cuomo, *Governor* Thomas C. Jorling, *Commissioner*

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Division of Hazardous Substances Regulation

QUESTIONS

1) What are the benefits to Ford of reducing waste?

2) How do total quality management principles relate to pollution prevention?

3) What data management techniques would improve the waste assessment process?

4) The case presented only improvements to *existing* processes. From a TQM standpoint, what might be done to design processes with the intent to prevent pollution?