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Applying Environmental Accounting to Electroplating Operations: An In-Depth Analysis

DISCLAIMER

Throughout this report, interpretations and analysis are provided on research findings generated through this project. This analysis and the accompanying conclusions should not be interpreted as representative of environmental accounting applications in other industries. Moreover, the findings and conclusions are based on a small sample of metal finishing operations visited in conjunction with this project and other WRITAR projects. Although WRITAR believes that many of the issues discussed in this report are generally representative of metal finishing operations, we recognize many of the barriers and contextual issues may not apply to individual facilities. As a result the issues concerning adoption of environmental accounting practices should not be extrapolated to the entire industry.

This report is intended for an audience with a basic understanding of environmental accounting concepts and metal finishing operations. For introductory or additional information on environmental accounting, or for more copies of this document, please call the Pollution Prevention Information Clearinghouse at (202) 260-1023 or visit the EPA's Environmental Accounting Project Web Site at:

<http://www.epa.gov/opptintr/acctg>

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**U.S. Environmental Protection Agency
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EXECUTIVE SUMMARY

This report presents research findings regarding the implementation of environmental accounting (EA) practices in the electroplating industry, conclusions regarding the potential for its wider adoption and use, and recommendations for investigating environmental cost structures in this industry. The research entailed 24 on-site investigations into both captive operations (electroplating included as part of a larger manufacturing process), and job shop facilities (specializing in providing electroplating services to manufacturers), and extensive literature reviews on electroplating costing practices and EA analysis. This report focuses on electroplating operations, and any references in this report to "metal finishing" pertains exclusively to electroplating operations.

Following are the primary research findings:

1. Many of the facilities visited are already using parts of EA without knowing or calling it that. Most "conventional" costs (e.g. wastewater treatment operations, hazardous waste disposal) associated with environmental management are recognized and captured in new project or process evaluations.
2. EA was found to have potential for elucidating "hidden" costs and creating a more robust and accurate economic evaluation of projects.
3. As can be expected, the five environmental costs of greatest significance to electroplating facilities are wastewater treatment (and its many individual cost components), hazardous waste disposal, sewerage, plating chemistry loss, and other process solution loss.
4. The cost issues most frequently found to be significant and underrecognized in facility decision-making situations are the chemistry and solution losses. These cost areas are especially appropriate for more in-depth analysis because of 1) the repercussions they have elsewhere in the facility's environmental management cost structure; and 2) its potential implications in highlighting the "true" cost of facility waste beyond disposal and wastewater treatment. However, these costs are more challenging to derive since they are

not hidden in overhead accounts, but must be assembled through materials balances and an examination of production records.

5. Environmental costs of all types can be quantified, but cost/benefit implications of gathering this information depends on facility needs and circumstances.

6. Environmental management costs which did not directly affect payroll and payables (e.g. labor costs of preparing a TRI report or manifesting) had often been left out of project evaluations, but in revisiting projects facilities found them useful to consider and quantify. However, metal finishers demonstrated some hesitancy to formally factor them into an actual economic evaluation of a project. Electroplating facilities were strongly oriented toward using conservative and reliable cost estimates in decision-making and factoring in only those issues directly impacting cash flow.

7. One of the most valuable uses and applications of EA in electroplating was found to be in generating greater facility interest in exploring process understanding and control issues. Applying environmental accounting suggested that three types of activities are typically undervalued in facility operations:

- Episodic activities -- such as disposal of tank bottoms, bath dumps, filter replacement, and decommissioning of process lines. Applying environmental accounting to these activities demonstrates a more powerful economic rationale to invest in process control and reexamine ways to reduce these episodic events.
- Rework activities -- which creates new types of wastes and unnecessary additional discharges. Because of underrecognized environmental cost implications, the facility's cost of quality is typically low. Full environmental costing of rejects creates a more powerful economic rationale to take a quality improvement approach which also prevents pollution.
- Rinsing activities -- the difference between what is technically needed to rinse sufficiently and what the facility is actually using. Every gallon of excess water use created an environmental cost that typically was found to be undervalued and underrecognized.

EA analysis can be used to fully cost these issues and in so doing demonstrate cost saving potential through pollution prevention activities which are far greater than originally anticipated.

8. Gathering and tracking information for certain types of environmental costs poses a potential obstacle since "mining" this information at a level of detail necessary for it to be allocated to the responsible processes may be an expensive thing for a facility to do. Without other opportunities for using this information, its collection and management may not be practical for a facility.

9. Allocating costs to processes responsible for generation is the largest barrier to greater EA adoption in electroplating. The amount of variation inherent in finishing, the systemic nature of finishing with complex cause and effect relationships, and the number of factors and episodic events affecting performance makes allocation quite challenging. Allocation based on actual contribution is outside the realm of possibility for most facilities, allocations based on estimated calculations requires some technical analysis, and allocations based on best professional judgment can be dramatically different from reality. Allocations based on an appropriate production factor (square feet processed, hours of operation, etc.) is perhaps the simplest type of estimated calculation applicable to many types of environmental costs.

10. EA can be a valuable tool to target facility improvement areas when used in conjunction with other targeting methods such as reject rate analysis. Targeting improvement areas based solely on relative contributions to facility environmental management overhead demonstrated a tendency to redirect facility attention from where the greatest gains could be realized.

1.0 PURPOSE OF THIS DOCUMENT

This document contains the findings and results of an 18 month investigation on the application of environmental accounting practices in electroplating facilities. The purpose of this research was to conduct a detailed examination of the mechanics of implementing EA practices within a specific industry.

Environmental accounting has been defined as "the addition of environmental cost information into existing cost accounting procedures and/or recognizing embedded environmental costs and allocating them to appropriate products or processes" (ICF Inc., 1995). As a powerful decision-making tool, environmental accounting practices are being widely promoted throughout all types of industry. Many companies have realized decision-making benefits from an adoption of this methodology and a higher quality understanding of their overall cost structures. Specifically, EA offers two primary advantages:

1) Capital budgeting decisions -- Misallocations and failure to factor in changes in cash flow expenditures pertaining to environmental management can affect the economic justification of environmentally preferable process or technology alternatives. The use of EA approaches to create a more robust and accurate economic analysis of capital projects is one of the primary benefits of EA adoption.

2) Targeting of improvements -- A related benefit to manufacturers is the use of EA methods to target and prioritize areas of improvement. Through EA analysis, a facility can rank order its waste streams based on contributions to facility environmental costs and prioritize pollution prevention efforts to target those areas which contribute the most to direct and indirect environmental management expenditures and generate the greatest cost savings to the facility.

While the advantages and benefits of EA are well documented, some of the issues in actually implementing an EA investigation may be less understood. In this research study, WRITAR examined moving from concept to practice by examining a variety of implementation issues pertaining to EA adoption in electroplating operations. Relevant issues studied included:

- the types of data gathering and management activities needed to support EA analysis in electroplating operations
- the infrastructure needed to support EA investigations on an ongoing basis
- an examination of the "value added" to be gained in decision-making and targeting through such an analysis; i.e. will the benefits of EA outweigh the costs to the firm?

The electroplating industry was chosen to be the focus for two reasons: the majority of metal finishers are small businesses with limited resources for conducting this kind of research on their own, and the fact that environmental benefits could be gained if metal finishers and those who work with metal finishers could access new information on a tool to improve environmental performance. The purpose of this document is to report the findings of the research and to provide guidance for metal finishers, assistance providers, and other professionals on implementing EA in this industry.

This project is part of a larger effort being sponsored by the EPA on environmental accounting methods. The goal of the EPA's Environmental accounting Project is to encourage and motivate businesses to understand the full spectrum of environmental costs and to incorporate those costs into decision-making. The objectives of this overarching initiative as defined by EPA's stakeholders are:

- to create better definitions of key terms and concepts;
- to create management incentives to upgrade managerial accounting practices;
- to conduct education, guidance, and outreach programs; and,
- to develop and disseminate analytical tools, methods, and systems.

The research contained in this report is meant to support these objectives by providing information on the application of environmental accounting methods within an industry of special interest. Electroplating/electroplating operations are a target industry for several environmental policy development and pollution prevention outreach efforts including the EPA Design for the Environment Program and the Common Sense Initiative. This research effort has worked in collaboration with these other electroplating initiatives and expands upon these efforts.

The report is broken into three primary parts. Section 2.0 provides additional background information on the research activities and method used for this project. Section 3.0

describes the research findings and an analysis of environmental management costs in electroplating facilities. Section 4.0 examines EA implementation issues in light of production and management realities of electroplating operations. Finally, section 5.0 presents strategy and recommendations for those interested in investigating electroplating cost structures and identifying areas of improvement.

This report assumes both a basic knowledge of electroplating processes and a basic understanding of environmental accounting methodology. For additional information on the basics of electroplating and associated environmental issues, readers are encouraged to review *Profile of the Electroplating Industry* available from the Cleveland Advanced Manufacturing Program, Cleveland, OH. For more information on EA, call the Pollution Prevention Information Clearinghouse at (202) 260-1023 and ask for an introductory packet on EA to be sent to you. Or visit the EPA Environmental Accounting website at:

<http://es.inel.gov/partners/acctg>

2.0 DEFINITIONS OF COST TERMS USED IN THIS DOCUMENT

As noted in the U.S. EPA publication, "An Introduction to Environmental Accounting as a Business Management Tool: Key Concepts and Terms," there are many different classifications and typologies of costs. The following is a glossary of terms for readers of this document. While we have tried to be as faithful as possible to generally accepted definitions found in this EPA publication as well as other documents, slight variations may exist in an effort to try and convey the cost issues associated with electroplating more clearly.

Environmental Accounting -- the identification, prioritization, quantification or qualification, and incorporation of environmental costs into business decisions.

Environmental Costs -- A general classification for several types of costs relating to the use, release, and regulation of materials in facility operations. For purposes of this report, it is comprised of environmental management costs, opportunity costs, contingent costs, and image costs.

Environmental Management Costs -- All expenditures directly associated with the environmental management function of the facility and in keeping a facility in regulatory compliance.

Opportunity Costs -- Lost value of process solution/chemistry and other lost material costs associated with unoptimal use of raw materials in facility operations

Contingent Costs -- Environmental costs that are not certain to occur in the future but depend on uncertain events. Sometimes referred to as liability costs or contingent liabilities. Not examined in this report.

Image Costs -- Less tangible costs incurred to affect subjective perceptions of management, customers, employees, communities, and regulators. Also known as relationship costs. Not examined in this report.

Conventional Costs -- Costs typically recognized in capital budgeting exercises and financial analyses of projects. Also known as usual costs.

Hidden Costs -- Environmental costs that may be potentially unrecognized by managers because of their infrequent/episodic nature and/or because of their collection in company overhead accounts.

Operating Costs -- Costs incurred through operating a process, system, or facility. The primary focus for this document.

Direct Costs -- Costs clearly and exclusively associated with a product or service and treated as such in cost accounting systems.

Indirect Costs -- All costs that are not accounted for as the direct costs of a particular process, system, product, or facility. Commonly pooled and allocated on the basis of some formula or are not allocated at all.

3.0 BACKGROUND ON RESEARCH STRATEGY AND IMPLEMENTATION

The project commenced with a literature review of a number of standard texts on job costing, manufacturing accounting, and activity based costing looking for relevant insights on cost tracking. A subsequent literature search identified articles pertaining to best practices in job costing and manufacturing accounting in electroplating operations. Primary resources are listed in the bibliography of this report.

With this background information in place, a number of interviews were conducted with leading experts in the field of electroplating to explore issues pertaining to the applicability and value-added of EA adoption. References were obtained from these experts for potential contacts of facilities which have attempted or implemented EA based analyses.

An interview strategy was designed and tested among representatives of electroplating firms with which WRITAR has a close association. Exhibit 1 is a basic outline of the research protocol. After obtaining basic background information on business trends and issues, process descriptions with supporting information on materials uses and releases were gathered. Examples were then reviewed of past process improvement / technology change efforts at the facility to review how the facilities examined costs in the past.

With the cooperation of the facility representatives, WRITAR then embarked on an investigation of EA application issues pertaining to electroplating operations. The investigation centered on hexavalent chrome processes and zinc cyanide processes -- both of which are under regulatory pressure and are common targets for change, and therefore likely opportunities for using EA analysis. Project researchers used an environmental cost category template developed by the Tellus Institute¹ as the analytical framework for the investigation (See Exhibit 2). In examining the various labor, materials and overhead cost elements, four questions comprised the focus of this portion of the research.

1. What is the applicability of these costs to electroplating?
2. How are they currently allocated and how likely could they be allocated or processes or parts?

¹ As adapted and reported in *"Improving Your Competitive Position: Strategic and Financial Assessment of Pollution Prevention Projects"* NEWMOA, 1994

3. What is the significance of various types of costs to electroplating?
4. If an assignment is made, would it be accurate?

Reviewing for applicability involved identifying which cost elements were relevant to electroplating operations and obtaining a better understanding of how they were relevant. Reviewing for allocation involved exploring how the facility currently accounted for these costs and assessing their ability to assign or allocate those costs to responsible products or processes to support decision-making. This review enabled researchers to gain an understanding of how environmental costs are currently handled, how they might be managed differently, and how to transition from a conventional cost analysis to an analysis based on EA.

The final two questions were investigated to better understand the practical implications of using EA in electroplating operations. WRITAR considered cost significance to be an important qualifying issue in adopting EA methods. It was assumed that establishing a threshold of significance helped ensure that the likely benefits of using this cost information for decision-making purposes would be greater than the costs of gathering and analyzing this information. For purposes of this report, .5% of gross annual revenues was selected as a "significance threshold." This was based on previous WRITAR experiences in working with metal finishers which indicated that cost issues of this magnitude are most likely to get the attention and interest of facility management. "Environmental management" costs in aggregate well-exceeded the significance threshold; 6% - 12% was a common range found in the course of the research². Within this collection of costs, particular emphasis was placed on reviewing and analyzing those elements exceeding the .5% criteria.

Allocation accuracy was chosen as another critical issue to help ensure against situations in which the value of EA analysis might be rendered moot by inappropriate relationships between various activities and elements of cost. It is evident that facilities often must estimate, use best professional judgment, or a combination of both practices to assign many environmental costs to processes. The research placed an emphasis on identifying circumstances in which the accuracy of allocation efforts would likely be low because it was presumed that inaccurate allocations could potentially mislead or misdirect facility decision making.

² This range was based on a consideration of all labor, materials, and other expenditures directly associated with environmental management activities and keeping a facility in compliance.

Throughout this report, qualifiers are used to describe facility conditions and practices. Cost definitions are found in the report appendix. Following are other definitions used by the project researchers during the course of the investigation and found in this report.

- *Allocated by product* -- cost is used as a line item for calculating a unit price for finishing a specific part or type of part
- *Allocated by process* -- cost is used to calculate the contribution of a unit operation to facility costs and/or unit price for a specific part or type of part.
- *"Accurate"* -- data from purchase records or similar; auditable
- *"Mostly accurate"* -- data from purchase records or similar, subdivided based on number of operations, number of tanks, number of parts produced, etc. and verifiable by production records
- *"Somewhat accurate"* -- based on data from production records and logs; values are obtained by multiplying volumes by cost data and should balance over long periods of times with purchase records.

WRITAR benefited from having the opportunity to tie this investigation into several concurrent projects being pursued with the electroplating industry. As a result, a total of 24 shops were visited ranging from small job shops to captive specialty plating operations in the aerospace industry. Of these, six were contacted and visited specifically under the auspices of this project. The remaining 18 sites were visited for other project purposes but were interviewed based on the protocol or sections of the protocol. In addition, another 20 telephone interviews were held with various facility representatives and experts pertaining to selected issues contained in the protocol. Interviews were held with environmental, accounting, production/quality, and inventory managers. Exhibit 3 provides a description of the types of facilities visited.

Exhibit 1 -- Research Protocol

Company Background

- a. Products
- b. Facility Descriptors
- c. Notable trends
- e. Corporate P2 program status
- f. Competition analysis
- h. Drivers for P2 and EA -- Regulations, Economics, Competition

Past Process Change Efforts

- a. Process improvement --associated cost analysis
- b. Pollution prevention --associated cost analysis

Process Descriptions

- a. Input - output
- b. Process flow (simple block diagram)
- c. Specifics for zinc cyanide and/or hexavalent chrome (decorative)
 - 1. Waste volumes for 1994 and 1995, est. 1996
 - 2. Material use volumes for 1994 and 1995, est. 1996
 - 3. Production volume
 - 4. Recent changes; planned changes
- d. Specifics for support processes

Costing

- a. Operating regulatory costs
- b. Materials costs
- c. Allocation procedures / relation to pricing
- d. Analysis of information quality

Exhibit 2 Potential Operating Costs Included in an EA Analysis

Materials

direct product materials
 catalysts and solvents
 wasted raw materials
 transport
 storage

Waste Management (Materials & Labor)

pre-treatment
 on-site handling
 storage
 hauling
 insurance
 disposal

Utilities

electricity
 steam
 cooling & process water
 refrigeration
 fuel (gas or oil)
 plant air & inert gas
 sewerage

Direct Labor

operating labor & supervision
 manufacturing clerical labor
 inspection (QA & QC)
 worker productivity changes

Indirect Labor

maintenance (materials & labor)
 miscellaneous (housekeeping)
 medical surveillance

Regulatory Compliance

monitoring
 manifesting
 reporting
 notification
 recordkeeping
 training (right-to-know, safety, etc.)
 training materials

inspections
 protective equipment
 labeling
 penalties / fines
 lab fees
 insurance
 R&D to comply with regulations
 handling (raw materials and waste)
 closure & post-closure care

Revenues

sale of product
 marketable by-product
 manufacturing through-put change
 change in sales from:
 increased market share
 improved corporate image

Exhibit 3 Descriptions of Visited Electroplating Operations

NUMBER OF EMPLOYEES	INDUSTRY SERVED	PROCESSES (MINOR PROCESSES)	CAPTIVE (C) JOB SHOP (JS)
20 production ¹ 2 maintenance ² 0 direct administrative ³ 0 direct sales	Tubular steel; furniture and displays	Copper/nickel/chrome (phosphating)	(C)
20 production 0 direct maintenance 3 administrative 1 sales	Tubular steel; furniture and displays; exercise equipment	Copper/nickel/chrome (bright nickel) (black nickel)	(JS)
6 production 1 maintenance 2 administrative 0 direct sales	Tubular steel; furniture and displays	Copper/nickel/chrome	(JS)
20 production 2 maintenance 2 administrative 0 direct sales	Cast, forged steel; hand tools and related equipment	Copper/nickel/chrome (phosphating) (anodizing)	(C)
32 production 3 maintenance 5 administrative 2 sales	Cast, forged steel; hand tools and related equipment	Copper/nickel/chrome	(JS)
14 production ⁴ 2 maintenance 5 administrative ⁵ 0 direct sales	Formed sheet steel; bumpers and auto trim; new and re-work	Copper/nickel/chrome	(JS)
120 production 10 maintenance 20 administrative 5 sales	Formed sheet steel; bumpers and auto trim; new	Copper/nickel/chrome	(JS)
45 production 5 maintenance 7 administrative 2 sales	Injection-molded plastic; nameplates and trim	Copper/nickel/chrome (gold)	(JS)
100 production 8 maintenance 0 direct administrative 0 direct sales	Cast brass; sanitary fixtures	Copper/nickel/chrome (bright nickel) (electroless nickel) (tin/lead solder)	(C)
75 production 12 maintenance 12 administrative 4 sales	Injection-molded plastic; sanitary fixtures	Copper/nickel/chrome (black chrome)	(JS)
32 production 6 maintenance 7 administrative 2 sales	Sheet steel, fabricated; electronics; housings and enclosures	Zinc and chromate (powder coating)	(JS)

¹Calculated as full-time equivalents

²Includes environmental

³ "Direct" refers to a position devoted to this activity in this area (in the case of captive shops) or facility (in the case of job shops. The activity, if listed as "0", is covered as part of another position.

⁴Includes stripping and buffing operations

⁵Includes counter sales

12 production ⁶ 0 direct maintenance 2 administrative 0 direct sales	Sheet steel, fabricated; electronics; housings and enclosures	Zinc and chromate (painting)	(JS)
6 production 0 direct maintenance 1 administrative 0 direct sales	Ferrous and non-ferrous machined parts; consumer goods; fasteners	Zinc and chromate (silver) (copper)	(JS)
38 production 4 maintenance 7 administrative 1 sales	Variety of substrates and forms; consumer goods; fasteners	Zinc and chromate (tin) (tin lead)	(JS)
24 production 2 maintenance 3 administrative 0 direct sales	Wide variety; no primary market	Zinc and chromate	(JS)
18 production 2 maintenance 4 administrative 1 sales	Wide variety; no primary market	Zinc and chromate	(JS)
60 ⁷ production 2 maintenance 3 administrative 1 sales	Steel enclosures and parts; military	Zinc and chromate	(JS)
5 production 0 direct maintenance 3 administrative 0 direct sales	Specialty; electronics	Zinc and chromate (precious metals) (anodizing)	(C)
20 production 2 maintenance 3 administrative 1 sales	Wide variety; no primary market	Electroless nickel	(JS)
12 production 2 maintenance 2 administrative 0 direct sales	Wide variety; no primary market	Electroless nickel	(JS)
6 production 0 direct maintenance 3 administrative 0 direct sales	Specialty; electronics	Precious metals	(JS)
49 production 4 maintenance 9 administrative 3 sales	Ferrous and nonferrous substrates; jewelry	Precious metals	(C)
14 production 2 maintenance 0 direct administrative 0 direct sales	Steel; printing	Hard chrome	(C)
8 production 0 direct maintenance 0 direct administrative 0 direct sales	Steel and other substrates; automotive	Hard chrome	(C)

⁶Other areas not involved in metal finishing not included

⁷Includes specialty cleaning operation

4.0. ANALYSIS OF ENVIRONMENTAL COSTS IN ELECTROPLATING OPERATIONS

Exhibits 4-7 summarize the research findings on cost issues found in electroplating operations. The research focused exclusively on operating costs -- both direct and indirect. Contingent costs (costs based on probabilities of events occurring in the future) and image costs (intangible costs associated with company goodwill of improving environmental performance) were not included as part of the investigation. The rationale for their omission is that these costs are highly context and situation specific while the purpose of this report was to generate information generally applicable to all electroplating facilities.

The following synopses of operating costs is based on the cost categories found in Exhibit 2. During the analysis, special attention was given to cost elements which other EA research studies had found to be frequently under recognized in operations in order to shed additional light and information on identifying, quantifying, and allocating these costs.

Following are synopses of each cost area.

4.1 *Materials*

Key wasted materials costs in electroplating

- Process chemistry
- Addition agents
- Cleaners
- Water
- Miscellaneous chemistries (e.g. strippers, chromates)
- Acids

Direct Product Materials -- Applicability and Significance

Costs for coating materials (zinc, nickel, copper, gold, silver, etc.) appear to vary greatly both comparatively and with respect to their significance in the overall facility cost structure. Precious metals and some other materials (like electroless nickel, electroless copper, and some alloys) are expensive to deposit. Significance is also affected by the scope of processes within a shop -- if a facility focuses on a particular type of plating

process, plating materials associated with this process will be a large item for the facility even if the materials are comparatively inexpensive. Hidden costs in terms of materials waste can be traced to two sources - a differential between the amount of coating materials purchased and the amount of metal that actually goes out on parts, and another differential between the amount of metal that goes out on parts and the amount that is actually needed to meet the desired production requirements. This, of course, has subsequent implications for wastewater and disposal costs.

Costs for addition agents (brighteners; pH adjustment; consumable components like cyanide) demonstrate enormous variation by process, and are dependent not just on market price of metals (as in the cost of coating materials), but also on the cost of formulation, size of market (small niches may feature high materials prices enabling manufacturers to recoup development costs), age of product (new materials cost more) and function of the process solution (run to depletion like electroless nickel vs. maintain for many years like nickel sulfate). The research suggests that by far the most ubiquitous and expensive (cost per unit volume as well as total cost) are brighteners. Research also suggested that cost understanding is often poor in this area as standard operating practices for additions is often highly subjective. As a result, a scan for price and use volumes is highly recommended in reviewing plating cost structures.

As with other direct materials inputs, costs for acceptable water vary greatly, and will depend on the type of process solution and products. Water inputs can be characterized most readily in reference to either 1) current water quality (usually most important when using ground water rather than drinking water) and/or 2) market niche (electronics requiring extremely pure water, most others increasingly requiring at least supplemental treatment up to and including deionization). Also influencing the variability and relative significance of water costs are noted trends toward generally higher water costs and, in some cases, restricted availability (South San Francisco Bay Area; Phoenix; Los Angeles County). Water costs are also linked to pretreatment costs, since capital costs for equipment are directly linked to hydraulic loadings of the system. This, in turn, establishes a relationship with other cost issues such as indirect labor since the greater the hydraulic loading, the larger the system, and the more maintenance is required. Its significance is enhanced by the fundamental relationship between water use and quality/process control.

EXHIBIT 4: EA IN METAL FINISHING -- MATERIALS

TYPE OF COST	SIGNIFICANCE	ALLOCATION PRACTICE	ASSIGNABILITY AND ACCURACY	DATA GATHERING AND MANAGEMENT ISSUES
Plating materials	Varies on type of plating	Product level when high volume material or expensive (e.g. precious metals)	Only assignable and accurate where volumes or material costs require it	Data gathering, management and analysis limits further ECA. Great care is advised in the decision whether or not to allocate plating materials as part of ECA.
Addition agents	Enormous variation by process. Brighteners typically most significant	Typically general overhead, very seldom at product or process level	Large (and inexplicable) variances found between purchase and use records suggesting accuracy problems	Cost understanding appears to be poor in this area. A scan for price and use volumes is definitely recommended
Water	Significant because of relationship to both environmental management costs and quality	General overhead, even in high cost situations	Theoretically possible but with limited accuracy because of valves in use ($\pm 20\%$)	Concurrent investments needed in monitoring and control equipment; more pressing issue is selling managers that this is worth doing
Solvents/ Other Cleaners	Alternative cleaners increasingly significant because of higher cost and treatment challenges	Almost always in general overhead	Possible to further allocate but plagued by general inability to say with confidence <u>how much</u> cleaner and solvent use would decrease	Must crosslink to quality and production management data and operating procedures to determine potential improvement numbers
Acids	Significant in some applications (e.g. electronics, plating on plastics); not in others	General overhead	See cleaners; possibly worse because of perceived lower value of information	Must crosslink to quality and production management data and operating procedures to determine potential improvement numbers
Filters	Low, but underrecognized	General overhead	Process level is possible	Because of its direct linkage to particular processes, one of the better and simpler cost candidates for ECA
Miscellaneous Chemistries	Low but underrecognized	General overhead	Expected to have low accuracy because of information gathering issues	Dispersed use patterns, episodic ordering and general lack of other reasons to keep and track this information

EXHIBIT 5: EA IN METAL FINISHING -- WASTE MANAGEMENT

TYPE OF COST	SIGNIFICANCE	ALLOCATION PRACTICE	ASSIGNABILITY AND ACCURACY	DATA GATHERING AND MANAGEMENT ISSUES
Wastewater Treatment	Very significant	Sometimes general overhead, sometimes allocated to department by volume and/or incidence	Possible, with some effort, to calculate a "\$ /gal treated" value; caution exercised given elusive nature of "incremental" savings in treatment; best examined when eliminating a need entirely	Value generation complicated by not knowing <ul style="list-style-type: none"> • what is really in waste water • when • how much it varies
Storage	Varies, depending on nature and size of facility	General overhead, in an established facility waste management line	Unless eliminating need entirely, reductions in need seldom have corresponding reductions in cost	Recordkeeping demands implementation
Handling / Disposal	Varies, depending on nature and size of facility	Typically overhead, in an established facility waste management line but may be charged back to departments	High and straightforward on a unit volume basis. High accuracy excluding labor	Examination of percent regulated materials adds information value
Insurance	Overall significant but very rare to find insurance exclusively pertaining to waste management	Overhead in a general and operations line.	Low, unless eliminating need entirely, reductions in need seldom have corresponding reductions in cost	Creation of cost per unit volume calculations clumsy; facility unable to accommodate analysis

EXHIBIT 6: EA IN METAL FINISHING -- UTILITIES

TYPE OF COST	SIGNIFICANCE	ALLOCATION PRACTICE	ASSIGNABILITY AND ACCURACY	DATA GATHERING AND MANAGEMENT ISSUES
Energy - Electricity	Very significant	Overhead - G&O line	Very unlikely; would require estimation of cost per unit volume of something that varies constantly	
Energy - Steam / Natural Gas	Significant	Overhead - G&O line	Very unlikely; no examples found of discrete component of steam use for products or processes	
Sewerage	Significant if special surcharges have been applied because of local conditions and requirements	Overhead - often a G&O line	Possible to assign but with very limited accuracy because varies continually. Can be improved by insuring segregation of process related sewerage from non-process related sewerage	Concurrent investments needed in monitoring equipment. Further complicated by the fact that sewer charges often no direct relationship to the amount of water actually being discharged from a facility. Is, however, getting growing management attention and may be ripe for ECA purposes.
Process Air	Increasingly significant with increases in amount of source reduction activity (agitation, blow-off, creation of fog rinses, etc.)	Overhead G&O	Possible by unit operation but only somewhat accurate because of wide variation in possible use and amount of access by operators	Cost of producing clean compressed air is difficult to calculate

EXHIBIT 7: EA IN METAL FINISHING -- REGULATORY COMPLIANCE

TYPE OF COST	SIGNIFICANCE	ALLOCATION PRACTICE	ASSIGNABILITY AND ACCURACY	DATA GATHERING AND MANAGEMENT ISSUES
<p>"Substance Driven Costs"</p> <p>(driven by use of particular substances in the facility)</p> <ul style="list-style-type: none"> ~ monitoring ~ protective equipment ~ lab fees ~ manifesting ~ labeling ~ R&D to comply with regulations 	<p>Varies, depending on nature of facility and types of processes.</p> <p>In total, can be significant</p>	<p>Overhead G&O</p>	<p>Assigned quite readily to processes</p> <p>Highly accurate when linked to one source, less accurate with multiple sources in facility</p>	<p>Recordkeeping demands limit allocation potential</p>

<p>"Regulatory Response Driven Costs"</p> <p>(driven by generalized need to respond to regulations)</p> <ul style="list-style-type: none"> ~ reporting ~ recordkeeping ~ inspections ~ notification ~ handling ~ fees, fines, penalties ~ audits / plan preparation ~ personal injury ~ closure and post closure care ~ insurance ~ training ~ consultants fees 	<p>Taken together, sum can be significant</p>	<p>Overhead G&O</p>	<p>Problematic without a means to assign on a volume basis.</p> <p>Only somewhat accurate</p>	<p>Recordkeeping demands limit allocation potential</p>
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Direct Product Materials -- Assignment and allocation

Costs for coating materials are assigned at the product level -- especially among users of precious metals -- and more of this type of assignment could probably be done. However, it does not appear valid to use the experience of the users of precious metals as a guide. Those companies are able to allocate costs at the product level because extremely accurate records are kept of additions, precious metal concentration in the process solution, surface area of parts, and thickness of precious metal coatings.

Base metals were only found to be allocated to the product level when it was either a high volume material or when it was expensive for other reasons. In these circumstances, allocation was found to be nearly always done using a gross multiplier during cost estimation (e.g. 1000 square feet surface area to be plated to a thickness of .0005 inches gets a "factor" of 20% added to the price.) This factor moves with the thickness and sometimes the surface area. Greater allocation to the product level would be technically possible, but probably be thwarted by the amount of record keeping required that is not useful for any other purpose. Therefore, most allocations are likely restricted to the process level. It is believed that this allocation would be accurate in nearly all cases.

Research suggests that costs for addition agents could probably be assigned but restricted to the process level. It is believed that this allocation would be accurate in nearly all cases. Costs for water could be allocated, but only with an investment in monitoring and control equipment. Such investments have proven to be unlikely unless linked to other facility needs. However, even if assigned, costs for water would only be somewhat accurate, with an estimated variance of $\pm 20\%$ as this is the estimated range for water flow through the most common valves in use. Even in high cost situations, water was found to be included with other general overhead charges and allocated in whatever way the facility chose to allocate general overhead.

Indirect Materials Use -- Applicability and significance

In finishing operations, a wide variety of indirect materials are used in surface preparation, in the finishing process itself, and in rework operations. As with direct materials, there is a significant amount of variability concerning the absolute and relative significance of indirect materials depending on the type of finishing operation. As alternative cleaners replace traditional organic solvents, the significance increases in two

ways. First, they are more expensive to purchase -- research found situations where purchase price of new cleaners exceeded old solvents by a factor of 12. Second, they can be more expensive to treat, or at least this is the presumption.

Costs for acids are not particularly significant except in easily discerned cases such as electronics; plating on plastics; and etching/deburring as pre-plate operations. Costs for filters and miscellaneous chemistries tend to be small in most shops but underrecognized and is therefore a good addition to EA.

Indirect Materials Use -- Assignment and Allocation

Costs for acids, filters, cleaning materials and miscellaneous chemistries (strippers, chromates) tended not to be allocated outside general overhead. These materials demonstrate dispersed use patterns, episodic ordering, and a lack of other reasons to keep the required records (mostly use logs) thereby inhibiting process or product assignment. Evidence from some facilities suggests that even if the allocation were attempted, it would not likely be accurate because of a reliance on individual effort and a perception of low value ascribed to the effort. Some evidence was found of allocation of cleaners to product and in other situations by process, since it involves a discrete unit operation. However, no approaches were found in the research that break that cost down between solvent actually used to clean parts and solvent lost to evaporation. Therefore, costs are likely to be completely accurate only where complete elimination is contemplated. Where more efficient operations (increased freeboard; reduced withdrawal rate) are proposed, costs are likely to be only mostly accurate.

By definition, process level allocation of filters is possible given that each filter is "assigned" to a particular process. Product level allocation is impossible.

Materials Storage

A final category of cost analysis pertaining to materials is storage. These costs are not very applicable to P2 analysis for electroplating operations. Most P2 options related to materials storage involve replacing materials and equipment which still requires storage. Research suggests that storage related to input materials is not usually a significant cost, and not often connected with other costs likely to be analyzed.

4.2. Waste Management

Key waste management costs in electroplating

- Handling
- Storage
- Disposal
- Wastewater treatment -- labor, chemicals, energy
- Insurance
- Transportation

Applicability and significance

Waste handling, storage, insurance, and wastewater treatment appear to have considerable potential to elucidate a P2 project analysis. Typically, handling and storage costs are subsumed together in a facility waste management line while insurance costs are often found in a general operations line. Insurance pertaining specifically to waste management operations is exceedingly rare. Insurance costs (overall) are clearly significant in most operations.

Moving materials from place to place, especially as segregation increases, appears to require considerable labor and equipment expense. Options short of elimination (segregation to facilitate recycling, for example) appear to increase this cost burden. Storage costs can be significant in larger operations where waste treatment areas can be 25% the size of production areas. In smaller operations these costs are marginally significant and it is probably best to think of them in combination with other related waste management activities.

Much of the cost analysis has its greatest relevancy when a facility is being designed. Capital costs related to buying tanks, building storage sheds, diking warehouse areas, etc. are very significant. Since sludge in many cases can only stay on-site for 90 days, the relevance to pollution prevention project analysis is typically limited to those circumstances when a massive overhaul could possibly prevent the need to build more storage. The same logic applies to insurance costs since systems/options can be assembled that could, if done well, change risk categories. Research suggests that a pollution prevention option that reduced the need for storage would not reduce the costs of storage, or at least not very often. Likewise an option that reduces the need for storage seldom reduces the costs of insurance.

The primary and priority cost center, operation and maintenance of a conventional wastewater treatment system, combines a wide variety of labor, chemical, and utility costs. The significance of cost burden for facilities is high and made higher by the need to reduce chrome or oxidize cyanide if those processes exist in a facility. Costs may also be unnecessarily inflated by less than optimal management practices. Similarly, the use of recovery technologies as "pretreatment" to the treatment system carries potentially significant costs and will generate wastes themselves. Caution must be exercised when reviewing cost implications of this technology use since costs appear to be shifted as often as they are actually reduced.

Assignment and allocation

Allocation of waste storage and handling costs only to processes or products generating the need for handling appears straightforward, especially when considered as part of the overall waste management line. Typical assignment would be on a unit volume basis. Insurance, however, poses a more challenging problem, and allocation of these costs only to processes or products generating the need for some discrete component of insurance seems unlikely. Such an insurance line item would involve estimation and/or calculation of the cost per unit volume to insure activities that seem hardly to be recognized in policies as risk vectors.

The accuracy of waste management costs is difficult to ascertain. It is doubtful that these costs could be readily audited, since it relies heavily on a labor component that would in turn rely on individuals differentiating their activities. Accuracy even of the overall waste management line is also somewhat suspect, since records seem to rely upon time assigned to duties, rather than tracking of actual time spent.

Wastewater treatment system costs typically appear as an overhead charge and are most frequently allocated across all processes based on square footage of production or some other related measure. Occasionally facilities were found in which veteran estimators knew that certain processes created larger treatment burden than others and made some attempt to differentiate charges. This practice, however, more often occurred in response to pricing sensitivity rather than to seek an understanding of the "true costs." In other words, more refined allocation measures were employed to figure out a way to pass the cost on rather than reduce it. In other, typically larger, facilities the treatment system was

a cost center with charge-backs to departments based on volumes and/or incidences such as bath dumps. However, charge-backs appear to be based on rather crude calculations.

4.3 Utilities

Key utility costs in electroplating

- Energy
- Sewerage
- Process air

Energy -- Applicability and significance

Electricity in general as a cost to electroplating facilities is extremely significant. However, its applicability as an area of cost analysis for pollution prevention purposes is inherently limited. By far the majority of electricity goes for application of coatings in heating and electrodeposition which have physical limits to their efficiency and is therefore rarely the focus of pollution prevention analyses. Steam and natural gas is used in some facilities for process heating, and for facilities with large boilers or ovens, this can be a significant cost. It also may, in some cases, be part of the need for an air permit. Natural gas may also be used for firing bake or dry ovens. These costs are nearly always subsumed in a "general operations" line.

Energy -- Assignment and allocation

Allocation of these costs only to processes or products generating the need for some discrete component of power or fuel use seems unlikely. This cost seems nearly impossible to allocate; it would involve estimation and/or calculation of the cost per unit volume of something that varies constantly; at a minimum, significant investment in monitoring equipment would be required. Likewise, assignment of steam costs only to processes or products generating the need for some discrete component of steam use seems unlikely.

An interesting sidelight discovered in the course of the research is the use of electrical consumption as part of a ratio to adjust measures of P2 progress. The theory is that use of

electricity declines when work activity declines, so a electricity/water use ratio could be derived that would shed some light on whether water use declined as a result of P2 activity or a decline in business activity. Unfortunately, this would still be very hard to use at anything other than the facility aggregate level.

Sewerage -- Applicability and Significance

Sewerage costs should be applicable to the analysis of any facility and any specific pollution prevention project dealing with water use and water waste streams. It is worthwhile to note that sewer charges can and are computed in many different ways -- many of which have no direct relationship to the amount of water actually being discharged from the facility. Some facilities have a standard sewer charge based on inputs into the facility rather than outputs. Others feature a cost computation based on broad categories rather than actual amounts -- for example the size of pipe combined with the amount of water purchased is determined to be equal to the amount of water sewered with a multiplier applied to monthly activity. Sewer costs can be especially significant if special surcharges have been applied because of local conditions and requirements. These costs are nearly always subsumed as part of other categories.

Sewerage -- Assignment and Allocation

It appears possible to assign these costs to processes or products generating the need for some discrete portion of sewer use. However, as with other utilities, this cost seems nearly impossible to allocate accurately as it would involve estimation and/or calculation of the cost per unit volume of something that varies continually. As with other utilities an increase in accuracy would require significant investments in monitoring equipment.

The quality of cost analysis and assignment in sewerage could be improved, however, by separating process-related from non-process-related sewerage. The research found many instances of large volumes of non-contact cooling water, water from cooling towers, domestic sewerage and even storm water being combined with process water, thus raising volumes and charges or, at a minimum, obscuring industrial use information which would be the focus of a P2 project analysis.

Process air -- Applicability and Significance

Costs for clean process air, especially compressed air, may be applicable to a P2 project analysis -- although the issue here is ensuring that this cost is accounted for in the economic analysis of the P2 option. Clean compressed air is an important component in several "keystone" source reduction concepts for electroplating facilities, e.g., dry air blow-off of process solution to reduce water use; clean air to increase agitation in water rinses and reduce need for water use; warm air mixed with water rinses to create "fog" rinses and reduce need for water rinse. A facility implementing the above source reduction option could easily outstrip existing compressed air capacity, especially since clean and/or dry is quite expensive to generate. These costs are often not significant, but may become significant with substantial source reduction activity. Several facilities contacted in the research reported costs for air outstripping costs for some acids. These costs are always subsumed in a general operating category

Process air -- Assignment and Allocation

Assignment of these costs by unit operation are possible, since most applications are designed with specific flows both required and controlled. However, two complicating factors exist. First, the cost of producing clean compressed air is difficult to calculate as no generally accepted default values were found to exist during the project research. Second, this allocation would only be somewhat accurate because of the wide variation in use possible and the amount of access by operators to the system

4.4 Direct Labor -- Clerical and Inspection

Applicability and Significance

Because pollution prevention projects in electroplating typically have strong process control, recordkeeping, monitoring, and analysis themes associated with them, manufacturing clerical labor expenses will tend to be applicable. P2 project analysis may also require specification and contract review, another purpose for which manufacturing clerical labor would be used. These can be significant costs in many operations and are related to similar activities undertaken to improve quality and/or productivity that may be part of a P2 project analysis.

Some P2 projects may also affect the need for parts inspection, especially in cases where overall process quality is improved or a particular finish is modified. Therefore, these costs may be applicable to P2 project analysis, albeit marginally. Research found that inspection costs are part of overhead in about 50% of facilities investigated, and part of a separate quality management and documentation system in the other 50% of facilities. In the latter case, inspection costs are sometimes identifiable as separate costs, but not at the product or process level. In a few cases of high-volume or sophisticated products, inspection costs may be both specific and allocated. Inspection activities tend not to be significant costs. In addition, the "quality revolution" has caused most inspection activities to be combined with the production duties of operators, which further reduces the significance of the costs, since inspection is almost always done in the "down time" that occurs while waiting for parts to be processed.

Assignment and Allocation

Manufacturing clerical costs could be assigned, but only in settings where workers in these labor categories already use activity coding for other purposes, or are specialists who could respond accurately to interview-based analysis. Allocation of these costs seems to be only somewhat accurate, apparently because a "life cycle" of recordkeeping was found in project research -- intensive in the early stages of project analysis, decreases to a somewhat lower level during decision making and implementation, and may disappear entirely at a later point. However, several cases were described that incorporated the new records and analysis into quality monitoring systems, thus permanently increasing these costs.

Assignment of inspection costs seems to be unlikely and, if attempted, inaccurate.

4.5 Indirect Labor

Applicability and Significance

Applicable indirect labor elements in electroplating includes maintenance and medical surveillance. Maintenance costs do appear quite applicable to a P2 project analysis and can come in many forms. Process solution maintenance tends to be done by production operators, with significant exceptions in the electronics products and aerospace industry

sectors. Mechanical maintenance is usually done by specialists, either in-house or contracted. Maintenance done by operators is often done during down time while waiting for parts to process, and may or may not be recorded separately while maintenance done by contractors, in-house specialists, and for special projects (process solution changeover on a weekend, for example) are often recorded and tracked through a system of work orders or job sheets. These costs are often significant, especially in larger facilities.

Medical surveillance costs may be applicable to a P2 project analysis, especially if the project contemplates eliminating particular substances or unit operations which cause the need for monitoring. These activities are nearly exclusively performed by clinics or outside contractors and are accessible as separate line items only in rare cases. In most facilities, these are treated either as "general operating" costs or even as part of "employee benefits." These costs are apparently only significant in a small group of facilities, but the cost significance issue may be rendered moot. Even if the P2 option reduces or eliminates the need, monitoring may still be either required, prudent, or very desirable.

Assignment and Allocation

Maintenance done by contractors, in-house specialists, and for special projects could probably be allocated accurately to the process or unit operation level. However, maintenance done by operators is probably impossible to assign separately unless supported by a work order / paper trail and distinguished from production activities.

Assignment of medical surveillance costs seems likely to be possible and will probably be quite accurate, inasmuch as they are driven by specific monitoring and not general screening.

4.6 Regulatory Compliance

Applicability and Significance

As with other industries, electroplating features an extensive array of cost items pertaining to the regulatory compliance and the environmental management function. For purposes of analysis, it is useful to segregate these compliance costs into two categories --

those driven by a facility's use of particular substances and those driven by the facility's generalized need to respond to environmental regulations.

Substance-driven costs would include:

- monitoring
- protective equipment
- lab fees
- manifesting
- labeling
- R&D to comply with regulations

These costs are usually applicable to a P2 project analysis and typically subsumed in a "general operating" category. Of this list, lab fees and monitoring can often be significant costs.

Regulatory response driven costs would include:

- | | | |
|-----------------|---------------------------------|-----------------------|
| • reporting | • closure and post closure care | • handling |
| • recordkeeping | • personal injury | • fines and penalties |
| • inspections | • notification | |
| • insurance | • training and materials | |

These costs are usually applicable to a P2 project analysis and usually subsumed in a "general operating" category. With the exception of closure which can be associated with very high costs, the individual cost elements may not be very great. However, taken together, their sum can be quite significant.

Assignment and Allocation

The purpose of distinguishing these compliance cost categories lies in their ability to be assigned to processes or products. The former set -- use driven costs -- can probably be assigned quite readily and the allocations would probably be quite accurate. Costs associated with generalized compliance response prove far more problematic. They can probably be assigned only on a volume basis (e.g. 10% of sludge is nickel so 10% of cost pool goes to nickel processes). Such assignments would only be somewhat accurate.

4.7 *Incremental Revenues*

Applicability and Significance

Revenue accruing from the production and sale from a marketable byproduct is common in electroplating and applicable to P2 project analysis. Most electroplating facilities selling byproducts seem to include these revenues as part of a general income line. These revenues tend not to be very large components of gross revenues and, furthermore, vary considerably because of their exposure to price swings in commodity markets. As a result, reliance on these revenues for cost/benefit analysis when doing project analysis is fairly rare.

Sales increases as a result of image improvements might be possible, but the research found no instance of a facility willing to consider this approach to valuing the results of P2 projects.

Assignment and Allocation

Byproduct revenues can be allocated accurately, but generally cannot be projected for use in capital budgeting efforts.

5.0 ISSUES IN IMPLEMENTING ENVIRONMENTAL ACCOUNTING IN ELECTROPLATING OPERATIONS

Electroplating firms contacted and visited for this project have recognized that waste management and regulatory compliance involve more costs than those in evidence as totals on just the checks written to treatment and disposal firms. In addition, these firms are seeing that more benefits accrue to their facility -- and financial statements -- from pollution prevention approaches than has usually been portrayed in the past.

EA has a role in facilitating this understanding, supporting better project analysis, and prompting more implementation. A generally accepted EA implementation strategy is comprised of the following steps:

- Identify environmental management costs
- Prioritize and select the costs to investigate in more detail
- Quantify or qualify the costs
- Allocate costs to products or processes responsible for their generation
- Integrate costs into facility decision-making

Following is a discussion of the relevant issues pertaining to each of these steps as they relate to finishing operations.

5.1 Identifying Environmental Costs

As the following table illustrates, environmental management costs in electroplating facilities might best be broken into two primary categories -- 1) direct and indirect operating costs associated with environmental management and compliance and 2) opportunity costs stemming from not using raw materials as efficiently or as productively as possible. The direct and indirect costs associated with environmental management issues highlighted in the previous tables vary in their relevance to finishing operations and in their "ability" to be identified depending on the types and nature of processes employed at the facility. Generally speaking, however, these direct and indirect costs can be quite readily identified by a facility. Those which require actual checks on a regular or semi-regular basis were quickly identified by the facilities visited and leave a paper trail

in the system. Smaller, more miscellaneous expenditures such as regulatory fees were also identified with some limited prompting.

Environmental Cost Components³

Type	Environmental Management Costs	Lost Material Costs
Examples	<ul style="list-style-type: none"> ~ labor cost for environmental compliance ~ regulatory fees ~ purchased materials for water treatment 	<ul style="list-style-type: none"> ~ wasted process solution ~ lost process chemistry
How Identified	<ul style="list-style-type: none"> Cost Accounting Review ~ general ledger review ~ payables review 	<ul style="list-style-type: none"> Cost Accounting Review plus Process Review ~ materials balance ~ process benchmarking

Environmental management costs which do not involve monthly check writing (e.g. indirect labor, etc.) were also readily acknowledged by facilities and recognized as something which should be reduced. An important complicating issue here, however, is the degree to which facilities can link them to specific activity drivers (e.g. separating the indirect labor pot into its components of recordkeeping, monitoring, notification, etc.). Although facilities recognize their existence, they proved to be far less willing or able to identify costs at this level of individual detail. From a standpoint of EA analysis, such an effort may not be necessary given the relative size of these items in relation to other cost elements.

The drivers of these direct and indirect costs, rather than the costs themselves, were most often underrecognized by a facility. This was especially true in target areas such as wastewater treatment and hazardous waste disposal. While facilities could generally develop cost totals for these areas, the understanding of the contribution and impact episodic events such as disposal of tank bottoms, rework of reject parts, and bath dumps have on these items was underrecognized. Applying environmental accounting to these

³ Two other cost categories which may be a part of environmental management costs are contingency costs and image costs. However, a consideration of these costs is not included in the report. See Section 3.0

activities was found to generate interest in reducing the frequency of these events through better process management and control.

A larger and more significant set of environmental costs for electroplating are the opportunity costs of unoptimized materials use. These opportunity costs are the value of lost process materials -- materials purchased but not sold, wasted, or not used as efficiently or as productively as could be. They are implicitly more difficult to identify for the following reasons:

- There are few readily available "best industrial practice" benchmarks to indicate to a facility how efficient or productive their processes could be from the standpoint of materials use.
- Reviews of electroplating cost and pricing literature found no way to track lost material through explicit or implicit loss allowances. It may exist in some electroplating facilities for very specific reasons, but nothing was uncovered in this project research.
- Cost accounting systems do not capture such opportunity costs with a line item called "wasted raw material." In fact, the opposite may be true -- cost accounting systems may artificially hide this cost of waste by building costing systems on standard loss allowances rather than actual losses.

Adding the opportunity costs with the direct and indirect environmental management costs gives a facility a more accurate measure of the facility's total cost of waste. They are also obviously interrelated: reduction in these opportunity costs will decrease primary environmental management costs such as wastewater treatment and hazardous waste disposal.

5.2 Prioritizing Costs to Investigate

For reasons described above, facility attention should first be focused on valuing the opportunity costs of materials losses before attempting to "unpack" environmental overhead in deeper levels of EA analysis. The research showed that for electroplating facilities the significance of environmental management overhead items generally pale in

comparison in amount and significance to these opportunity cost issues. For example, in one of the zinc shops visited:

Apparent cost of F006 sludge based on payments to TSD and hauler:	\$525/ton
EA-generated share of overhead cost	<u>\$67/ton</u>
Apparent cost of sludge adjusted for allocated overhead	\$587/ton
Cost of lost process chemistry ⁴	<u>\$306/ton</u>
Cost of sludge adjusted for environmental management and opportunity costs	\$893/ton

In this example, the opportunity costs of lost material exceeded the overhead allocated costs by a factor of nearly five. In many of the shops visited, opportunity costs exceeded environmental management costs by a factor of ten.

The opportunity costs likely to generate motivating numbers for the facility to consider are:

- value of lost process solution and chemistries
- excess water use

Once this understanding is gained, it can be used as part of the analysis for other direct "big ticket" EA cost items such as wastewater treatment, sewerage, and waste disposal. For example, every gallon of excess water use creates an environmental management cost that is typically undervalued. Care should be taken to always divide total environmental management costs related to wastewater into wastewater volume since EA analysis has shown that wastewater costs can be surprisingly high.

5.3 Quantifying or Qualifying Costs

Efforts to quantify environmental management costs begin with the ability to access cost information. Assuring the accuracy of this quantification effort is equally important.

⁴ [Sludge at 1% zinc metal/ton = 320 oz. zinc metal/ton) ÷ (zinc cyanide plating solution at 4.7 oz/gal)] x (zinc cyanide plating solution at \$4.50/gal) = \$306.38

Quantifying direct and indirect environmental management costs, as described earlier, can be quite straightforward for certain items (those with invoices) and less so for other elements (e.g. labor component, liability). The challenge found throughout project research was the ability to quantify these costs at a level of detail to help facilitate an EA analysis. Electroplating facilities visited and contacted for this project tended to aggregate many costs into very general categories, at least when preparing financial statements such as balance sheets and profit and loss statements. Moreover "mining" this information at a level of detail necessary to enable allocation is potentially an expensive thing for a facility to do and there often appears to be no other particular production or management reason for collecting and managing information at this level of detail. Without other opportunities for using this information, its collection and management is even less likely for a facility.

Labor costs are often major components of "hidden" environmental management costs. Both direct and indirect labor are captured on the general ledger and subsequent statements as aggregated costs. Supporting documentation, usually time sheets, use codes, part numbers, job names, or similar appellations are used to distinguish between work activities for production and support staff, and usually use considerable less detail for salaried personnel, e.g., a manager in charge of research and record keeping for regulatory compliance. These can be used to help allocate costs to responsible products or processes. However, two issues arose which affected the use of labor costs in an EA analysis:

- Minimal or no effect on cash flow -- In no facilities reviewed would a strategy offer the potential to actually reduce labor costs in such a way that cash flow is affected. Discussions with facility representatives on the labor valuation issue suggested a hesitancy to assign "savings" to activities which did not directly affect payroll or payables.
- Need to recognize labor trade-offs -- Facilities recognized that reducing necessary investments in environmental labor offered the potential to reallocate human resources to more productive activities. However, finishing facilities are quick to point out that whatever pollution prevention technique or technology is being evaluated is likely to also have its own increases in labor costs. Environmentally preferable processes or recovery technologies typically have tighter operating windows requiring more careful monitoring practices and new

standard operating procedures. Recovery technologies typically are quite sophisticated demanding increased maintenance, monitoring, training and control efforts. The National Association of Metal Finishers has reported technology failure rates of 30-40% for various types of recovery technologies within the industry, and experts believe a portion of this failure may be due to labor issues and the sophistication of the technologies.

It is clear that environmental labor issues are important and relevant to an analysis, and decreases in regulatory-related labor activities of all types is certainly in the best interest of a facility. Many facilities also seem to benefit from quantifying these labor costs to obtain an understanding of the potential productivity gains which may be available. However for actual economic evaluations of projects, many of these labor issues might be best factored into an analysis in a qualitative fashion.

Quantifying the opportunity cost component is an ongoing challenge of finishing operations because it requires an ability to assess "how good the process could be." Quantifying the opportunity cost component faces two key problems:

- 1) Accuracy of cost information is frequently questionable -- The reality in electroplating is that only information based on an invoice or similar documentation can be trusted to be completely accurate. Data derived from internal records and calculations, or even from interviews of personnel, are at their most reliable still highly variable, simply because of the ever-changing nature of electroplating operations. Some facilities will add to that variability with spotty record keeping, personal bias, and lack of equipment for proper monitoring. The only exceptions seem to be records that are also required to be kept for other purposes, such as demonstration of compliance with customer specifications or documentation for quality management systems.
- 2) Need for strong supporting production information systems -- Robust production management information is needed to be able to support the EA analysis and numbers. In parallel with the system of bookkeeping and accounting is the record keeping and analysis required to produce job cost estimates, schedule production and maintenance, do short- and long-range company planning, and track and assure quality. This system tends to be less accurate, mostly because it is heavily influenced by subjective responses, records kept by humans, and the

ebb and flow of customer demands. This is the very system that must produce documentation that would be used to cross-check estimates (acid purchased vs. acid used), analyze options (length of time required to rinse "thoroughly"), and gauge information needs for implementation (estimated down time for conversion to non-cyanide zinc).

5.4 Allocating Costs to Products or Processes Responsible for their Generation

The question of whether to allocate to processes or products depends on the type of project being investigated. Some pollution prevention technologies -- ion exchange, reverse osmosis, replacement of organic solvent cleaning, cyanide elimination, and others--are best supported by cost allocations to the process level. That is to say, as many costs as possible that are associated with a given process (the "target" of a pollution prevention technology) should be dis-aggregated and made part of the pollution prevention project analysis. Cost of process solution, cost of utilities, cost of labor: all become a legitimate part of the analysis. In that case, the technologies and allocation level "match"--what is needed happens to be for the most part available.

For other projects -- especially those having implications regarding water use, procedure modifications, or process re-design -- allocations to the process level are often insufficient. The success of these projects is many times product-specific, meaning that the relative effect of a product on the costs of operating a process is at least as important as the costs of process chemistry and waste management costs associated with a process. In these cases, pollution prevention project analysis requires knowing not just how much a given process costs in terms of process operations and waste treatment, but also what percentage of those costs are caused by Part A , Part B and Part C. Cost allocation at the product level is quite rare.

For most facilities visited, how to allocate was typically a greater issue than on what level to allocate. As in quantifying costs, individual pieces of EA analysis vary in degrees of difficulty with respect to allocating to their sources. Three allocation options facilities may consider are allocations based on actual contribution, allocations based on estimated calculations, and allocations based on professional judgment.

5.4.1 *Allocation Based on Actual Contribution*

Most of the "hidden" environmental management costs -- are extremely difficult to allocate based on their actual contributions. The number of product and process variables affecting actual contribution are typically too complex and systemic for most finishing facilities to be able to (or want to) generate actual contribution numbers. This is true even for the high profile environmental management costs. For example, in many shops, a large environmental management cost is the system used to satisfy the limits on concentrations of various materials in wastewater discharge permits. In order to accurately allocate to the process level the costs of creating and managing metal hydroxide sludge, a shop would have to account for:

- variation in product mix
- potential variation in operating procedures
- variation in chemical concentrations
- potentially numerous sources for each constituent of concern

A review of the literature found company examples that had documented in excruciating detail the relative contributions of different parts and solutions to different wastewater streams. Site-specific data were in fact generated, but so many variables were controlled as to render general transferability of this data to other facilities completely moot. The research required to allocate large costs like water, sludge generation, and concentrated process solution disposal appears to be too complicated and too expensive to be conducted by any but the most sophisticated electroplating operations.

5.4.2 *Allocations Based on Estimated Calculations*

Given these inherent difficulties, facilities have responded by allocating these costs based not on actual but estimated contribution. Estimations are typically generated in one of two ways -- using standard surcharges or "kickers" which the facility uses to price products; or using activity based measures.

Standard surcharges are commonly found in electroplating. A finishing operation might add 15% to the cost of the chrome finished products to cover treatment costs, but a 30% charge to cover cyanide processes. These percentages might also be used for cost allocation purposes. This approach is well-accepted in the industry. WRITAR found

evidence in our research of using "default values" based on sources such as the plating literature, discussion with peers, and personal or organizational experience. However, as with labor costs, these surcharges are "loaded" with extraneous costs not pertinent to a pollution prevention project analysis; typically assembled to recover production costs, not to reveal activity costs; and therefore yield high levels of inaccuracy.

An alternative way to allocate is through engineering estimates. Environmental management activity is first subdivided into separate categories of activity (e.g. cyanide destruction, chrome reduction, etc.) These activities are then assigned a cost, in this case usually on a "per gallons treated" basis by calculating the predicted costs of treatment for a specific concentration, flow, method, etc. These controlled variables are chosen to be nearly representative of actual facility conditions as possible, and the cost is "built" by analyzing each step of the process. Engineering estimates have higher levels of accuracy, and the greater the controlled variables reflect facility reality, the more accurate the estimates will be. Developing engineering estimates, however, is a sophisticated, technically demanding effort, and may be outside the scope of non-process experts.

Allocations based on an appropriate production factor (square feet processed, hours of operation, etc.) is perhaps the simplest type of estimated calculation and a possible short-cut to full engineering estimates. This allocation approach can be complemented by electroplating literature which will contain published industry averages like "dollars per gallon treated." Users however must recognize these estimates are averages and can vary significantly based on the production factors cited earlier (product configuration, concentration, flow, other materials in waste stream, etc.) As an example, in the hexavalent chrome facilities visited for this project, the dollars per gallon chrome reduction estimates varied by a factor of 22. As a result, production factor allocations are probably best used when high levels of accuracy are not determined to be critical.

5.4.3 *Allocations Based on Professional Judgment*

Another response to the difficulty of deriving actual values from records in electroplating is deriving relative contributions of the different components of an aggregated environmental cost using the best judgment of facility staff. Because real numbers are not generated, this approach is not used for capital budgeting. However, it could be used for targeting opportunities and prioritizing improvement activities.

To evaluate the efficacy of this approach, WRITAR had facility staff generate contribution estimates based on professional judgment. The costs were then allocated accordingly. These cost allocations were then cross-checked through WRITAR's assessment procedure⁵.

The best "match" between "estimated" allocation and assessment-based allocation was obtained when the following constraints were met:

- Production records already gathered and analyzed for other purposes
- Process analysis and control was documented and cross-checked by supervisor
- Approval was required for discharge to treatment
- Waste treatment and environmental management staff familiar with production operations

However, in only three facilities did staff allocation estimates come within 25% of what were eventually accepted as somewhat accurate allocations (see earlier definition in this report). In several facilities variances were as high as 400-500%.

Many interpretations are possible of the basis for these inaccuracies. The most likely, based on our research, is that many electroplating operations rely on cost structures that are very general unless allocation is required by some outside force (customer, shareholder, banker, etc.). This leads to working with and accepting information that is perfectly acceptable for day-to-day operations, but which can falter when brought to bear on a more rigorous and detailed effort such as improvement targeting. As a result, allocation based on professional judgment should be interpreted with caution.

5.5 Integrating Costs into Decision Making

EA has potential application in several areas of facility decision-making including capital budgeting and targeting of improvement actions. The following section describes some

⁵ WRITAR's assessment procedure entailed an allocation based on engineering estimates and materials balances. Materials use amounts were generated from a variety of production records and cross checked. Electroplating engineering handbooks were then used to calculate the amount of process consumption which would be necessary to accomplish the facility's production volumes and specs. The balance would be considered lost process material requiring treatment.

of the research findings and conclusions about EA use in these two decision situations for electroplating shops.

5.5.1 *Capital Budgeting Decisions*

In the sample of shops visited, conventional costs were routinely captured in project analysis. In six of the shops in our sample, parts of EA addressing direct and indirect costs associated with environmental management had been used to justify pollution prevention projects requiring capital investments. The parts of EA selected focused on large environmental costs that could be fairly easily allocated because they were either comprised of the costs to manage a single waste or type of waste that would be eliminated (e.g., switching from organic solvents for degreasing to aqueous alkaline cleaners) or because the linkage to environmental management costs was completely obvious (e.g., eliminating cyanide inputs from the flow-through portion of the pretreatment system which reduced disposal costs and eliminated the need for a unit operation). Many shops have been using parts of EA without knowing it or calling it that, much like the way shops do "pollution prevention" without calling it that in the normal course of improving operations.

The idea of consistently applying a full EA framework including contingent and image costs did not seem likely to any representatives in the sample. There is a very strong sense of individuals using only what is 1) high-potential in terms of cost reduction, and 2) solid in terms of accuracy. Although facilities found indirect costs (those not directly affecting payroll and payables) useful to consider and quantify, metal finishers demonstrated hesitancy to formally factor them into an actual economic evaluation of a project. Electroplating facilities were strongly oriented toward using conservative cost estimates in decision-making.

A broader issue concerns the type of capital projects best supported by EA analysis. The optimal situation occurs in capital projects in which entire operations such as cyanide destruction, chrome reduction, or solvent cleaning can be eliminated. This avoids the need to engage in difficult allocation mathematics. However, research found that in most cost areas, process substitution results in incremental reductions rather than complete elimination. For most of the facilities, some cyanide destruction and chrome reduction capacity needed to remain because of other processes in the facility. While theoretically an estimated savings based on volume reduction might be generated, the problems of data

quality and tracking and allocation challenges arose. No shop in the zinc cyanide sample could approach being able to figure out a percent contribution by source for cyanide destruction. Difficulties of this nature are found in other EA cost categories including waste management and regulatory compliance costs. As a general rule, the best candidates for a more fully developed EA analysis are those that are focused on a single waste stream and address complete, rather than partial, elimination of environmental cost categories.

Perhaps the most useful application of EA in the capital budgeting area is to help the facility make better choices on the types and sizes of capital projects needed in the facility. The need to invest in process optimization before making capital budgeting decisions has long been recognized in electroplating. Perhaps the best example of this principle can be found in efforts to create a closed looped wastewater system. According to *Plating and Surface Finishing* (October, 1993) a pursuit of zero water discharge *without upfront process optimization* can cost a facility 2-5 times more than conventional end of pipe treatment. Using EA to examine costs of loss material in a facility and identify where process improvement is prudent can provide valuable input into facility capital planning.

5.5.2 Targeting and Prioritizing Improvement Opportunities

EA also has value in targeting and prioritizing improvement opportunities for facility operations. However, the key to targeting was again found to be rooted in understanding and quantifying the cost of the lost material portion of an EA analysis. Moreover, to obtain the best results, EA is best used in conjunction with traditional targeting methods such as reject rate analysis to get the best environmental as well as financial benefit.

Targeting improvement areas based solely on relative contributions to facility environmental management overhead and ignoring lost material issues may misdirect facility attention from where the greatest gains could be realized. WRITAR compared the results of targeting based solely on contributions to environmental overhead with those based on an assessment approach based on materials accounting and lost process solution. The best "match" between allocated overhead based targeting and assessment-based targeting was obtained when the following constraints were met:

- Limited variation of products

- Limited use of multiple-use process solutions (other than rinses)
- Limited total number of processes

The project lacked sufficient resources to define "limited" in much detail, but this much is clear: When the total of the number of products plus the number of multiple-use solutions plus the total number of processes (yielding total "factors") exceeded 20, the overhead focused methodology actually became worse than a guess, since it actively misdirected the investigation because of its issue-specific approach. As an example, a manufacturer of nickel-plated hand tools:

--has three products
 --uses two different cleaners, two different acids -----> Total "factors" = 9
 --uses two electroplating solutions

In this extremely simple, probably anomalous, production situation. the overhead allocation method and the assessment method both pointed to the nickel plating solution as being the most deserving of P2 attention with the goal of reducing environmental management costs. (In this case, the calculated approach focused on allocating water, sewer and sludge costs because of the effect of wastewater volume on total sludge volume.)

In a more typical (at least for this coating/product mix) production situation, a manufacturer of enclosures for the electronics industry which are zinc plated and chromated:

--has (on the one line chosen for analysis) 12 "primary" products
 --uses two cleaners, three acids ----> Total "factors" = 21
 --uses one electroplating solution, three chromate solutions

In this case, the target recommended by environmental overhead allocation (once again allocating water, sewer, and sludge costs) was the chromate portion of the process. However, the assessment-based approach pointed to the zinc solution and related process control issues (because of the effect on reject rates and corresponding impacts on materials use and waste issues), with the chromates a close second. As the cases examined increased in "complexity", at least as indicated by the "factors" approach used

above, the two approaches pointed less and less frequently in anything like the same direction.

Targeting based solely on the allocation of environmental overhead may not result in the best projects in terms of environmental and financial returns. Targeting based on an EA analysis which first examines loss process solution costs and then allocates environmental management cost components can be a powerful targeting tool.

5.5.3 Applying EA to Hexavalent Chrome and Zinc Cyanide Substitution Projects

To examine and illustrate some of the issues and challenges of EA analysis in pollution prevention projects, WRITAR investigated two plating processes that appeared to be best tailored to potential EA application -- substitution of zinc cyanide processes and substitution of hexavalent chrome processes. Besides being regulatory targets and therefore the focus for existing change efforts, these two processes appeared to satisfy the condition of well defined, technology-based changes which appear to be very amenable to EA analysis.

WRITAR visited eight shops using zinc cyanide processes and ten shops using hexavalent chrome processes for decorative plating. Working jointly with the facilities, WRITAR applied an EA analysis to the decision on whether to switch to appropriate alternatives.

With the exception of two cost categories -- utilities and insurance -- WRITAR found that applying EA methodologies offered the potential for elucidating and incorporating other costs which would help justify a process change. However, three issues arose which are likely to be found in other types of project evaluations:

1. *More cost savings is not necessarily the implementation key*-- Because of the regulatory pressures, nearly all the firms were already quite aware of the general economics of alternative processes. That the economic justification could be "beefed up" was generally not an issue. General resistance to change, inability to change due to perceived or codified requirements, labor skill base, and other factors rather than the numbers were stopping implementation. This issue is not a fault or limitation of EA;

rather, it simply demonstrates that cost is just one of a multitude of potential issues affecting pollution prevention implementation.

2. *EA analysis is better served by decision situations featuring complete, rather than incremental reductions* -- As discussed earlier, allocation challenges created the major roadblock for EA analysis. In facilities where entire operations such as cyanide destruction or chrome reduction could be eliminated, EA offered tremendous potential. The corresponding environmental management and regulatory costs associated cyanide destruction could be readily assembled and factored into the analysis. However, research found that in most cost areas, process substitution result in incremental reductions rather than complete elimination. For most of the facilities, some cyanide destruction and chrome reduction capacity needed to remain because of other processes in the facility. While theoretically an estimated savings based on volume reduction might be generated, the problems of data quality and tracking described earlier immediately came to the surface. Difficulties of this nature were found in other EA cost categories including waste management and regulatory compliance costs.

3. *Indirect labor costs exist for alternatives as well* -- Indirect labor "savings" associated with environmental management could be roughly approximated, but full costing demanded "equal time" on the other side of the ledger and labor cost changes were approximated for alternative processes. Many of the environmental management labor savings were offset by increased labor costs associated with the alternative processes which generally demand more careful maintenance and control practices and embodied their own training issues.

6.0 GUIDANCE FOR INVESTIGATING LOST MATERIAL COSTS IN ELECTROPLATING

Because the environmental management cost structures of a facility are really a function of how and how well materials are used in operations, obtaining an understanding of existing process performance and materials use is a good starting point for EA in electroplating. Investigators should begin by exploring what types of efforts have been made to:

- improve process controls
- reduce water use
- understand and optimize materials use
- implement and monitor standard procedures

to obtain a sense of where facilities have and have not invested in process improvement.

Once this understanding is gained, the economic justification for further activity can be made through an application of EA. The value of waste as lost process solution is the critical calculation worth performing since it provides a sense of the opportunity costs available to the facility, identifies the best cost-saving targets, and it can be very useful as part of the disposal costs portion of an EA framework. This can be done through the recommended steps described below. These opportunity costs can then be added to the EA-generated environmental cost numbers (which capturing the environmental management cost components) to get the true "cost of wasting."

Linking environmental management costs to ongoing improvement needs proved to be another useful way to generate facility interest in pollution prevention. EA can be used to bolster the economic argument and identify the facility's "true cost of quality." The key to realizing the value-added of EA in electroplating is to link this tool with materials balancing and materials accounting. The opportunity costs of wasted raw materials and materials losses in electroplating are not only the most significant costs to consider, they are the linchpin in understanding the reasons for the facilities environmental management cost structures.

Calculating Value of Process Solutions and Lost Process Solution

- Step 1 --** Determine total annual cost of material inputs
- Step 2 --** Determine list of material inputs that individually are responsible for at least 5% of the total material input costs
- Step 3 --** Determine value of individual process solutions on annual basis and in cost per liter of solution. Start with electroplating solutions, then do acids and cleaners. Occasional use solutions (strippers; chromates; other special-use surface treatments) are optional at this time -- focus on "big tickets" first
- Step 3a Determine "formula" for each process solution
 - List of constituents
 - Concentration of each constituent
 - Step 3b Determine cost of each constituent
 - Step 3c Calculate value of solution
- Step 4 --** Rank process solutions by cost
- Step 5 --** Choose top-ranked electroplating process solution. Determine total metal purchased for that solution as kg/year. Assure that all sources are accounted for. For example, nickel metal in an electroplating process solution is derived from, at a minimum:
- solid nickel anodes
 - nickel sulfate solution
- and may have other sources.
- Step 6 --** Determine total metal plated from that solution as kg/year. This is done by determining total square decimeters of product processed through the solution, and multiplying by the average thickness of the plated coating. Convert to kg using weight to thickness tables.
- Step 7 --** Subtract total in Step 6 from total in Step 5. Difference is metal lost to dragout, although recognize that incorrect data can skew the analysis
- Step 8 --** Repeat Steps 5-7 as necessary until 80% of costs due to purchase of electroplating process materials has been analyzed

Full EA Costing of Rejects

Step 1 -- Determine list of most common reject situations

Step 2 -- Describe actions taken to correct rejects, starting with most common cause or problem

- Inspect
- Sort and re-plate only bad parts
- Strip and re-plate all parts
- Purchase new parts and plate

Step 3 -- Determine cost of each action

- Cost to detect rejects (inspection; return from customer)
- Cost to correct reject (purchase new parts; strip and re-plate parts; spot re-plating)
- Cost of lost production time (rejected parts took the place of parts that could have been sold to generate income)
- Cost of treatment and disposal of materials associated with corrective action
- Overhead costs associated with corrective action

Step 4 -- Repeat Steps 1-3 until 80% of reject volume has been analyzed

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