Options for Minimizing Metal Finishing Waste

By Clifford W. Walton, CEF; and Kevin J. Loos

To establish a successful waste minimization program, it is necessary to have a knowledge of waste assessment procedures, process options for remediation and recycling. Factors to consider include EPA priorities, the requirements for an efficient assessment system and elements of previously successful programs. This article describes the basic steps toward satisfying these factors and discusses some existing and potential technologies.

With increased public concern about waste management, finding more efficient methods for minimizing waste-disposal becomes more critical. Federal and state hazardous and solid waste regulations have made it both more difficult and more expensive to dispose of unwanted by-products, prompting the development of prevention techniques as alternatives to disposal.

Some undesirable wastes-such as liquids-have been, or will be, banned from landfills completely, while methods for disposing of other wastes will be restricted even further. A consequence of these restrictions is a shortage of approved disposal facilities, which is driving waste removal costs higher and higher.

The financial and legal incentives built into reducing or completely eliminating unwanted by-products, coupled with the fact that those who generate them are required to certify that they have instituted a waste minimization program, have all but mandated the implementation of such a program.[1] By doing so, a company can save money through reduced waste treatment and disposal costs, raw material purchases, and other operating expenses. Also successful programs will meet state and national waste minimization policy goals, reduce potential environmental liabilities, protect public and worker health and safety, along with the environment,' as well as promote a better corporate image.

An important first step in the elimination or reduction of undesirable by-products is to identify them. Some common by-products generated by metal finishers include industrial treatment sludge containing toxic metals, such as copper, chromium and nickel; spent plating and process solutions, including various cleaner: and contaminated solvents.[3]

U.S. EPA Priorities

The former administrator for the U.S. Environmental Protection Agency (EPA) announced Pollution Prevention as the environmental goal in the '90s.[4] Table 1 show the ranking of priorities for waste management, established by the EPA[5,6], with particular emphasis on source reduction-the concept of preventing or minimizing the production of material that must be treated as waste, by altering the actual production process or "source." Measures might include process modifications, feedstock substitutions or improvements in purity, better housekeeping and management practices, increased efficiency of machinery, recycling within a process and production of valuable by-products.

Table 1
U.S. EPA Priorities for Waste Management's

Rank	Procedure/Process
1	Source Reduction
2	Recycling
3	Waste Separation and Concentration
4	Waste Exchange
5	Energy/Material Recovery
6	Waste Treatment
7	Disposal

Recycling is the use or reuse of otherwise-undesirable by-products as effective substitutes for commercial products or as ingredients or feedstock in industrial processes. It can occur on- or off-site, and includes the reclamation of useful components from a waste material or the removal of contaminants from a waste to allow it to be reused. It is often less expensive to recycle a chemical than to purchase new material and pay for disposal costs. Though a material may no longer meet the specifications for a process in which it was being used, it may still be suitable for other purposes within the facility.

Undesirable by-products that may require unusual treatment or disposal should be separated from other process materials. The EPA rule for a hazardous waste mixture states that "... mixing a regulated hazardous waste with a non-hazardous waste renders the whole mixture legally hazardous." Therefore, recycling a material requires that the waste remain as clean as possible, prior to reuse.

Waste treatment is any method, technique, or process that changes the physical, chemical, or biological character of any hazardous waste in a way that neutralizes the waste or renders such waste non-hazardous, less hazardous, safer to manage, able to be recovered. able to be stored, or reduced in volume. Disposal is the discharging, depositing, injecting, or placing of hazardous waste into or on any land or water. If a waste has hazardous characteristics, disposal in a hazardous waste disposal facility is required. If the waste is treated

Table 2
Some Environmental Laws and Regulations Pertinent to the Surface Finishing Industry[3]

Regulation	Description
40 CFR 122, NPDES	Federal regulations governing the discharge of wastewaters to surface waters of the United States
40 CFR 413,433	Federal regulations specifying effluent limitations, pretreatment standards, and new source performance standards for the electroplating and metal finishing industries
40 CFR 268	Federal regulations that restrict the disposal of spent solvents and solvent-containing wastes
CCR Title 23 Subchapter 9	State regulation governing the discharge of wastewaters to surface waters. Includes provisions for issuance of permits and setting effluent limitations
Local municipal codes addressing discharges to POTWs	Discharge requirements set by local POTWs, restricting the concentrations of pollutants in wastewaters discharged to sanitary sewers
CCR Title 22 Sections 66900 & 66905	Restrict the land disposal of certain liquid and solid hazardous wastes and set time schedules for implementing the restrictions
CHSC Chapter 6.95	Requires local government agencies to implement hazardous material management programs requiring local businesses to submit applications for the storage and handling of hazardous materials
CCR Title 22, Division 4 Chapter 30, Article 6	Sets requirements for generators of hazardous wastes, including restrictions on how long wastes can be accumulated in a non-permitted storage facility
CHSC 25202.9	Requires certification by waste generators permitted as TSD facilities that a waste minimization program is in operation and that the treatment, storage and disposal methods minimize the threat to human health and to the environment

NPDES-National Pollution Discharge Elimination System
CFR-Code of Federal Regulations
CCR-California Code of Regulations
CHSC-California Health and Safety Code

to eliminate these hazardous traits, it can be disposed of in a non-hazardous waste landfill, which is considerably less expensive.

The use of the various options depends on federal and state regulations. Table 2 presents a brief list of the prevalent laws and regulations that have an impact on the surface finishing industry. Note that the list cannot be construed as comprehensive, and any interested party should contact the appropriate federal, state, or local authority regarding the specifics of the regulations.

Essential Elements and Common Barriers to Successful Minimization Projects

Various studies of waste minimization programs have identified characteristics of successful programs. Three key elements found were:[1]

- Management's active involvement and encouragement at all levels
- Production personnel strongly motivated to implement and maintain necessary changes
- "Elegantly simple" technologies

At least one of these elements was missing in each minimization project failure.[1]

People involved in implementing waste reduction programs have noted several inhibiting factors that must be identified by those attempting to develop an appropriate strategy. This is essential to recognizing and overcoming resistance. Some barriers to waste reduction are:[3]

- Lack of information about available waste reduction techniques and the benefits that can be achieved

This can be overcome by seeking information on other's successes. For example, 3M Corporation has had a "Pollution Prevention Pays" program since 1975. In 10 years, the 1,500 projects supported by this program saved the company more than $235 million, in pollution control facilities that did not have to be built, in reduced pollution control operating costs, and in retained sales of products.[1] Other examples can be found in case studies published by the EPA.[7,8]

- Concern with upsetting product quality

Both operators and management must be convinced that pollution prevention changes will not adversely affect quality. This means a commitment to and effective application of a new process or technology, including complete training of operators.

- The "If it ain't broke, don't fix it" attitude

For more than 50 years, the U.S. Navy has been using the same hard chromium plating methods. During this time, improved processes had been developed by other sources. The Navy created a program to reduce waste from chromium plating operations and, incorporating the improved processes, updated its entire chromium plating operation. The result was zero-discharge plating that also produced a more uniform plate, while using a considerably smaller tank area.[1]

- A reluctance to develop innovative ideas because of the fear of failure

Management must take the initiative and absorb all effects of failures, so operators and middle managers will be unafraid to break new ground.

- The attitude that a new technology will not succeed because it is outside the company's normal range of expertise.

This can be solved by seeking outside views and help. Governmental agencies, consultants, and organizations like AESF can assist in answering questions.

It is critical, when developing and implementing a waste reduction program, that management be committed, be willing to experiment with new ideas and be prepared to experience failure along with success.[3]

Waste Minimization Assessment Procedure

The waste minimization assessment procedure begins with the recognized need to minimize waste. The procedure may then go through these phases:[2]

1. Planning and organization
2. Assessment
3. Feasibility analysis
4. Implementation

The planning and organization begin with getting management's commitment. Overall assessment program goals must then be set, and a program task force appointed. Next is assessment, which begins with collecting process and facility data that is prioritized so assessment 'targets" can be selected. It is important to choose people for your teams who will review data and inspect the sites. Options are then screened and singled out for further study.

After the assessment is completed, feasibility analysis begins. This includes technical and economic evaluation, using outside help with technical evaluation, if the company does not have sufficient expertise on staff. After these evaluations a final report is written and specific options will be chosen for implementation. This step includes justifying projects and obtaining funding, procurement and installation of equipment, training and activating the program, and an evaluation of its performance.

The entire process is repeated, selecting new assessment targets and re-evaluating previous options. When the waste minimization assessment procedure is administered in its entirety, successful waste minimization is the end result.

Waste Reduction Opportunities

A waste reduction effort can be broken down into two broad areas: Procedure and process. The procedure includes employee training, changing methods, preventing spills, and inventory control; while process includes optimizing solutions, substituting products, concentrating waste and changing equipment.

The most important aspect of the procedure is employee training. Though management's commitment and direction are fundamental to a successful waste minimization program, the entire organization must also be committed, to overcome barriers. Employees often can increase the generation of waste, so they become pivotal in contributing to its reduction. Bonuses, awards, plaques and other forms of recognition often are effective ways to motivate and boost employee cooperation.[2]

For example, a chemical engineer at a major consulting company spent the early part of her career as an environmental coordinator for a major aircraft manufacturer.[1] Solvents kept turning up in the storm drains, and the source was traced to several floor drains in the shop area, where workers were pouring used solutions. She posted signs that read, "Next Stop Is Your Faucet At Home." The violations stopped. When the workers asked her what they could do to reduce waste, she said, "Act as though your mother were looking over your shoulder."[1]

Some other control methods that could be implemented are:

- Minimize the number of different raw materials, such as cleaning fluids, oils, etc., and supplies used. This helps clear up shelf-life problems and reduces the number of partially filled containers that need disposal.

- Purchase container sizes appropriate to actual use. It can be less expensive to buy smaller containers of perishable materials than to buy bulk quantities-at cheaper prices—that ultimately require disposal of the expired portion.

- Reduce the inventory of hazardous materials to the minimum. It must be ensured that containers are being rotated on the shelves so the oldest materials are used first. This will reduce the need to dispose of those with an expired shelf-life.

Steps such as these will cut spending on raw materials and waste disposal, as well as the investment tied up in inventory. Careful inventory control and preventing spills are also simple tools for cutting significant amounts of waste.

After preparing an inventory of chemicals used, and wastes produced from all processes, do an evaluation, to determine if the number and volume of chemicals can be reduced. Optimizing solutions; taking the waste from one process and adapting it for use in another; substituting less-hazardous products for hazardous ones; and concentrating waste are all possible modifications.[1]

When dealing with a change of equipment, simplicity is best. Typically on successful projects, off-the-shelf equipment is adapted to the new application, and complex, specialized equipment is avoided. The greater number of modifications attempted at the same time, or the more experimental the equipment is, the greater the chance that problems will occur, and a potentially beneficial project is abandoned for the more reliable and proven methods.[1]

In the surface finishing industry, there are a number of simple approaches. For example, several improved rinsing techniques that can reduce the amount of drag-out loss include:[1, 3, 9,10]

1. Extended drip times-The faster an item is removed from the process solution, the thicker the film on its surface and the greater the drag-out volume will be. Extended drip times are an extremely easy and inexpensive adjustment to make, working best with cold process solutions.

2. Workpiece positioning-The amount of drag-out loss can be reduced if the workplaces are oriented so that process chemicals cannot be trapped in grooves or cavities when removed from the tank. This change is also easy to implement, but needs to be considered when designing the plating racks. Improving workpiece positioning is still a fairly cost-effective method to use.

   Suggestions for orientation include:

   - Tilt objects to avoid table-like surfaces and pockets where solution can be trapped.
   - Avoid the positioning of parts directly above or below each other. Staggering them eliminates drainage of solution from one part to the one under it.

3. Spray/fog rinsing-Another method involves spray rinses above heated baths, to replenish the loss of process solution through evaporation. This is also fairly easy to implement. Deionized water should be used for such a spray system, and should flow at a rate equal to that of the evaporation.

4. Countercurrent rinses-Countercurrent rinsing involves a sequential immersion of parts in a series of tanks. The parts are immersed, countercurrent to the rinse flow. Optimum countercurrent rinsing (cost vs. minimum water consumption) usually uses three tanks, opcrating in series. This method can reduce rinse flows by more than 90 percent compared to single overflow rinses. For a drag-out rate from the plating bath of one gal/hr, a countercurrent rinse flow of 10 gal/hr would be sufficient, compared to 1,000 gal/hr for a single rinse tank.[1] The

Table 3
Summary of Recovery Technology Applications[3]

	Decorative Chromium	Hard Chromium	Nickel	Electroless Nickel	Cadmium	Zinc (CN)	Zinc (Cl)	Copper (CN)	Tin (BF_4)	Silver
Evaporation	x		x		x	x	x	x	x	x
Reverse Osmosis			x			x		x		
Ion Exchange	x		x	x						x
Electrolysis					x	x	x	x	x	x
Electrodialysis			x		x	x	x	x	x	x

technique is high-priority and has become a standard in the surface finishing industry, but is more expensive and more difficult to retrofit to existing lines.

5. Use of drain boards or drip tanks-Drain boards are used to capture process chemicals that drip from the workpiece when it is being transferred between successive tanks. The board is mounted at an angle that allows drainage of the chemical solution back into the first tank. Drip tanks serve to capture chemical drips in a tank placed between process and rinse tanks. Then the contents of the drip tanks can be recycled to the process bath.

These methods can be expensive to install and are not necessary, if the steps discussed earlier are properly taken. But, they are useful, if there is enough space between tanks, and if chemicals would otherwise drip onto the floor and enter the wastewater system when the floor is washed down.

6. Air knives-Air knives can be used above process tanks to improve drainage. As the rack is raised from the tank, air is blown across the surface of the workplaces. This air stream improves the drainage of the drag-out solution back into the tank. The drawback to this method is that it causes part to dry, which might not be beneficial for a particular part, and can cause more difficulties when certain chemicals must be rinsed off the part.

7. Reduce surface tension-Wetting agents can be added to a process bath to reduce surface tension of a solid and, as a result, reduce volume of drag-out loss. The use of wetting agents in the surface finishing industry has been estimated to reduce such loss by as much as 50 percent. The drawback is that these agents can cause foaming problems in the process solution, and may affect the chemistry of the bath itself, when such things as catalysts are used.

8. Use of turbulence or agitation-Turbulence or agitation in a rinse or process tank can cause better removal of solution from parts. Usually an in-tank filtration system is needed when turbulence or agitation is used, in order to remove dirt or non-chemical impurities from the bath. This method can be combined with a countercurrent rinse system, to help optimize plating line performance.

Waste Reduction Technologies

Evaporation, ion exchange (IX), reverse osmosis (RO), electrolysis and electrodialysis (ED) have been used to recover chemicals and metals from rinsewaters. General and site-specific factors must be evaluated to determine the best recovery method for a specific situation. Factors include the type of metal to be recovered, drag-out rates, rinsewater concentrations and flows, space and staffing requirements, availability of utilities (i.e., steam, electricity), and cost for water and wastewater treatment and sludge disposal.[1] Table 3 shows typical recovery technologies related to specific plating solutions.

Evaporation is the oldest method used to recover chemicals from rinse streams. Enough rinsewater is boiled off to concentrate the solution sufficiently to return it to the particular process. Because of their high-energy use, evaporators are most cost-effective in concentrating rinsewaters that are to be returned to hot baths, such as in chromium plating.[1]

Ion exchange uses charged sites on solid resin to selectively remove either cations or anions from the solution. The ions removed are then replaced by equivalent charged ions, displaced from the resin. In general, ion exchange systems are suitable for recovery applications where the rinsewater has a relatively diluted concentration of plating chemicals. IX systems are not cost-effective when drag-out rates are low and concentrations high.[1]

Reverse osmosis is a demineralization process in which water is separated from dissolved metal salts by forcing the water through a semipermeable membrane at high pressures (400 to 800 psig). RO use is limited to moderately concentrated rinsewaters, and its cost-effectiveness varies, depending on several factors.[1]

Electrodialysis concentrates or separates ionic species in a water solution through use of an electric field and semipermeable, ion-selective membranes. ED has been used to recover cationic metals from plating rinsewaters. The maximum concentration of an ED unit is limited only by the volubility of the compounds in solution, allowing ED to produce a more-concentrated solution than IX or RO. ED units are easy to use, economical, compact, and can operate continuously with little maintenance. However, ED cannot selectively remove ions, meaning that periodic bath treatments are required, to remove impurities. Along with evaporation, ED has the quickest payback of the metal recovery processes.

Table 4 lists some typical costs of applying these technologies to recover specific materials from a single-source wastewater. To achieve savings that justify the purchase of recovery technology requires the waste stream to be fairly concentrated and continuous. Information necessary to determine economic feasibility includes waste stream generation rates, chemical concentrations and the value of materials to be recovered.[3]

Closed-Loop Recovery Systems

In a near closed-loop recovery system that uses such processes as ED, IX, and RO, there are four necessary elements for success.[1] These are:

1. Rinsewater recycling
2. Chemical recovery
3. Volume reduction
4. Bath purification

Table 4
Some Material Recovery Technology Costs (1985)[3]

Technology	Materials Recovered	Equipment costs
Evaporation Unit: Capacity of approx. 20 gph	Rinsewater and chromic acid	$47,000
Reverse Osmosis Unit: Capacity of approx. 100 gph	Nickel plating chemicals	$27,000
Ion Exchange Unit: Capacity of approx. 20 gph	Rinsewater and chromic acid	$38,000
Electrolytic Unit: Capacity of approx. 15 gph	Rinsewater and copper	$25,000

Rinsewater recycling is important because rinsewater is usually kept at a low concentration of contamination in order to be effective. Rinsewater can be used again, as long as the recycled solution is relatively "clean." Chemical recovery involves reclaiming chemicals, especially toxic ones, from the waste. Recovering them can eliminate the major toxic components from the waste stream and simplifies disposal of any blowdown stream. This is beneficial because it is often less expensive to recycle a chemical than to purchase new material and dispose of the old. Recycled materials can also be suitable for other processes in the plant.

Reducing the volume of wastewater can reduce disposal costs. If volume is cut sufficiently, while concentration is proportionately increased, it can be feasible to recover useful materials from the waste. Bath purification allows better recycling (fewer impurities), easier segregation of wastes, and higher process efficiency.

Each of the metal recovery processes has specific areas in which it performs best. if a system is needed for rinsewater cleanup, all the close-loop systems will be adequate. Chemical recovery requires the use of IX or ED processes. If a system is needed for volume reduction, innovative rinsing or evaporation is acceptable. For bath purification, ED, porous pot or IX processes will be useful.

It is necessary to identify needs and research a system that will best meet those needs. Every system has advantages and disadvantages; so, careful consideration must be given to which method will work best in a given situation.

Developing a waste minimization program has become a necessity in the industry. As EPA regulations on waste disposal become stricter, newer and more efficient minimization methods are needed. For example, open-loop systems, such as chemical precipitation, will soon fail to meet EPA standards. Closed-loop systems, such as ED, will need to be on line, reducing or eliminating the necessity to dispose of sludge or precipitate in an appropriate landfill. Waste management methods that reduce or eliminate unwanted by-products will prove to be more cost-efficient and environmentally sound-characteristics that will be in high demand in the near future. •

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Note: Additional technology and case-study information can be obtained from: U.S. EPA • ORD Publications • P.O. Box 19962 • Cincinnati, OH 45219-0962

Request "ORD Publications Announcement" (e.g., EPA/600/M-91/048) and "Technology Transfer" Newsletter (e.g., EPA/600/M-91/042).

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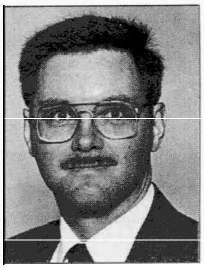
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