



Environmental Regulations and Technology

The Electroplating Industry



Cover Photograph:

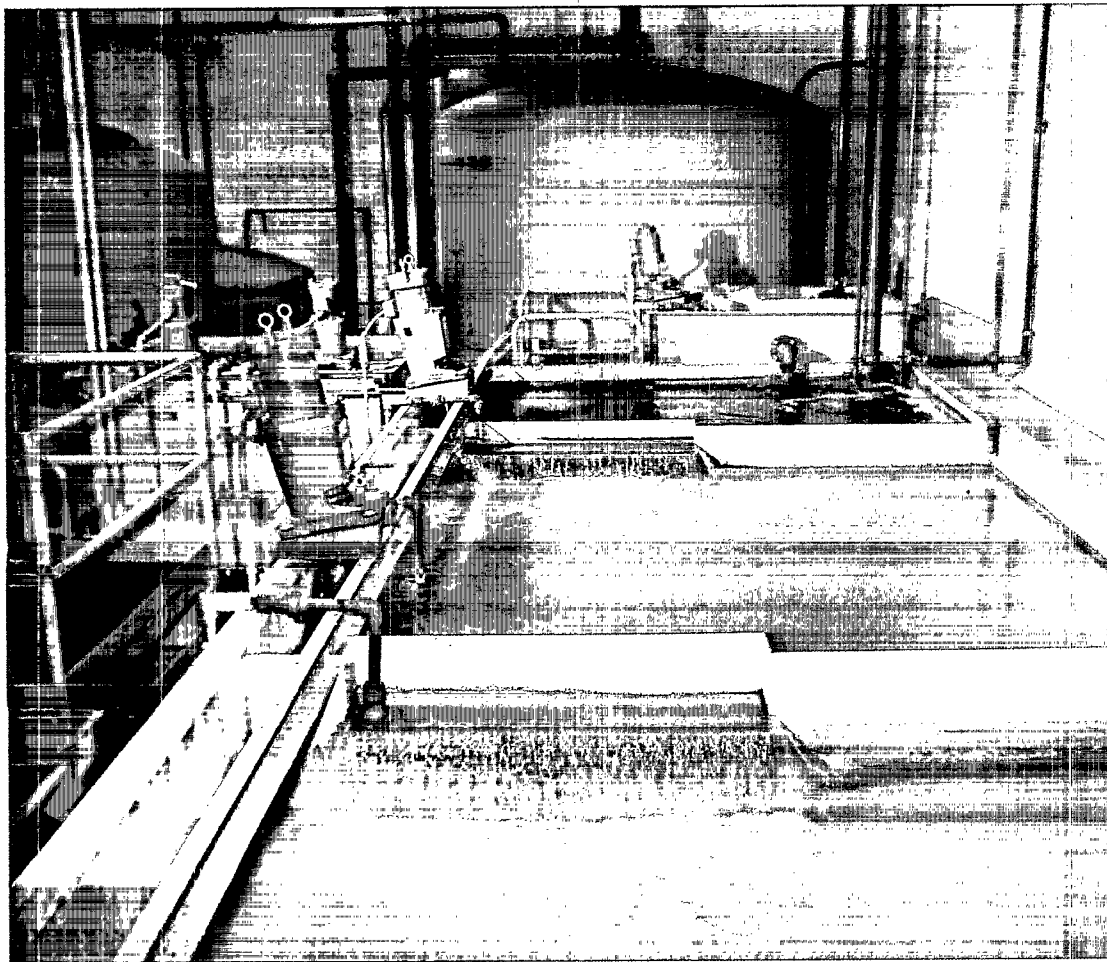
Blend tank following the reduction of chrome and cyanide from electroplating wastewater.

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Three-stage blending and neutralization system.

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1. Overview

Under Federal law, the electroplating industry is bound by a multitude of pollution control requirements for wastewater and solid waste residues. The U.S. Environmental Protection Agency (EPA) is responsible for preparing the detailed regulations and establishing the administrative procedures for carrying out these laws. Because the wastewater and solid waste laws were passed at different times, EPA's schedule for implementing pollution control requirements differs for each of these areas. Consequently, electroplaters must keep informed of new and changing regulations. An integrated approach to compliance can reduce compliance costs considerably.

Electroplating wastewater pollutants of greatest concern are toxic metals (cadmium, copper, chromium, nickel, lead, and zinc); cyanide; toxic organics (grouped together as total toxic organics); and conventional pollutants (total suspended solids and oil and grease). These and other constituents degrade water quality and endanger aquatic life and human health. They also corrode equipment, generate hazardous gases, cause treatment plant malfunctions, and make the sludge disposal more difficult.

This publication provides the electroplating industry with a summary of the laws, regulatory activities, and technologies that affect decisions regarding wastewater treatment and solid waste handling and disposal. EPA's recently promulgated regulations on water pollution control are presented

in Chapter 2, and wastewater treatment technologies and case histories are discussed in Chapters 3 and 4 respectively. Chapter 5 presents information on the current status of sludge disposal regulations and technologies, and operating techniques that can reduce sludge disposal costs. Various sources of financial assistance available through Federal programs are presented in Chapter 6.

This publication is an update of a 1980 EPA publication of the same name (EPA publication number 625/10-80-001). It has been revised to reflect changes in the EPA regulations as well as the pollution control technologies that affect the electroplating industry.

A companion document, *Environmental Pollution Control Alternatives: Reducing Water Pollution Control Costs in the Electroplating Industry* (EPA publication number 625/5-85-016a), explores the cost tradeoffs of wastewater reduction and materials recovery technologies and includes a brief discussion of sludge handling. It is intended to assist in the process of selecting an optimum wastewater control system.

2. Water Pollution Control Regulations

Electroplaters must understand and comply with several environmental regulations, particularly the regulations developed for the metal finishing and electroplating categories. This section is intended to summarize and clarify these regulations and the laws behind them.

Legislation

The environmental legislation passed by Congress since 1972 which has affected water pollution control and waste management in the electroplating industry is summarized in Table 1. Prior to 1972, water pollution control requirements were established by the states and were based primarily on waterbody uses such as drinking, swimming, fishing, and navigation. The state agencies were to identify water uses, establish the water quality conditions necessary to support these uses, and apply a water quality standard to each stream or stream portion. Where a standard was not being met, attempts were made to exact compliance through technical discussions and enforcement action. This strategy was generally ineffective due to political, technical, and legal weaknesses: some stream use designations were tailored to protect or attract industrial development; adequate information was not available to link water quality with wastewater discharges; the health of aquatic ecosystems was not adequately considered; and implementation of requirements were not consistent from state to state.

Congress addressed these problems in 1972 with the passage of Public Law (PL) 92-500, the Federal Water Pollution Control Act (FWPCA) Amendments. The goals of the Amendments were to:

- Achieve "fishable/swimmable" quality for all waters by 1983
- Eliminate pollutant discharge to all waterways by 1985
- Eliminate all toxic pollutant hazards.

Not only did the Amendments strengthen the current system of setting water quality standards based on the waterbody use, but they also established limitations on industrial effluents and applied them uniformly across the nation by:

- Establishing three levels of effluent limitations for direct dischargers of a specific industrial category (that is, plants discharging directly into public waterways). These "technology-based" limitations were to reflect controls that an entire industry is capable of based on technology that is being used or can be used (as opposed to controls to achieve specific water quality standards for a particular waterbody). The three levels were: best practicable technology (BPT), to be achieved by 1977; best available technology (BAT), to be achieved by 1983 (later changed to 1984); and new source performance standards (NSPS), to be achieved when a new source begins operation. The Act defines "new source" as any source whose construction begins after the publication of applicable proposed regulations.
- Establishing industry-specific effluent limitations for indirect dischargers, that is, plants discharging into publicly owned wastewater treatment works, or POTWs.
- Establishing an expanded Federal program of financial assistance for planning and constructing POTWs.
- Establishing special controls for toxic pollutants.
- Requiring National Pollutant Discharge Elimination System (NPDES) permits for all sources of pollution; this provided the first major direct enforcement mechanism to bring violators into compliance.

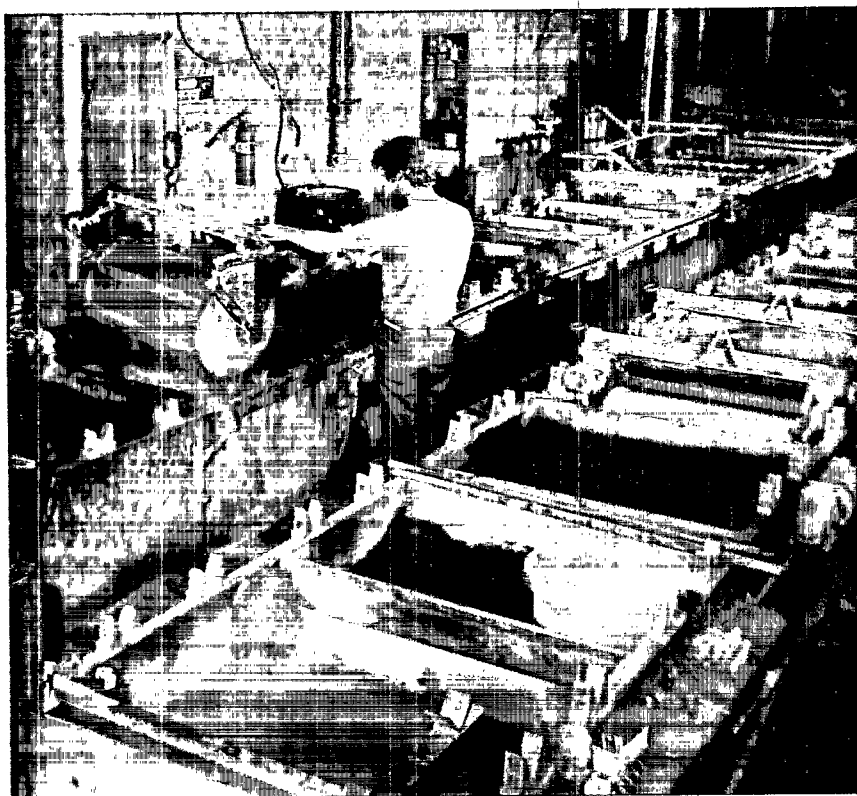
Table 1.**Summary of Environmental Legislative Activities Affecting the Electroplating Industry**

Year	Legislation	Requirements
1972	Federal Water Pollution Control Act (FWPCA) Amendments (Public Law 92-500)	<p>Required all industries discharging into waterways to meet technology-based standards of pollution control:</p> <p>Best Practicable Technology (BPT) - By July 1, 1977</p> <p>Best Available Technology (BAT) - By 1983 (later revised to 1984)</p> <p>New Source Performance Standards (NSPS) - If source begins construction after publication of the applicable proposed regulations.</p> <p>Required all industries discharging into municipal systems to attain industry-specific effluent limitations (pretreatment standards).</p> <p>Required periodic review and updating of technology-based requirements.</p> <p>Established National Pollutant Discharge Elimination System (NPDES) permit program.</p> <p>Required self-monitoring by plants discharging to navigable waters.</p> <p>Established Federal control over municipal systems.</p>
1976	National Resource Defense Council (NRDC) Consent Decree (NRDC et al. vs. Train)	<p>Committed EPA to a schedule for developing BAT effluent limitations for 21 major industries covering 65 recognized toxic substance classes (129 specific compounds). This schedule was later incorporated into the Clean Water Act.</p>
	Resource Conservation and Recovery Act (RCRA) (Public Law 94-580)	<p>Established controls for disposal of all solid wastes.</p> <p>Defined hazardous solid wastes. Established tests to determine which wastes are covered.</p> <p>Established standards for solid waste generators, storage facilities, and disposal sites.</p> <p>Established manifest system for transportation of hazardous wastes.</p>
1977	Clean Water Act (Public Law 92-217)	<p>As an amendment to FWPCA, revised FWPCA deadlines.</p> <p>Defined classes of pollutants as toxic, conventional, and nonconventional with major emphasis on the toxic compounds associated with the NRDC Consent Decree.</p> <p>Linked pretreatment standards to BAT guidelines for toxics.</p> <p>Established BCT (Best Conventional Technology) level of compliance for industrial discharges of conventional pollutants (e.g., oil and grease, pH, suspended solids, biochemical oxygen demand) based upon the cost to municipalities to treat conventional pollutants and industries' incremental treatment costs.</p> <p>Authorized municipal systems to relax pretreatment standards under certain conditions for individual dischargers.</p>
1984	Hazardous and Solid Waste Amendments of 1984 (Public Law 98-616)	<p>As an amendment to RCRA, brought small-quantity generators (100 to 1,000 kg/month) under RCRA requirements. Small-quantity shipments must be accompanied by manifests; small-quantities can be stored on-site for 180 days.</p> <p>Required certification by generators after 9/1/85 that the generation of hazardous wastes have been minimized.</p> <p>Required new underground storage tanks of petroleum and hazardous wastes to be constructed to prevent leaks, and existing tanks to be monitored for leaks.</p> <p>Prohibited landfilling of bulk or noncontainerized liquids after 5/8/85.</p> <p>Banned certain wastes from land disposal unless they can be demonstrated not harmful to human health and human environment.</p> <p>Required certain surface impoundments receiving hazardous wastes to be retrofitted with double liners, groundwater monitoring capabilities, and leachate collection systems.</p> <p>Required EPA to report to Congress on hazardous wastes not addressed by RCRA because they are sent through municipal sewers.</p>

In 1976 EPA was sued by the National Resources Defense Council (NRDC) and others for not expeditiously issuing regulations under the 1972 Amendments. Later that year, EPA agreed to focus its attention on potentially toxic substances. This agreement (referred to as the NRDC Consent Decree or the Settlement Agreement) required that toxic pollutants be controlled to the extent technologically feasible by including toxic substances in the standards to be issued for individual industries. The agreement committed EPA to a schedule for developing BAT effluent limitations for 21 major industries (including electroplating and metal finishing) for 65 classes of toxic pollutants. EPA later refined the 65 classes of pollutants into a list of 126 specific substances.

In 1977 many provisions of the NRDC Consent Decree and other changes were incorporated into water pollution control legislation as the Clean Water Act of 1977 (PL 95-217). The goals of the Clean Water Act of 1977 were identical to those originally defined in the 1972 FWPCA amendments, but the language of the Act placed strong emphasis on the control of toxic pollutants and the control of industrial wastes discharged to POTWs. In addition, these changes were made:

- Three classes of pollutants were defined: toxic, conventional, and nonconventional.
- A new level of technology which was to be based on treatment costs was defined (BCT, or best conventional technology) for conventional pollutants.
- EPA was required to address the 65 classes of pollutants (126 specific substances) for both direct and indirect dischargers.
- Individual POTWs were authorized to relax pretreatment standards for individual dischargers if the POTW could be shown to remove certain pollutants of the discharger.



Barrel electroplating operation.

Regulations

In order to provide specific guidance for carrying out the requirements of the legislation, EPA has prepared a number of regulations. These provide permit writers, whether from a state, or EPA with a municipal authority, guidelines for incorporating discharge or effluent limitations into a permit. While EPA retains ultimate authority to enforce compliance with the conditions of the permit, most states currently operate permitting programs under EPA jurisdiction. The regulations contain specific performance standards for processes and contaminants that sources should be able to achieve.

Wastewater regulations, including enforcement mechanisms, have been divided into several layers of categories: those for existing and new sources; and those for direct and indirect dischargers. Direct dischargers are regulated by the NPDES, under which EPA or its state equivalent issues a separate permit to each discharger containing specific discharge limitations, reporting requirements, and compliance schedules. NPDES permits are renewable every five years. Indirect dischargers must conform to national pretreatment standards, both general and specific, which are enforced by the local government under EPA oversight authority. The Federal government has authority to ensure compliance with the conditions of the permit. If violations of state-issued permits are not followed by appropriate enforcement action, EPA can initiate its own action after 30 days notice.

For regulating purposes, electroplating plants have been further divided into several categories. Facilities are first divided into captive and job shops. A captive shop owns more than 50 percent of the area of the materials undergoing metal finishing in a calendar year. A job shop owns 50 percent or less.

Captive and job shops are further divided into integrated plants (those that combine electroplating waste streams with other process waste streams prior to discharge) and nonintegrated plants (those whose wastewater discharges come only from electroplating operations). Most integrated facilities are captive operations that perform a wide range of metal finishing processes.

The electroplating and metal finishing water pollution control regulations are contained in the U.S. Code of Federal Regulations (CFR), Title 40, Parts 413 and 433, respectively.* The specific regulation which applies to a particular facility is presented in Table 2. It should be noted that all sectors of the industry are covered by the metal finishing regulations except for existing job shop and independent printed circuit board manufacturers' (IPCBM) facilities which are indirect dischargers. Details of the regulations are discussed below following topics of interest to all plants: monitoring requirements, variances, and pollutants in intake waters.

*The Code of Federal Regulations, Title 40, Protection of the Environment, can be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

Monitoring Requirements. To provide regulatory officials with information on the amounts of pollutants being discharged, monitoring reports must be submitted to the permitting authority by both direct and indirect dischargers. EPA requires, through the NPDES permit process, that direct dischargers monitor their own wastes in a manner specified by EPA in the industry regulations and by the permitting authority. The discharger must keep adequate records and furnish them to EPA on request or annually unless other requirements are imposed by the NPDES authority. Indirect dischargers must submit monitoring reports twice yearly to the permitting authority.

Monitoring frequency, which is based primarily on wastewater variability and flow, is specified in the permit. Plants with large and/or highly variable waste streams are usually required to monitor more frequently. In most cases, plants are required to monitor a minimum of one sample per month for metals and cyanide. The electroplating regulations specify that monitoring for cyanide must be carried out at one of two locations: either after cyanide treatment and before dilution with other streams, or from the final effluent if the limitations in the plant's permit are mathematically adjusted based on the dilution ratio of the cyanide waste stream flow to the effluent flow.

In lieu of requiring monitoring for total toxic organics (TTO), the permitting authority may allow dischargers to certify that concentrated toxic organics are not dumped into wastewaters and that an approved toxic organic management plan is being implemented. This certification will allow plants to avoid the high cost of TTO analysis. If a plant performs TTO monitoring, the analysis can be limited to those pollutants that would reasonably be expected to be present.

Variances. Electroplaters who can substantiate that their processes are fundamentally different from those that were used as the basis for the categorical technology-based standards can apply for a variance from the standard. This applies to both direct and indirect dischargers and to all types of pollutants. Variances granted by the permitting authority can establish equal, more, or less stringent standards than the categorical standard.

Normally, indirect dischargers must apply for variances within 180 days of the date on which the requirements became effective or the date on which a source applied for and was ascertained to be in a certain source category. For electroplaters this normal time period has elapsed. However, because of a court case, the period will be reopened by EPA; therefore, an indirect discharger should contact the permit issuing authority regarding eligibility.

For direct dischargers, the initial time period to apply for variances has expired. However, any time an NPDES permit is being renewed, the discharger may apply for a variance during the public comment period.

Pollutants in Intake Waters. No direct or indirect discharger is required to install treatment equipment just to treat pollutants that are in a plant's intake water. Upon the discharger's request, technology-based standards shall be adjusted to reflect credit for pollutants in the discharger's intake water if 1) the effluent limitation guideline provides for it, or 2) the discharger demonstrates that its proposed control system would meet the limitations in the absence of pollutants in the intake water.

Table 2.

Applicable Effluent Limitation Guidelines for Existing Sources and New Sources

	Applicable Guidelines ^a	
	Direct Dischargers	Indirect Dischargers
EXISTING SOURCES		
Nonintegrated Plants		
Electroplating—Job Shop	MF	E
Electroplating—Captive	MF	E & MF
Independent Printed Circuit Board Mfg.	MF	E
Non-Independent Printed Circuit Board Mfg.	MF	E & MF
Integrated Plants		
Electroplating Job Shop	MF	E
Electroplating Captive	MF	E & MF
Independent Printed Circuit Board Mfg.	MF	E
Non-Independent Printed Circuit Board Mfg.	MF	E & MF
NEW SOURCES	MF	MF

^aE = Electroplating Effluent Limitation Guidelines (40 CFR 413). See also Table 5.

MF = Metal Finishing Effluent Limitation Guidelines (40 CFR 433). See also Table 3.

E & MF = Source first had to meet the electroplating guidelines, then the metal finishing guidelines.

Note: Iron and steel mills that have electroplating operations were exempted from the electroplating guidelines but must meet the requirements of the metal finishing guidelines.

Existing Direct Dischargers

Under the provisions of the Clean Water Act, every facility discharging into a waterway must apply for an NPDES permit which specifies what pollutants may be discharged and a schedule for compliance, monitoring and reporting. The acceptable levels of pollutants in the effluent are based on a series of effluent guidelines published by EPA for specific industries.

In specific cases, if these regulatory guidelines do not control a particular pollutant, the permit issuer may still limit that pollutant on a case-by-case basis. The guidelines do not restrict the power of any permit-issuing authority from imposing more comprehensive or more stringent requirements, as long as they conform with the purposes of the Clean Water Act. Indeed, if state water quality standards or other provisions of state or Federal law require more stringent pollutant limits, the permit-issuing authority must apply those limitations. The authority may also insert different but equivalent units in a permit; for example, pounds per day instead of milligrams per liter.

While many industries have increasing levels of stringency for the BPT and BAT standards, there is only one set of limitations in the metal finishing regulations, i.e., the level of stringency for BPT and BAT are the same. The effluent guidelines for existing direct dischargers are listed in Table 3. These limitations had a compliance deadline of June 30, 1984.

Table 3.

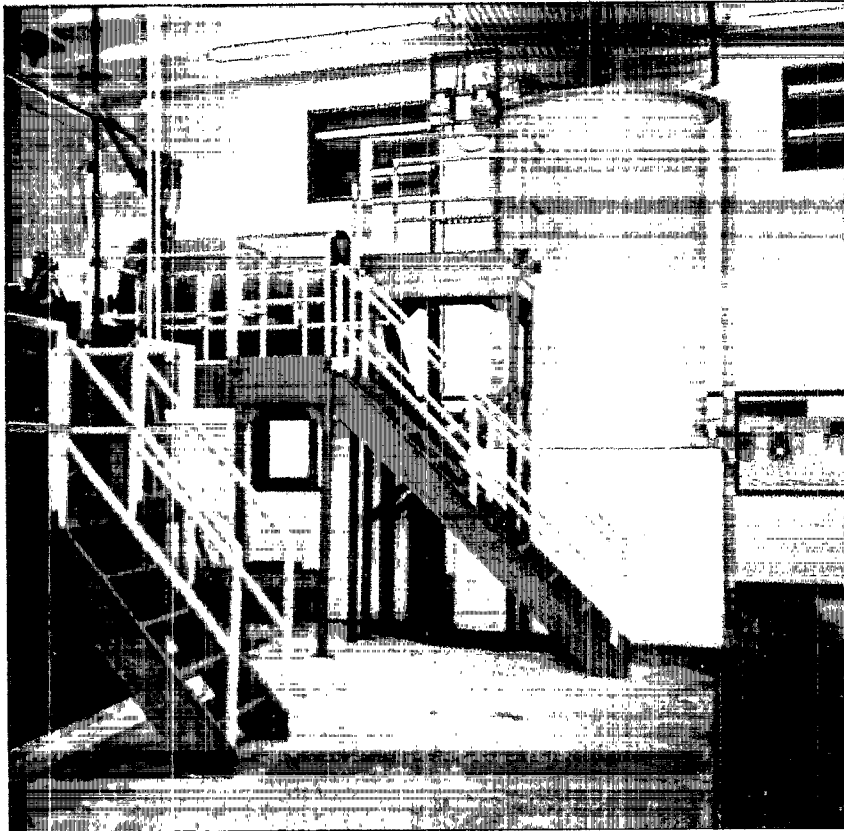
Effluent Limitations for Existing Direct Dischargers, Existing Indirect Dischargers with Metal Finishing Facilities, and New Sources

	Effluent Limitation (mg/l except for pH)			
	Direct Dischargers		Indirect Dischargers: Metal Finishing Facilities	
	Maximum Daily	Monthly Average	Maximum Daily	Monthly Average
Cadmium				
Existing Sources	0.69	0.26	0.69	0.26
New Sources	0.11	0.07	0.11	0.07
Chromium	2.77	1.71	2.77	1.71
Copper	3.36	2.07	3.36	2.07
Lead	0.69	0.43	0.69	0.43
Nickel	3.98	2.38	3.98	2.38
Silver	0.43	0.24	0.43	0.24
Zinc	2.61	1.48	2.61	1.48
Cyanide ^a				
Total	1.20	0.65	1.20	0.65
Amenable ^b	0.86	0.32	0.86	0.32
Total toxic organics	2.13	—	2.13	—
pH	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0
Total suspended solids	60	31	60	31
Oil and grease	52	26	52	26

^aSelf-monitoring for cyanide must be conducted after cyanide treatment and before dilution with other streams. Alternatively, samples may be taken of the final effluent if the plant limitations are adjusted based on the dilution ratio of the cyanide waste stream flow to the effluent flow (40 CFR Part 433.12(c)).

^bCyanide amenable to chlorination may be substituted for total cyanide with agreement of control authority.

SOURCE: 40 CFR Part 433.



Iron-packed drum (blue) for treating chelated effluent.

EPA and the state have the right to visit any manufacturing site and examine permit-related records, check sampling and monitoring equipment, and sample wastewater or treated effluent. This information becomes a matter of public record unless trade secrets or proprietary information would be revealed in the process. In these cases, provisions are made to allow access only by regulatory officials. (By law, however, effluent data cannot be considered proprietary.) The law further states that any responsible corporate officer who willfully or negligently violates any permit condition can be punished by a fine up to \$25,000, by imprisonment for not more than six months, or by both.

Existing Indirect Dischargers

A POTW is essentially designed to treat domestic sewage. Many industrial wastes are also compatible with the treatment system in that the POTW can treat and discharge these industrial wastes and still satisfy its NPDES permit. However, many other industrial wastes either pass through the POTW untreated or interfere with the POTW's normal operation. In either case, the POTW may then be in violation of its permit or be unable to recycle or dispose of its sludge.

Pretreatment regulations permit industry continuing access to a central wastewater treatment system while at the same time protecting the quality of the receiving waterbody, protecting the operations of the POTW, and preventing POTW sludge recycle or disposal problems. EPA has developed these regulations along two lines:

- General pretreatment regulations, which delineate responsibilities of EPA, states, POTWs and industrial dischargers
- Industry-specific pretreatment regulations which set limits on the concentration or loading of the effluent discharged to the POTW.

The general pretreatment regulations are found in 40 CFR 403. Specific pretreatment regulations affecting electroplaters are found in 40 CFR 413 for existing job shop and IPCBM nonintegrated facilities, and in 40 CFR 433 for all metal finishing facilities and for electroplating operations other than job shops and IPCBMs.

The effluent limitations for existing metal finishing facilities are presented in Table 3; in nearly all respects, they are identical to those for direct dischargers.

The effluent limitations for job shop and IPCBM facilities are more complex. They depend on the types of operations employed at the facility and may be either concentration based or mass-based performance levels. The operations covered are listed as subparts of 40 CFR 413 and are presented in Table 4. The effluent limitations, or pretreatment standards, governing these operations are presented in Table 5.

Table 4.**Applicable Subparts for Existing Indirect Nonintegrated Sources**

Code of Federal Regulations, Title 40, Part 413, Subpart:

A—Electroplating of common metals (Al, Cd, Cu, Cr, Fe, Ni, Pb, Sn, Zn, and any combination)

B—Electroplating of precious metals (Ag, Au, In, Pt, and Rh)

C—(Reserved)

D—Anodizing

E—Coating (chromating, phosphating, immersion plating)

F—Chemical etching and milling

G—Electroless plating

H—Printed circuit board manufacturing

Note: Each of the operations listed may also involve stripping, coloring, phosphating, acid cleaning and alkaline cleaning.

SOURCE: 40 CFR 413.

Table 5.**Pretreatment Standards for Existing Dischargers with Indirect Nonintegrated Facilities**

	Effluent Limits (mg/l except as noted)							
	Basic Standard Concentration-Based		Alternative 1 Mass-Based				Alternative 2 ^b Concentration-Based	
			Subparts A-G		Subpart H ^a			
	Daily	4-day Average	Daily	4-day Average	Daily	4-day Average	Daily	4-day Average
Plants discharging < 10,000 gal/day								
Cadmium	1.2	0.7						
Cyanide (amenable)	5.0	2.7						
Lead	0.6	0.4						
Total toxic organics	4.57	—						
Plants discharging ≥ 10,000 gal/day								
Cadmium	1.2	0.7	47 ^d	29 ^d	107 ^d	65 ^d	1.2	0.7
Chromium	7.0	4.0	273 ^d	156 ^d	623 ^d	357 ^d	—	—
Copper	4.5	2.7	176 ^d	105 ^d	401 ^d	241 ^d	—	—
Lead	0.6	0.4	23 ^d	16 ^d	53 ^d	36 ^d	0.6	0.4
Nickel	4.1	2.6	160 ^d	100 ^d	365 ^d	229 ^d	—	—
Silver ^c	1.2	0.7	47 ^d	29 ^d	—	—	—	—
Zinc	4.2	2.6	164 ^d	102 ^d	374 ^d	232 ^d	—	—
Total metals	10.5	6.8	410 ^d	267 ^d	935 ^d	609 ^d	—	—
Cyanide (total)	1.9	1.0	74 ^d	39 ^d	169 ^d	89 ^d	1.9	1.0
Total toxic organics	2.13	—	2.13	—	2.13	—	2.13	—
pH	—	—	—	—	—	—	7.5-10.0	7.5-10.0
Total suspended solids	—	—	—	—	—	—	20.0	13.4

^aSubpart H, printed circuit board manufacturing.^bCan only be used in the absence of strong chelating agents, after reducing of hexavalent chromium wastes, and after neutralization using calcium oxide (or hydroxide).^cApplies only to Subpart B, electroplating of precious metals.^dExpressed in units of mg per m² processed per operation. An operation is any metal finishing step that is followed by a rinsing step.

SOURCE: 40 CFR 413.

As shown in Table 5, facilities discharging less than 10,000 gal/d are subject to more lenient standards than larger facilities. For large facilities, two alternatives are available for complying with the basic standards (subject to approval by the POTW). The first alternative, referred to as the mass-based standard, restricts only the mass of pollutants discharged without regard to their actual concentration in the effluent. The mass of pollutants allowed in the discharge is a function of the quantity of work processed (in terms of m² of surface area) and the number of plating operations performed (a plating operation is defined as any step in metal finishing that is followed by a rinse). This option may appeal to facilities where, for instance, closed-loop recovery systems have been installed and the effluent volume is quite low but rather concentrated.

The second alternative, referred to as the concentration-based alternative standard, restricts the concentration of a smaller number of pollutants than is covered in the basic standard. This standard replaces the limits on the levels of copper, nickel, chromium, zinc, and total metals in the basic standard with limits on pH and total suspended solids. This option is only available for nonchelated effluents which have been neutralized with Ca(OH)₂ and where all hexavalent chromium has been reduced.

Table 6 shows the compliance dates for all existing indirect dischargers. The dates are differentiated between metals and cyanide, and total toxic organics; they are further differentiated between captive and job shops and between integrated and nonintegrated facilities.

Removal Allowances. Indirect dischargers may be exempt from certain pretreatment requirements through a removal allowance (also referred to as a "credit allowance"). The removal allowance program provides that, under conditions specified below, a POTW may revise a plant's discharge limits for a pollutant if it can be shown that the POTW itself is removing the pollutant in question. The removal allowance must be applied for by the plant from the municipality, which in turn must receive EPA approval for the allowance.

The application for a removal allowance requires a demonstration by the POTW, through actual data, that the pollutant is being removed by the POTW. (The municipality may charge the electroplater for the cost of the demonstration.) The concentration limit for the electroplater would be revised by:

$$Y = \frac{X}{1-r}$$

where:

Y = revised discharge concentration
 x = concentration (or mg/m²/operation) required by specific standards for electroplaters
 r = demonstrated fraction removed by the POTW.

For example, if the data show that the POTW removes 60 percent of a specific pollutant (by EPA-specified sampling methods), a pollutant with an initial pretreatment concentration requirement of 2 mg/l would be revised to:

$$\frac{2}{1 - 0.6} = 5 \text{ mg/l}$$

Table 6.**Compliance Schedule for All Existing Indirect Sources**

	Compliance Deadline			
	Captive Operation		Job Shop	
	Nonintegrated Facility	Integrated Facility	Nonintegrated Facility	Integrated Facility
Metals and Cyanide:				
Electroplating (see Table 5)	April 27, 1984	June 30, 1984	April 27, 1984	June 30, 1984
Metal Finishing (see Table 3)	Feb. 15, 1986	Feb. 15, 1986	NA	NA
Total Toxic Organics:				
Interim (4.57 mg/l) ^a	June 30, 1984	June 30, 1984	July 15, 1986	July 15, 1986
Final (2.13 mg/l) ^a	Feb. 15, 1986	Feb. 15, 1986	July 15, 1986 ^b	July 15, 1986 ^b

NA = not applicable

^aBasis for 4.57 mg/l is good housekeeping practices; basis for 2.13 mg/l is good housekeeping practices plus control equipment.

^bJob shops discharging < 10,000 gal/d have only to comply with the 4.57 mg/l standard for Total Toxic Organics. Job shops discharging > 10,000 gal/d must comply with 2.13 mg/l standard for Total Toxic Organics.

The demonstration of pollutant removal fractions requires the municipality's cooperation. For example, EPA specifies that the influent and effluent data taken at the municipal treatment system shall be derived from a minimum of 12 samples taken at approximately equal intervals throughout the year. Average concentrations must be measured in the influent and the effluent samples in order to derive consistent removal capabilities of the municipal system. When sampling is for pollutants such as cyanide that cannot be held for long periods before analysis, grab samples can be used.

Certain conditions must be met before a municipality can provide the removal allowance to its industrial users. Of major importance, the removal allowance must not cause the municipality to violate its NPDES limit, and the disposal of the municipal sludge must not be impaired.

New Sources

It is important to note that all new facilities (in both electroplating and metal finishing) are subject to the same new source performance standards (NSPS or PSNS) regardless of size, type of facility (job shop or captive, integrated or nonintegrated), or type of discharger (direct or indirect). Table 3 presents the concentration limits which apply to all new sources in the electroplating and metal finishing industries. The only difference between the standards for new sources and the standards for the existing dischargers included in the table is in the cadmium limitation (the new source standard is more stringent). The difference between the new source standards and those for existing indirect job shop and IPCBM sources is that the new source standards are nearly always more stringent, as can be seen by comparing Tables 3 and 5. It should also be noted that, for new sources, there is no difference in the standards between large and small facilities.

3. Water Pollution Control Technologies

The costs of complying with pollution control legislation and the increasing costs of raw materials, water and wastewater treatment have driven electroplaters to seek ways to reduce their costs of operation. Experience has shown that the two cost factors most responsive to improvements are related to the volume of water used and discharged and the amount of plating chemicals which end up in the waste treatment system. When plating chemicals are conserved in the process stream, for example, less chemicals must be replaced in the plating bath, removed from the wastewater before discharge, and disposed of in residues. Similar benefits are realized when the volume of process water is reduced: less water needs to be replaced or treated, and, when wastewater is finally discharged to a public sewer system, the cost of treatment is reduced.

Today's electroplater has a number of options for cost-effectively bringing a facility into compliance with water pollution control regulations. Within the three general options — modifying the process, treating the wastewater, and becoming a direct discharger — there is a wide variety of possible modifications and treatment technologies to choose from.

The selection and design of a control system entails the following general tasks:

- Performing a field investigation to define current and achievable waste stream parameters (flow rate, pollutant types and concentrations, wastewater variability)
- Developing conceptual models of proposed treatment processes based on data obtained in the field investigation
- Conducting bench-scale treatability studies on wastewater samples to simulate the proposed treatment processes
- Evaluating the results of these studies to assess the ability of the proposed system to meet discharge requirements
- Using the results of this assessment to develop optimal design parameters for the full-size system
- Estimating the capital and operating costs of the proposed system, based on the operating parameters needed for adequate pollutant reduction and on vendor quotations for the equipment specified.

Choosing among the different options also requires a careful cost and benefit analysis considering:

- The reliability of the systems to consistently reduce the pollutants to the levels specified in the discharge permit or in other regulations
- The investment cost of the systems
- The operating costs of the systems, including labor, utilities, wastewater treatment chemicals, and sludge disposal
- The savings in raw materials and sewer charges as a result of reduced water flow and the reuse or recovery of plating chemicals.

Process Modifications

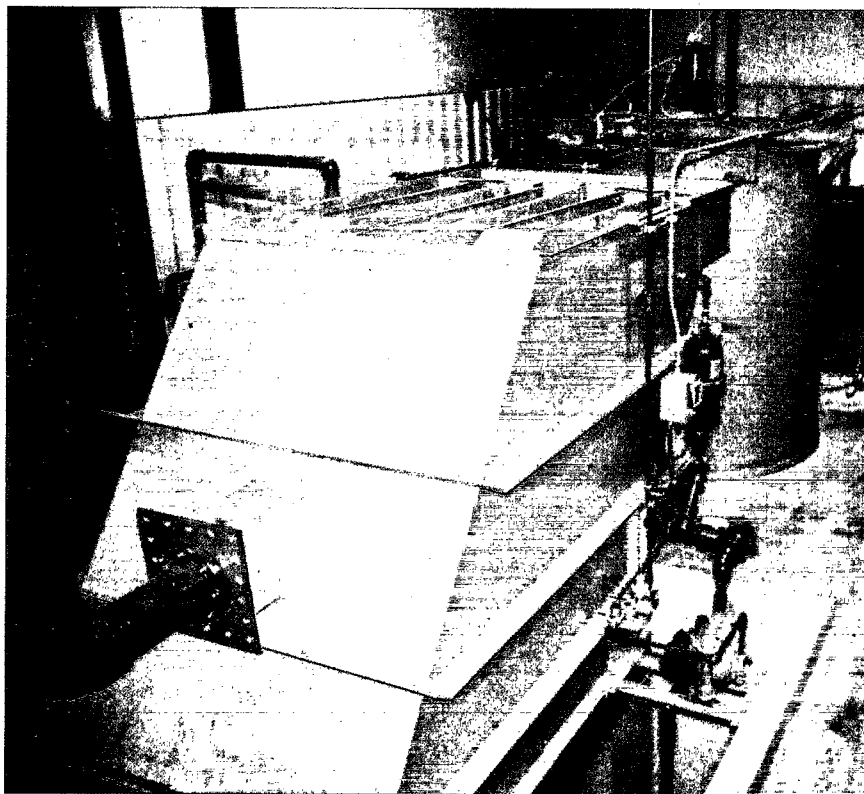
Process modifications are designed either to reduce water use (e.g., by installing flow restrictors) or to conserve plating chemicals (e.g., by recycling or recovering the chemicals).

There are a number of ways to reduce water use, including:

- Implementing a rigorous inspection program to discover and quickly repair water leaks
- Installing antisiphon devices equipped with self-closing valves on water inlet lines
- Using multiple counterflow rinse tanks to substantially reduce rinse water volume
- Using spray rinses to reduce rinse water volume
- Using conductivity cells or flow restrictors to prevent unnecessary dilution in the rinse tanks
- Reusing contaminated rinse water and treated wastewater where feasible
- Using dry cleanup where possible, instead of flooding with water.

Modifications to minimize the loss of plating chemicals, consequently reducing pollutant loads, include:

- Implementing a rigorous inspection and housekeeping program to locate and repair leaks in process baths and to replace faulty insulation on plating racks (thereby reducing drag-out), and installing drip trays
- Using spray rinses or air knives to minimize drag-out from plating baths
- Using air agitation or workpiece agitation to improve plating efficiency
- Recycling rinse water to the plating bath to compensate for surface evaporation losses
- Using spent process solutions as wastewater treatment reagents (e.g., using spent acid and alkaline cleaning baths as reagents in a neutralization tank)
- Using minimum concentrations of chemicals in plating baths
- Using plating bath purification to control the level of impurities and prolong the service life of the bath
- Installing recovery systems to reclaim plating chemicals from rinse waters and recycle them to the plating bath.



Rear view of lamella plate clarifier.

A closed-loop recovery system may be appropriate for wastes that are difficult or expensive to treat. In the case of rinse streams requiring treatment other than neutralization and clarification (containing cyanide or chromium, for example) or rinse streams containing pollutants that are not effectively removed by conventional treatment (such as certain chelated metal complexes), installing a closed-loop system to recycle the rinse may reduce the water pollution control costs. A small-volume purge stream from the closed-loop recovery system will require treatment, but this should not be a major expense.

Recovery systems have been evaluated under EPA research projects. Reports of this research are available and are listed in the reference section. They include the following topics:

- General⁶⁻⁹
- Evaporation^{12,17}
- Reverse osmosis^{20,22,25,26,28}
- Electrodialysis^{14,19}
- Electrolytic Recovery¹⁵
- Ion Exchange.^{10,11}

Conducting a cost analysis of each of the options is important in selecting the most appropriate process modifications for an operation. In such an analysis the capital and operating costs of the modifications are weighed against the total of the benefits from reductions in raw material losses, wastewater treatment capacity and chemicals, and sludge disposal fees. Case History 1 (in Chapter 4) highlights the significance of a thorough analysis. If the evaporator installation were only justified by the value of the chromium recovered, the investment would yield a significant loss. However when reductions in wastewater treatment costs were included, a net profit results, yielding a 22 percent return on investment.

Wastewater Treatment

Once the water stream has left the process, it must be treated before being discharged. Several treatment choices are available to the plater, and proper selection and design of the system will ensure that current discharge requirements can be met.

The wastewater treatment system typically consists of the processes listed below and illustrated in Figure 1:

- Wastewater collection: Waste streams from chrome-plating and cyanide baths are isolated and directed to the appropriate waste treatment unit. Effluents from these units are then combined in an averaging tank with other wastewaters such as those from acid/alkali baths and rinses, other plating baths and rinses, and chemical dumps. They are then sent to the neutralization tank.
- Chromium reduction (as needed): Hexavalent chromium is converted (reduced) to the trivalent state, which is then precipitated as chromium hydroxide by alkali neutralization. A substitute process for chromium reduction is electrochemical reduction.

- Cyanide oxidation (as needed): Toxic cyanide-bearing waste streams are oxidized by chlorination or ozonation, forming less harmful carbon and nitrogen compounds.
- Neutralization/precipitation: The combined waste streams are treated with acid or alkali to adjust the pH to acceptable discharge limits and to precipitate the dissolved heavy metals as metal hydroxides.
- Clarification: The neutralized waste stream is treated with coagulants and flocculants to promote the precipitation and settling of the metal hydroxide sludge, which is separated from the clarified liquid.
- Sludge handling: The collected hydroxide sludge is gravity-thickened, mechanically dewatered, and sent to an approved hazardous waste disposal site.

While these processes effectively treat most electroplating waste streams, they may not be suitable for all applications. Furthermore, there is no guarantee that the "normal" design parameters (such as retention time and reagent dosage) will effectively remove the pollutants from every electroplating wastewater discharge. Treatability studies are often needed to verify the applicability of a treatment process to a specific wastewater.

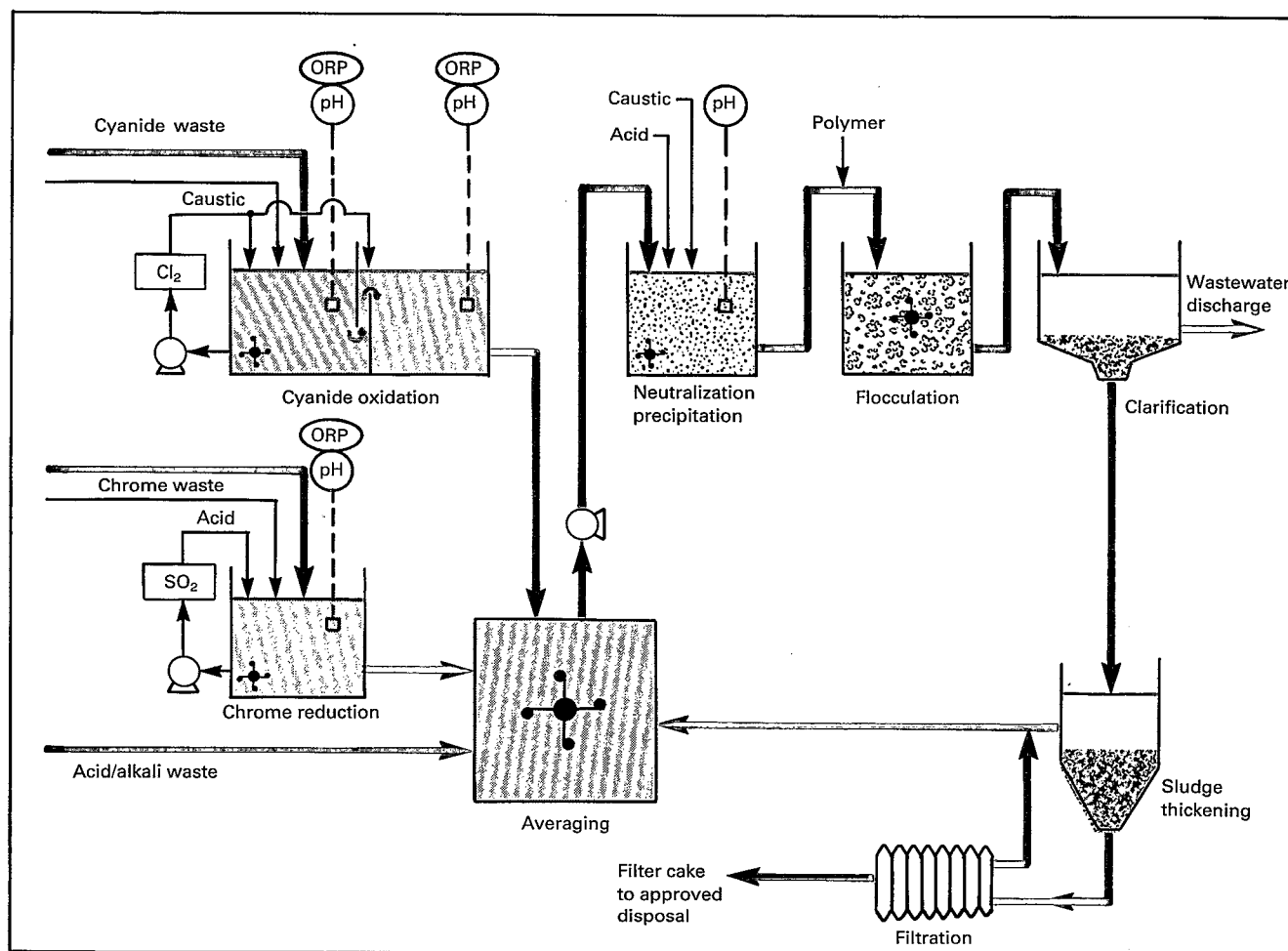


Figure 1. Conventional Wastewater Treatment System for Electroplating

Several alternative treatment processes have been developed to overcome the problems encountered in conventional treatment. Attention has largely focused on a problem frequently encountered in the neutralization/precipitation step in which the solubility of dissolved metals cannot be brought to the low levels required for discharge. The problem arises when plating wastewaters contain substances, known as chelating agents, which react with dissolved metals and interfere with their precipitation as metal hydroxides. Such chelating agents as ammonia, phosphates, tartrates, and EDTA* are commonly used in plating operations and consequently find their way into the wastewater. Chelating agents react with the dissolved metal ion to form a "chelate complex" that is usually quite soluble in neutral or slightly alkaline solutions.

Two methods of overcoming the solubilizing effects of chelating agents are:

- Precipitating the metal from solution by a method that, unlike hydroxide precipitation, is relatively immune to chelating effects
- Pretreating the wastewater to free the metal ion from the chelating agents.

*Ethylene diamine tetra-acetic acid

The first category includes such processes as sulfide precipitation, ion exchange, and water-insoluble starch xanthate (ISX) precipitation. Sulfide precipitation, which precipitates metals as sulfides instead of hydroxides, has been found capable of achieving low levels of metal solubility in highly chelated waste streams. The process has been proven as an alternative to hydroxide precipitation or as a method for further reducing the dissolved metal concentration in the effluent from a hydroxide precipitation system (see Case History 5).

In ion exchange, a resin which has a strong affinity for heavy metal ions (as opposed to the calcium and sodium ions normally present in the wastewater), is used as a means of filtering heavy metal ions out of solution. Ion exchange has been proven to be a cost-effective means of lowering the metal concentration in electroplating discharges (see Case History 6).

ISX precipitation can remove heavy metal cations from wastewaters. The ISX acts as an ion exchange material, replacing sodium or magnesium ions on the ISX surface with heavy metal ions in the solution. It is currently used both as an alternative to hydroxide precipitation and to "polish" treated wastewater (i.e., to lower the residual metal concentration). Because ISX is insoluble in water and its precipitation reaction rate is rapid, it is used either as a slurry with the stream to be treated or as a precoat on a filter through which the waste stream is passed.

If the problems associated with chelating agents are not resolved by precipitation, the waste stream is usually segregated and pretreated either by raising the pH to a highly alkaline level (high pH lime treatment) or by lowering it to a very acidic level. At these extreme pH conditions, the metal complex often dissociates, freeing the metal ion. A suitable cation (such as calcium) is then used to tie up the chelating agent, preventing it from recombining with the metal ion when the solution is neutralized. While this type of treatment requires a high dosage of reagents, it has proved to be an effective means of treating many wastewaters containing chelating agents.

Another frequent problem in wastewater treatment is metals concentrations in the effluent which exceed the discharge requirement even though the total amount of dissolved metals in the effluent is quite low. This condition indicates precipitated (undissolved) metals in the effluent, a condition which results from an overloaded clarifier, ineffective conditioning (coagulation or flocculation), or poor pH control. The problem can be resolved by correcting the process deficiency or by using a solids removal (polishing) device, such as a sand or mixed-media filter, to clean the clarifier overflow.

EPA and the Department of Defense have funded research to assess the cost and effectiveness of many wastewater treatment techniques, the results of which are reported in the following publications:

- General^{6-9,13,15,23,24}
- Sulfide precipitation²⁹
- Ion exchange^{10,11}
- Cyanide waste treatment^{18,27}

Becoming a Direct Discharger

Satisfying the pretreatment requirements for discharging to a POTW can often produce an effluent that will also satisfy the requirements for the direct discharge to waterways. Where a suitable receiving waterbody is available, sewer fees can be completely avoided by becoming a direct discharger. Even though the sampling and reporting requirements are more stringent for a direct discharger, this could be an important alternative in those situations where a POTW uses advanced wastewater treatment processes, which have significantly increased sewer charges to industrial firms using the public system.

Figure 2 presents the annual sewer fees levied against a firm as a function of its discharge rate; it includes a range of typical rates per gallon discharged.

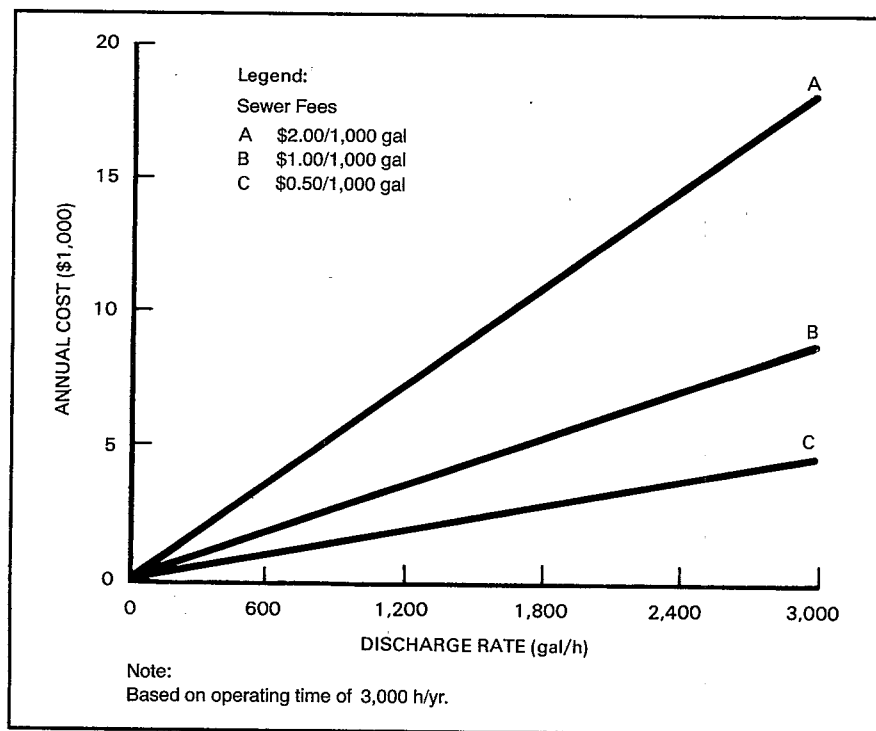


Figure 2. Annual Sewer Costs as a Function of Flow Rates

4. Water Pollution Control Case Histories

The case histories presented in this chapter illustrate a few of the solutions to wastewater and solid waste management problems faced by the electroplating industry. They do not address the gamut of the industry's problems; rather, these discussions demonstrate the analysis and innovation required to develop optimal solutions to these problems.

Case History 1. Evaporator Installation

The Phillips Plating Company, Phillips, Wisconsin installed a rising film evaporator to concentrate the chromium plating bath drag-out in the rinse stream so that it could be recycled to the plating bath. Installation of the 75 gal/h (280 l/h) closed-loop recovery system reduced the need for replacing anhydrous chromic acid (CrO_3) to the plating solution by approximately 4 lb/h (1.8 kg/h).

The total cost to install the recovery system in 1979 was approximately \$60,000. Table 7 shows the annual costs and savings realized by installing and operating the unit. If the savings in plating chemicals alone are considered, the investment would have a net cost of approximately \$9,000/yr. However, if the analysis also includes savings in treatment chemicals (Phillips uses a Sulfex™ insoluble sulfide treatment system) and in solid waste disposal charges (based on disposal at 25 percent solids by weight at a cost of \$0.19/gal of sludge), totaling \$28,400/yr, there would be a net savings before taxes of nearly \$20,000/yr and the system would pay for itself in just under four years.

Table 7.

Economic Evaluation of Evaporator Installation^a

	Cost
INSTALLED COST for 75-gal/h evaporator (\$)	60,000
ANNUAL COSTS at 6,000 h/yr (\$/yr):	
Depreciation (10-yr life)	6,000
Taxes and insurance	600
Maintenance	3,600
Labor (1/2 h/shift at \$6/h)	2,250
Utilities:	
Steam (at \$3.50/10 ⁶ Btu)	16,000
Electricity	600
General plant overhead	2,600
Total annual cost	30,650
ANNUAL SAVINGS (\$/yr):	
Replacement CrO_3	21,600
Waste treatment reagents	23,000
Sludge disposal	5,400
Total annual savings	50,000
Net savings before tax (\$/yr)	19,350
Net savings after tax, 48% tax rate (\$/yr)	10,060
Payback after tax (yr)	3.8
Payback if investment tax credit and accelerated depreciation are used (yr)	2.6

^aThese figures reflect 1979 conditions.

The payback period can be reduced even further by taking advantage of the investment tax credit and accelerated depreciation allowances. As shown in Table 7, the investment payback was reduced to under three years, a most acceptable investment rate of return. The Phillips Plating case highlights the need to consider all of these factors in evaluating chemical recovery modifications. Note that although this case history is based on 1979 conditions, before significant changes to tax laws were made, a present day analysis of a similar case would yield similar results for costs and payback period.

In addition to the evaporator installation, considerable cost savings were achieved in the Phillips plant with relatively minor engineering refinements. Phillips used a closed-loop system of the kind shown in Figure 3a. In this case, the rinse rate, which equals the evaporative loss, is the critical design parameter. In order to ensure adequate rinsing in the final rinse tank, the flow through the closed-loop system may have to be quite high. If Phillips were to use a closed-loop recovery system in the first two rinse tanks with a running rinse in the final rinse tank (Figure 3b), adequate rinsing would be assured and the plant could still achieve significant drag-out recovery. This approach would significantly reduce the steam costs associated with evaporation and also would require a smaller, less expensive evaporator. Figure 4 illustrates the annual costs and savings for open-loop evaporator systems at different evaporator feed rates.

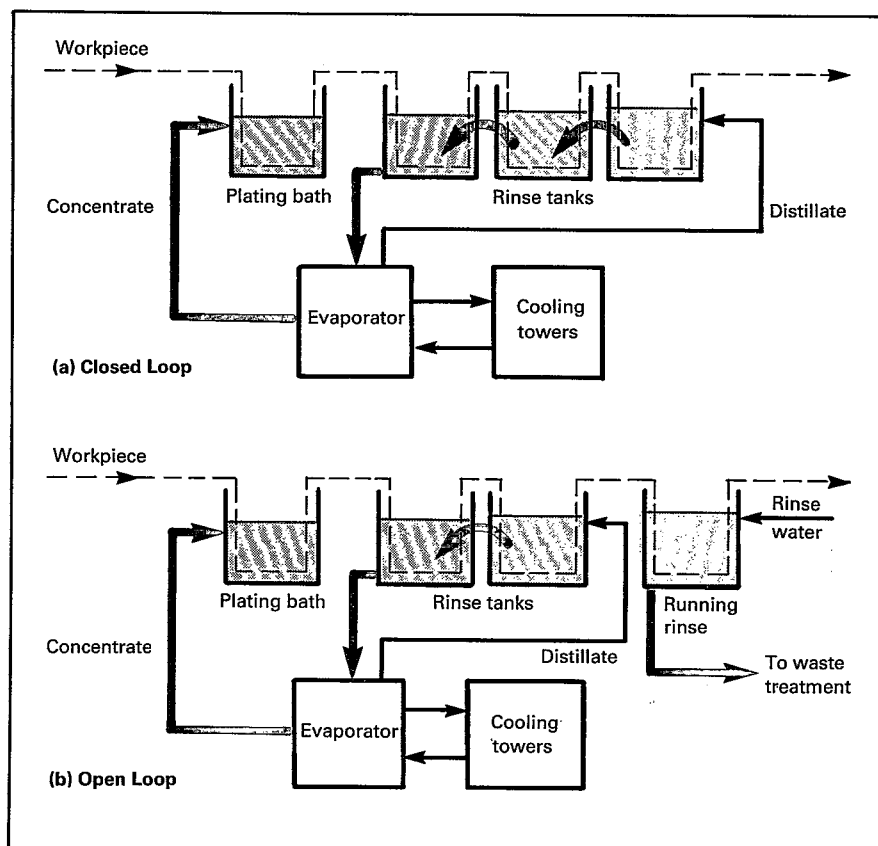


Figure 3. Evaporative Recovery Systems

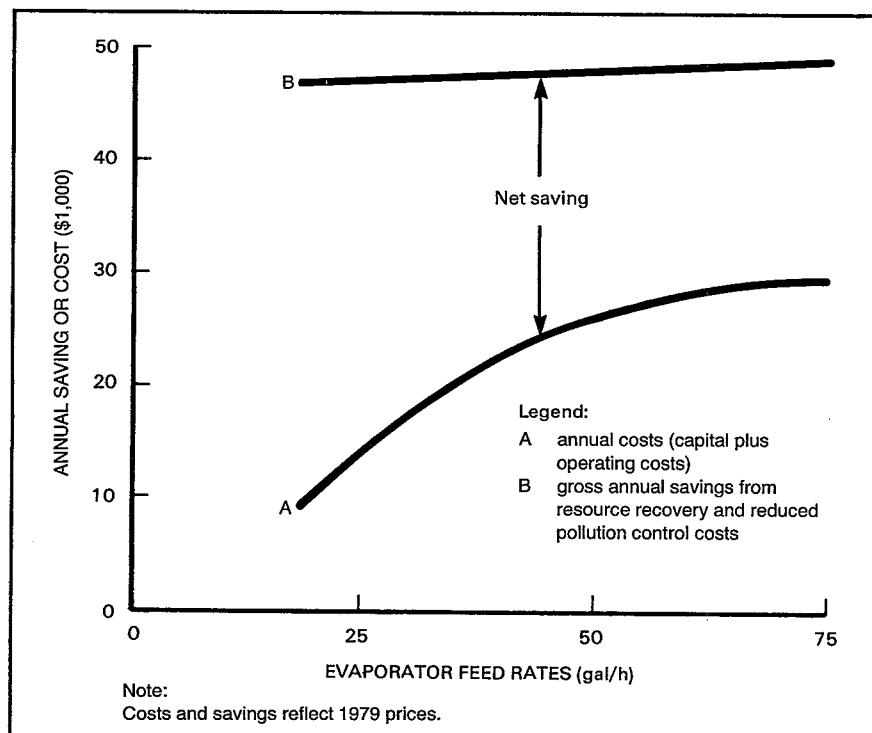


Figure 4. Annual Costs and Savings as a Function of Evaporator Systems

Case History 2. Automated Drag-out Recovery

The Gillette Company Safety Razor Division, Boston, installed an automated drag-out recovery system that recovered 85 percent of the nickel drag-out from three plating tanks. The system (Figure 5) uses four countercurrent rinse tanks to provide both rinsing of the workpiece and a source of solution makeup for the plating tanks. The drag-out recovery system allows closed-loop operation of the nickel plating bath; all rinse water is recycled to the plating bath with no flows to waste treatment. Level control probes in the three plating tanks control the addition of rinse water collected from the most highly concentrated rinse tank to make up for surface evaporation losses from each of the plating tanks. A level control in the concentrated rinse sump controls the addition of makeup water in the final rinse tank. To minimize the buildup of impurities in the system, the makeup water is deionized by a reverse osmosis water purification unit.

Three factors determine the percentage of drag-out that can be recovered when this approach is used:

- The surface evaporation rate from the plating tank, which determines the amount of rinse water that can be recycled
- The ratio of the drag-out volume to the volume of rinse water recycled to the plating bath
- The number of countercurrent rinse tanks used for recovery.

Figure 6 shows the percentage of drag-out that can be reclaimed in terms of these factors.

The system installed at Gillette included the reverse osmosis unit, three chemical transfer pumps, the concentrated rinse sump (operating on the U-tube principle), a control panel, and the necessary control loops. The total investment cost in 1979 was \$8,500.

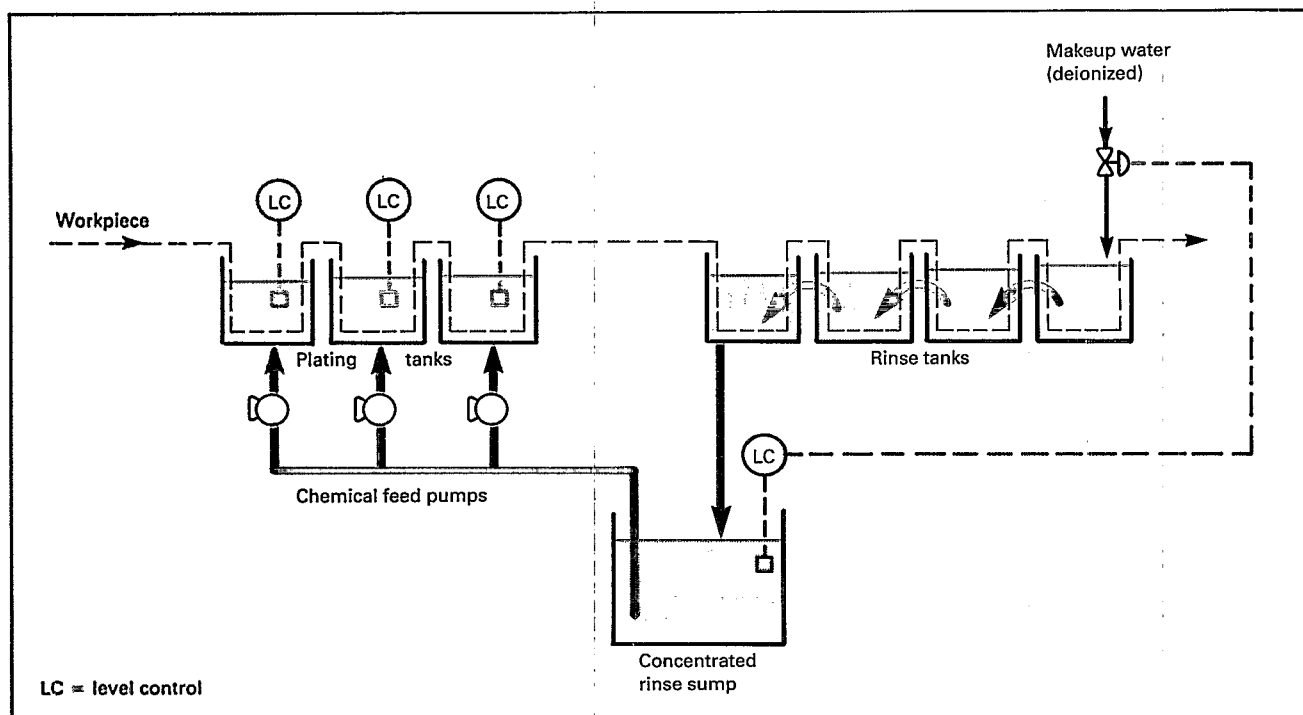


Figure 5. Automated Drag-Out Recovery System

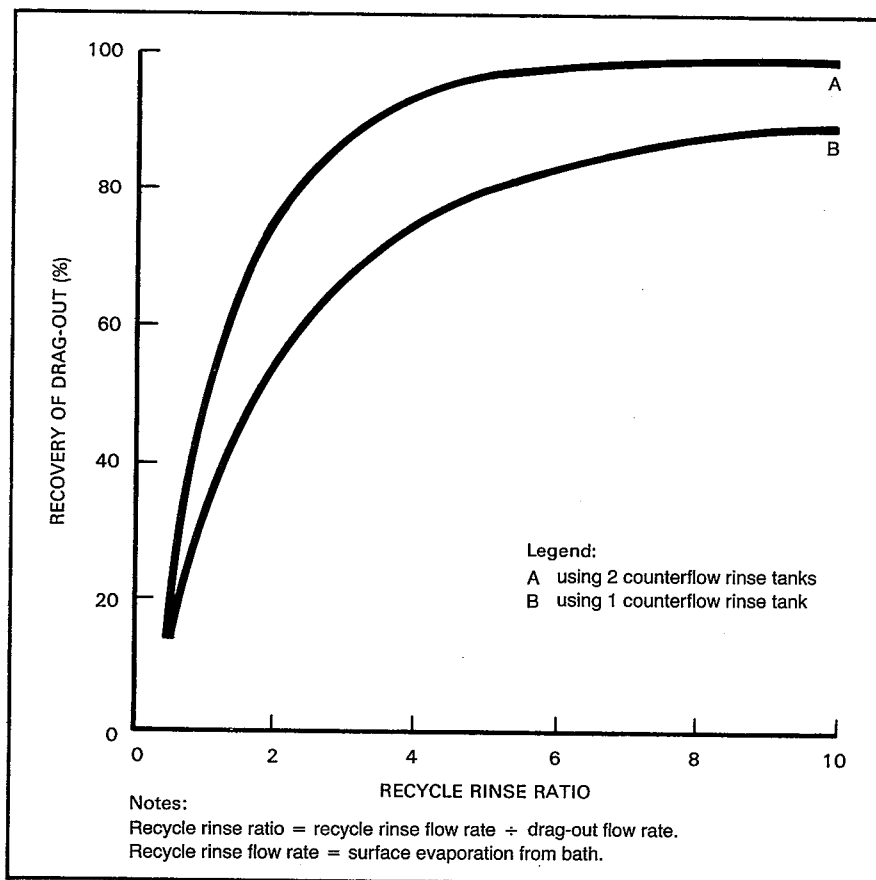
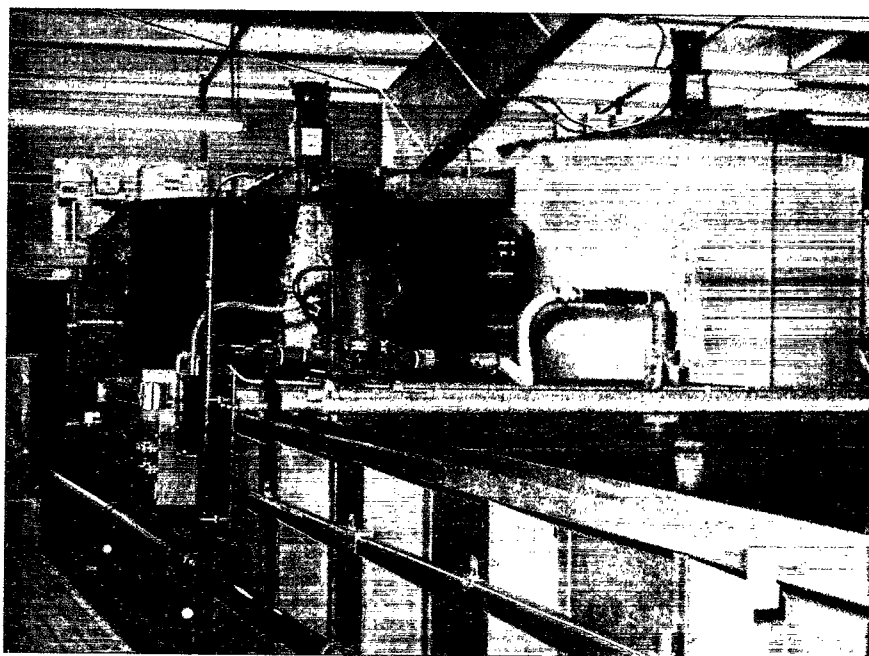


Figure 6. Drag-Out Recovery as a Function of Recycle Rinse Ratio



Conventional wastewater treatment system for electroplating operations.

Case History 3. Electrochemical Recovery

Allied Metal Finishing, Baltimore, is a job shop involved mostly with zinc, nickel and cadmium plating. Faced with effluent discharge standards, a wastewater reduction program was initiated to reduce treatment needs and minimize sludge production.

The first step of the program was a reduction in water use from 127,000 to 66,000 gal/d. Many of the water reduction measures were simply related to operating practices, such as instructing operators to turn off the main water valve during breaks and other line stoppages. Others involved the use of inexpensive devices to reduce water flow automatically. For example, one effective method was to install timer devices which turn the rinse water flow on and off at 15 minute intervals; this cut water usage in half without diminishing the quality of the rinse water.

Next, an electrochemical reactor was installed to recover cadmium. This unit makes use of a carbon fiber cathode, which has an enormous ratio of surface area to volume — approximately 1,000 times greater than other types of cathodes. Rinse water containing cadmium is passed over the cathode, plating the metal on the cathode. The metal is removed from the cathode by reversing the current or rinsing the cathode with a stripping solution which is returned to the plating bath. The reactor is also capable of electrolytically oxidizing cyanides at a lower cost than that of the reagents used in the conventional alkali-chlorination process. This recovery system reduces wastewater treatment requirements and minimizes sludge generation.

Figure 7 shows the system at Allied. The solution from the process rinse is pumped through a filter to remove particulate matter and then through the reactor, which houses the carbon fiber cathode. The treated water is returned to the rinse tank. The power for the treatment unit is supplied by a common rectifier.

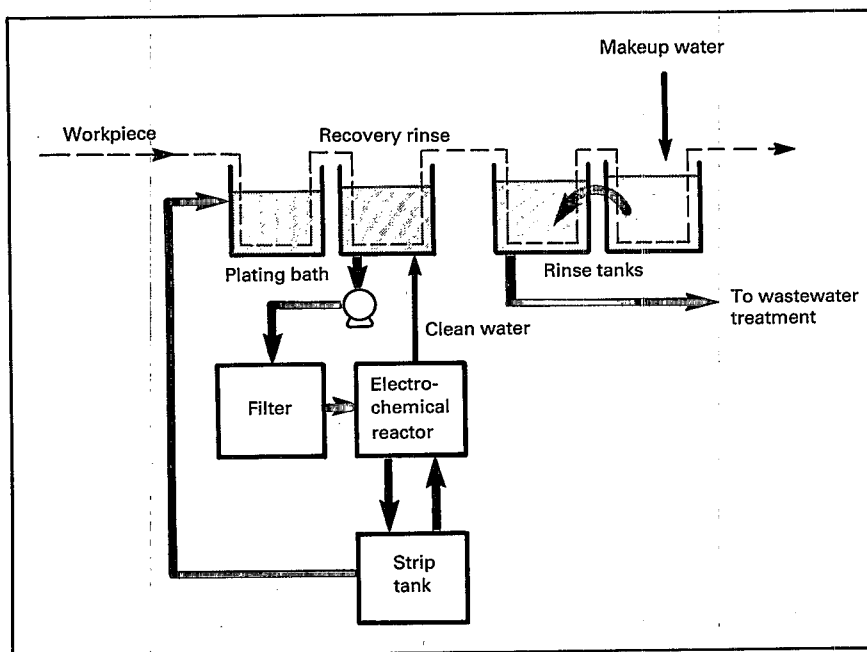


Figure 7. Electrolytic Recovery System

Case History 4. Stream Segregation

In order to enhance its conventional wastewater treatment system performance, the Medford Plastics Company, Medford, Wisconsin segregated a waste that was particularly difficult to treat and demonstrated a cost-effective means of treating that waste before discharge. The plant, which plates copper, nickel, and chromium on plastic components, installed the wastewater treatment system shown in Figure 8.

During the treatability studies conducted before a system was selected, it became obvious that the nickel concentration could not be reduced in a common treatment system to the level required by the discharge permit. It was proposed to segregate the electroless nickel plating rinse flow from the rest of the wastewater. A system was evaluated in which nickel was precipitated at a high pH and clarified independently of the other wastewater flows. The nickel rinse effluent was then combined with the balance of the wastewater before discharge. Testing indicated that this approach should provide a total effluent nickel concentration below the permit specifications.

Table 8 indicates that the treated discharge achieves the removal levels called for in the discharge permit, levels which are much lower than national new source performance standards. When the system was first installed, however, the discharge consistently exceeded the nickel level requirement. To correct this problem, the plant cut the flow to the nickel treatment system in half by further rinse water recycling. The wastewater flow reduction created increased retention time in the treatment system which, when coupled with the dilution achieved from adding the copper-chrome wastewater, eliminated the problem.

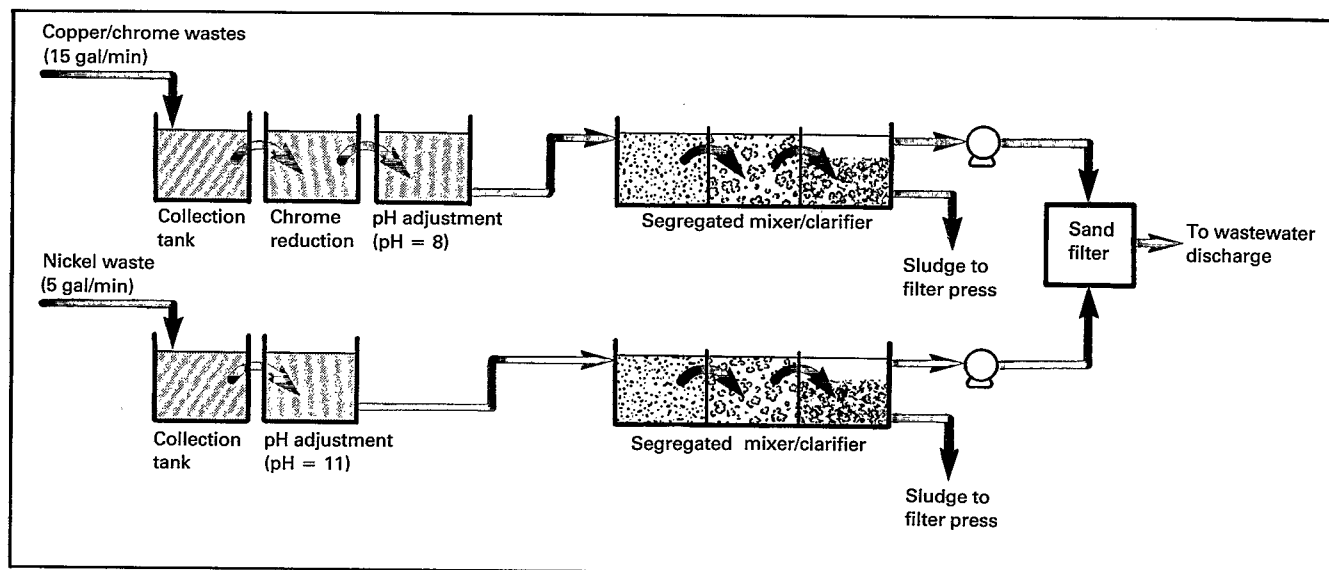


Figure 8. Wastewater Treatment System with Segregated Treatment of Nickel

Table 8.

Effluent Quality After Segregation of Nickel Waste Stream

Effluent Characteristic	Permit Requirements ^a	Treated Effluent ^a
Total suspended solids (lb/d)	8.8	<0.1
Chromium (lb/d):		
Total	0.22	0.13
Hexavalent	0.02	0.004
Nickel (ppm)	1.3	0.16
Copper (ppm)	0.17	0.06
pH	6.0-9.5	9.3

^aMonthly average of daily values.

Case History 5. Sulfide Precipitation

Holly Carburetor, a Division of Colt Industries, Paris, Tennessee has demonstrated the feasibility of reducing metal concentrations in wastewater to low levels using sulfide precipitation instead of hydroxide precipitation. Part of the wastewater from the plant results from surface treatment of parts used in the assembly of carburetors. This waste stream contains varying concentrations of iron, zinc, and chromium (hexavalent and trivalent).

The sulfide precipitation system marketed as Sulfex™ was installed as an EPA demonstration project funded under a grant to the National Association of Metal Finishers. The Sulfex system precipitates metals as sulfides instead of hydroxides and because metal sulfides are considerably less soluble than hydroxides, lower metal concentrations can be achieved in the effluent. Table 9 compares the effluent quality of the system with the discharge limits required by the local permitting authority. It shows the system to be effective in removing the metals to the levels required by the permit.

Figure 9 shows the components of a treatment system using sulfide precipitation. It should be noted that most of the equipment components of the sulfide system are common to hydroxide systems. Consequently, this process offers a low-cost means of modifying an existing hydroxide system to improve metal removal capability.

Two distinct sulfide precipitation processes (insoluble and soluble) are being used to treat wastewaters containing heavy metals. The system at Holly Carburetor is known as insoluble sulfide precipitation (ISP), in which ferrous sulfide is the sulfide source. Ferrous sulfide is relatively insoluble in water; consequently, the level of dissolved sulfide in the wastewater is kept to a minimum. The main advantage of ISP over the soluble sulfide approach is that there is no detectable hydrogen sulfide odor associated with the process. Soluble sulfide precipitation (SSP) uses a water-soluble reagent, such as sodium hydrosulfide (NaHS) or sodium sulfide (Na₂S).

Table 9.

Effluent Quality After Sulfide Precipitation

	Concentrations (mg/l)	
	POTW Requirements	Treated Effluent
Zinc	5.0	0.015
Chromium		
Hexavalent	0.05	0.02
Total	5.0	0.10
Copper	5.0	^a

^aBelow detectable limits

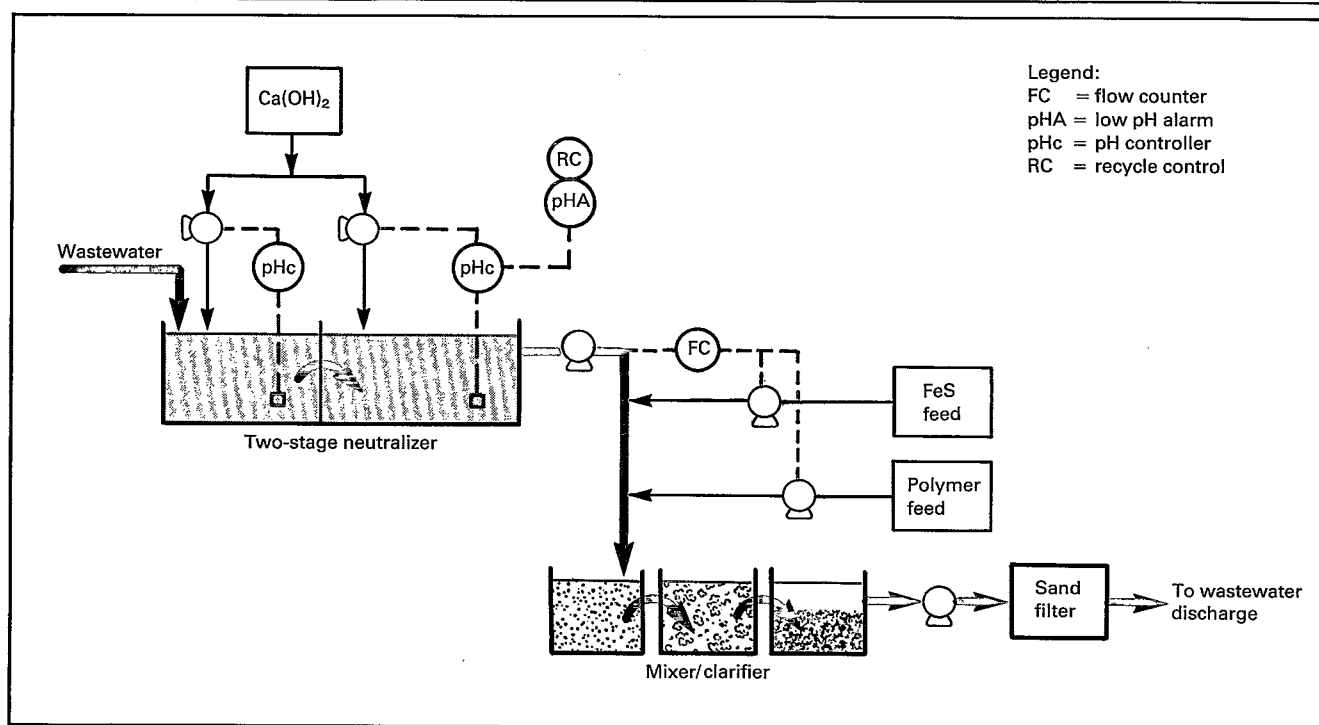
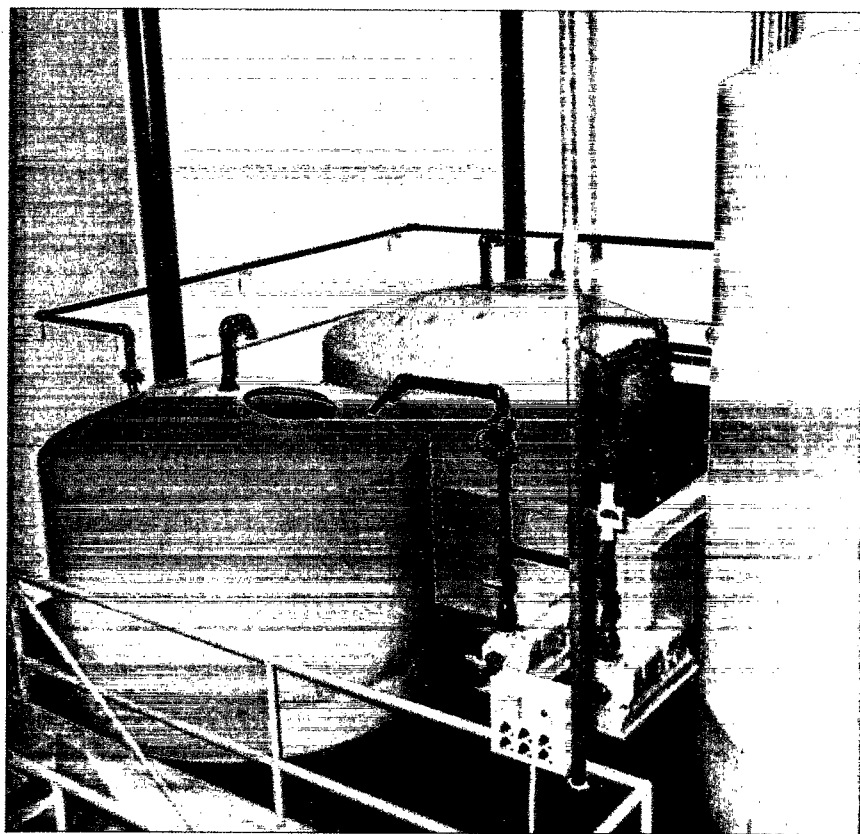


Figure 9. Wastewater Treatment System with Sulfide Precipitation



Chromium wastewater surge tank (left) and cyanide wastewater surge tank with retaining wall (background).

Case History 6. Ion Exchange for Heavy Metal Removal

The Hurd Lock and Manufacturing Company, Greenville, Tennessee uses an unusual wastewater treatment system combining batch and continuous operations. Four waste streams are collected in four separate sumps. Each stream is then processed separately through the single continuous treatment system shown in Figure 10. The continuous treatment for each batch uses the following steps:

- Chromium reduction (as appropriate)
- Neutralization (pH is adjusted to achieve maximum metal removal for each waste processed)
- Flocculation (with polymer addition)
- Pressure filtration (with diatomaceous earth precoat)
- Ion exchange polishing.

The ion exchange unit is used to reduce the concentration of metals in the effluent to the required level. Table 10 presents the permit requirements and a typical set of concentrations found in the effluent, indicating that all metal requirements are met. The plant was allowed to exceed the chemical oxygen demand (COD) discharge level because this pollutant could be effectively reduced by subsequent POTW treatment.

The resin used in the ion exchange columns selectively removes heavy metals from the waste, but allows alkali and alkaline earth cations to pass through. A two-stage ion exchange unit in which the first stage uses a hydrogen ion resin and the second stage uses a sodium ion resin was shown to be the optimal treatment for this waste. Because the resin proved more selective for heavy metals in the presence of calcium ions, the plant shifted from caustic soda to lime for neutralization.

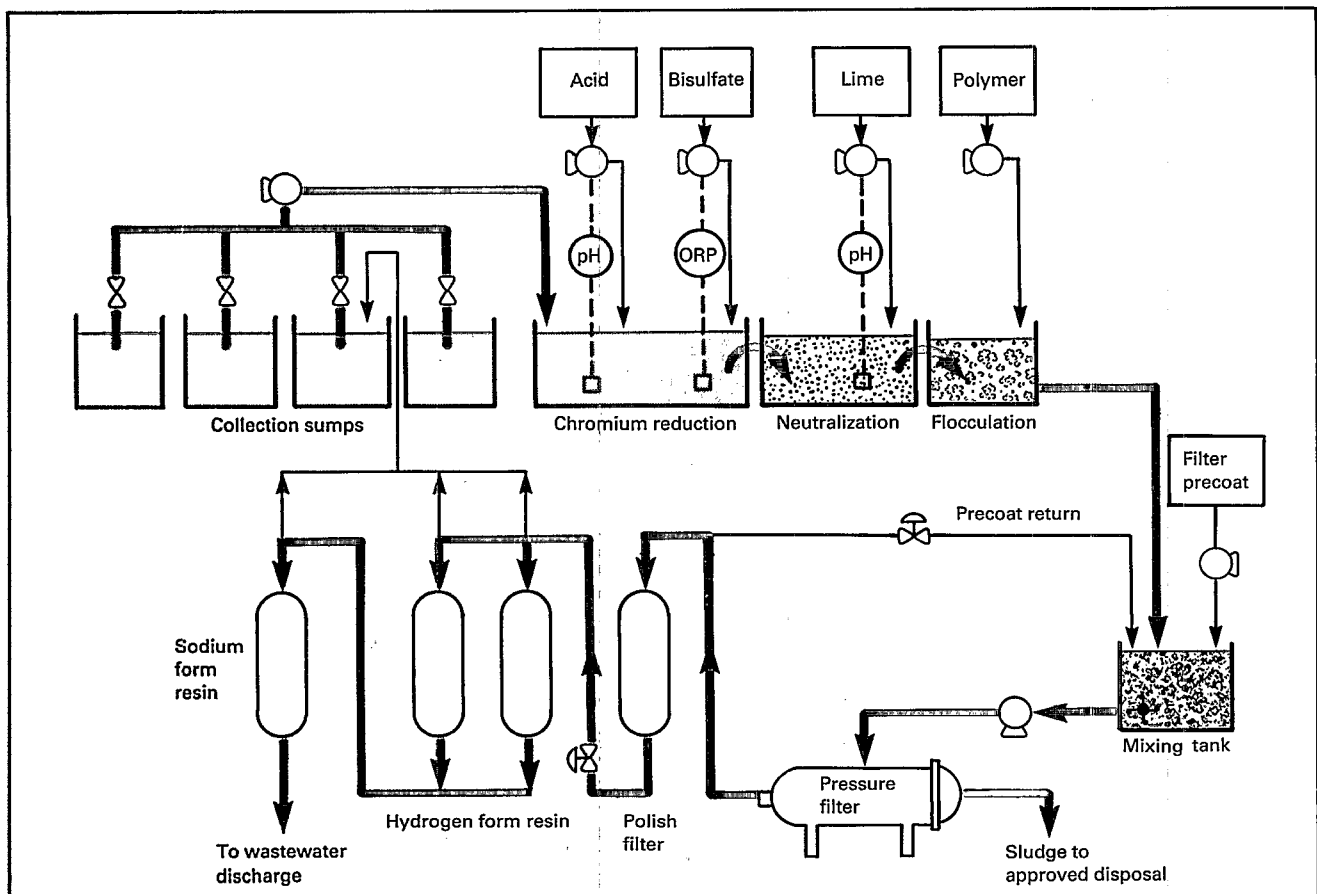
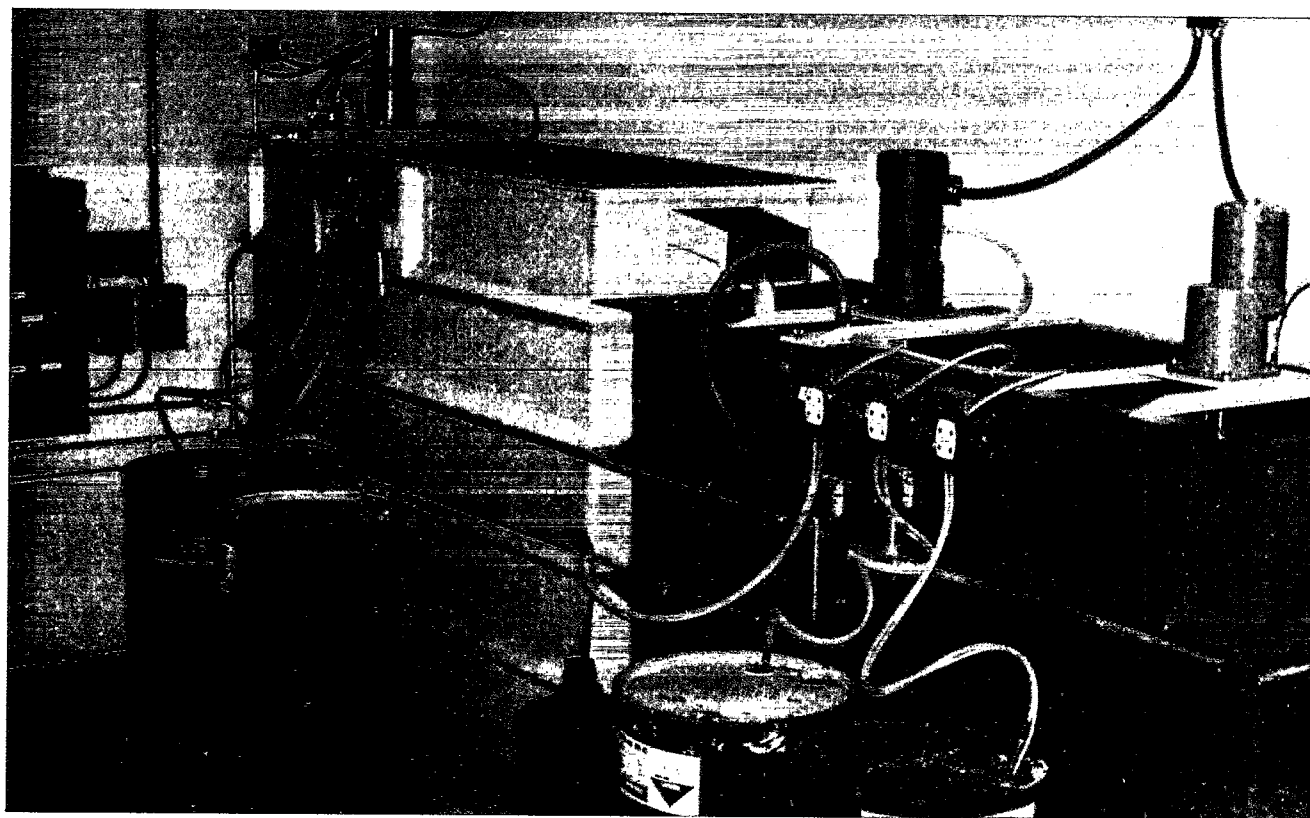


Figure 10. Combination Batch and Continuous Treatment System

Table 10.

Effluent Quality After Ion Exchange

	Permit Requirements	Typical Effluent Concentration			
		Chrome Floor	Chrome Rinses	Nickel Rinses	Zinc Pit
Pollutant (mg/l):					
Cadmium	0.01	<0.005	<0.005	<0.005	<0.005
Chromium	0.05	<0.02	<0.02	<0.02	<0.02
Copper	0.05	<0.05	<0.05	<0.05	<0.05
Iron	0.50	<0.05	<0.05	<0.05	<0.05
Lead	0.05	<0.05	<0.05	<0.05	<0.05
Nickel	0.10	<0.05	<0.05	<0.05	<0.05
Zinc	0.10	<0.02	<0.02	<0.02	<0.02
Total suspended solids	15	<1.0	<1.0	<1.0	<1.0
COD	20	928	210	217	500
pH	6.5-8.5	11.0	11.0	6.9	11.6
Color units	12	0	0	0	0



Compact 40 gal/h single-stage cyanide oxidation unit (blue) with neutralization/flocculation units (red).

5. Hazardous Waste Regulations and Management

The treatment of electroplating wastewater as required by the national pretreatment standards or NPDES requirements will result in two streams:

- An effluent that must comply with regulations for acceptable pollutant discharge
- A residue (sludge) containing a high concentration of the substances which the wastewater regulations prohibit discharging.

Because electroplating wastewater treatment systems commonly remove regulated heavy metals, most electroplating sludges contain high concentrations of toxic heavy metals and are therefore considered hazardous. Hazardous waste regulations promulgated in recent years have drastically altered the manner in which these materials are stored, treated, and disposed of. This chapter outlines these regulations and discusses the most cost-effective means by which electroplaters can bring their operations into compliance with them.

Hazardous Waste Regulations

EPA regulates the management and control of all hazardous wastes from their point of origin to final disposal. These regulations are the direct result of two congressional mandates on hazardous waste practices embodied in the 1976 Resource Conservation and Recovery Act (RCRA) (PL 94-580) and the 1984 Hazardous and Solid Waste Amendments to RCRA (PL 98-616).

Air and water pollution regulations vary from one industry to the next. However under RCRA the same rules apply to all firms that generate, store, transport, or dispose of hazardous waste. Most electroplating facilities will be considered generators of hazardous waste and some may be considered storage or disposal facilities. The procedures to determine whether certain wastes are hazardous and the requirements for those who generate, store, and dispose of hazardous wastes are described below.

Identification of Hazardous Wastes.

Solid wastes include all substances destined for disposal and not already regulated by the Clean Water Act or the Atomic Energy Act of 1954. Under regulations promulgated in May 1980,² EPA specified criteria for four properties, any one of which characterizes a waste as hazardous:

Ignitability is determined by measuring the flash point of a substance. The flash point is the lowest temperature at which a substance gives off flammable vapors which, in contact with a spark or flame, will ignite. Substances with a flash point of 60°C (140°F) or lower are considered ignitable.

Corrosivity refers to the capacity of a waste to extract or solubilize toxic contaminants from other wastes. A waste is considered corrosive if it has a pH below 2 or above 12.5, or if it corrodes steel (following a test developed by the National Association of Corrosion Engineers).

Reactivity refers to the tendency of a waste to explode, autopolymerize, create a vigorous reaction with air or water, or exhibit thermal instability with regard to shock or to the generation of toxic gases.

Toxicity refers to the release, through improper disposal, of toxic materials in sufficient amounts to pose a substantial hazard to human health or to the environment. Toxicity is perhaps the most important characteristic to electroplaters. In EPA's toxicity test (called the Extraction Procedure [EP] Toxicity Test), soluble materials are extracted from the waste at a pH of 5 over a 24-hour period. If the test extract exceeds established limits for certain contaminants, the waste is considered toxic and therefore hazardous. Among the 14 contaminants currently specified in the EP Toxicity Test, eight are metals, several of which are commonly used in electroplating. Table 11 lists these metals with the current limit for each.

In addition, the regulation deems certain wastes hazardous unless proved otherwise. These include:

- Wastewater treatment sludges (toxic)
- Spent plating bath solutions (reactive and toxic)
- Sludges from the bottom of plating baths (reactive and toxic)
- Spent stripping and cleaning bath solutions (reactive and toxic).

Requirements for Hazardous Waste Generators. Producers of hazardous waste (called generators) are ultimately responsible for the proper identification, storage, transportation, and disposal of the waste (see Figure 11). The generator first determines whether the waste is hazardous according to the criteria outlined above though, alternatively, the generator may simply declare the waste hazardous and treat it accordingly. If the waste is known to be nonhazardous, the generator need not test it. The responsibility for the accuracy of the determination of whether the waste is hazardous or not lies with the generator.

Generators of hazardous wastes are also responsible for notifying EPA and maintaining records of their activities, using appropriate containers, labeling the containers, and ensuring proper disposal. The law requires most generators of hazardous waste to use a manifest system to ensure the proper transport and disposal of the wastes. The manifest system records the movement of hazardous wastes from the generator's premises to an authorized off-site treatment, storage, or disposal facility. The manifest, signed by the generator, transporter, and disposer, is an official record confirming that all Department of Transportation (DOT) and EPA requirements have been met. The generator must maintain original manifests for three years, and must report to EPA if the manifest is not returned to him within 45 days. An exception report must be completed for any unreturned manifests. Annual reports documenting shipments of all hazardous wastes originating during the report year also are required. All information submitted by a generator is available to the public to the extent authorized by the Freedom of Information Act and EPA rules related to that Act.

Table 11.
Toxic Waste Limits Set by EPA's
Extraction Procedure Toxicity Test

	Extract Level (mg/l)
Arsenic	5.0
Barium	100.0
Cadmium	1.0
Chromium	5.0
Lead	5.0
Mercury	0.2
Selenium	1.0
Silver	5.0

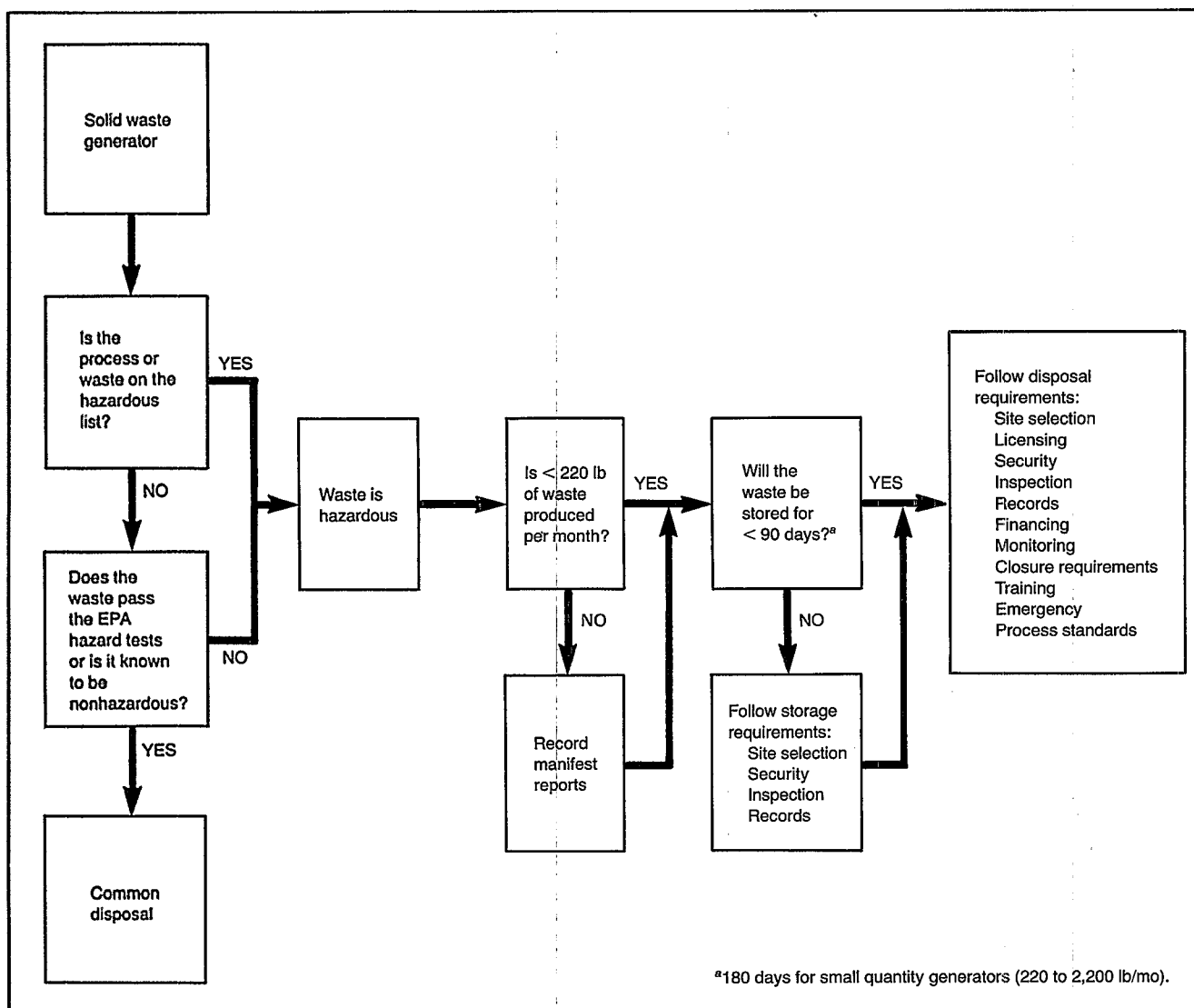


Figure 11. Obligations of Hazardous Waste Generators Under RCRA

Under the 1984 RCRA Amendments, hazardous waste generators will be affected by many new requirements. For instance, the landfilling of bulk or noncontainerized liquids is prohibited, and EPA must soon decide whether land disposal methods can be used at all for disposal of certain hazardous wastes. After September 1, 1985, generators will have to certify that the amount and toxicity of the hazardous waste generated has been reduced to the maximum degree economically practicable. Many of these new requirements are expected to increase the hazardous waste disposal costs of existing generators and to bring additional small-quantity generators and other sources under RCRA.

Special Provisions for Small Quantity Generators. A "small quantity generator" is a business or organization that produces hazardous waste in quantities less than 2,200 lb (1,000 kg) per month. Most electroplaters fall into this category.

Under the May 1980 hazardous waste regulations, small quantity generators were required only to determine whether or not they produced hazardous waste, and to see that the waste was sent to facilities approved by EPA or a state to manage municipal or industrial solid waste.

In the 1984 Amendments, however, Congress directed EPA to publish regulations covering generators of more than 220 lb (100 kg) but less than 2,200 lb (1,000 kg) of hazardous waste per month. These regulations must be published by March 31, 1986. In these regulations, EPA must, at a minimum, require these small quantity generators to see that their hazardous waste is disposed of at a hazardous waste facility permitted under RCRA to manage hazardous wastes.

The new law also specifies that by August 1985, generators of 220 to 2,200 lb (100 to 1,000 kg) of hazardous waste per month are required at a minimum to complete certain portions of the manifest to accompany hazardous waste they ship off their premises:

- Name, address, and signature of the generator
- Shipping name and hazard class, as found in DOT regulations ¹
- Number and type of containers
- Quantity of hazardous waste being transported
- Name and address of facility designated to receive the hazardous waste.

Requirements for Storage and Disposal Facilities. Any generator who stores hazardous wastes on-site for 90 days or longer* is subject to the same regulations that apply to owners and operators of hazardous waste storage and disposal facilities. The storage regulations promulgated in May 1982, are intended to prevent the release of hazardous waste from storage areas into the environment.

Storage areas must have a continuous base impervious to the material being stored and must provide for spill containment with either dikes or trenches. Under the RCRA Amendments, hazardous waste storage impoundments may have to be double-lined and a groundwater monitoring system may have to be installed depending upon the hydrogeology of the site and its proximity to drinking water sources. Wastes must be stored in tanks and containers that meet EPA specifications for the storage of flammable and combustible liquids. Containers must be constructed of or lined with materials which are compatible with the waste. In addition, records must be maintained throughout the storage period to show the identity and location of all stored hazardous wastes.

*180 days for small quantity generators.

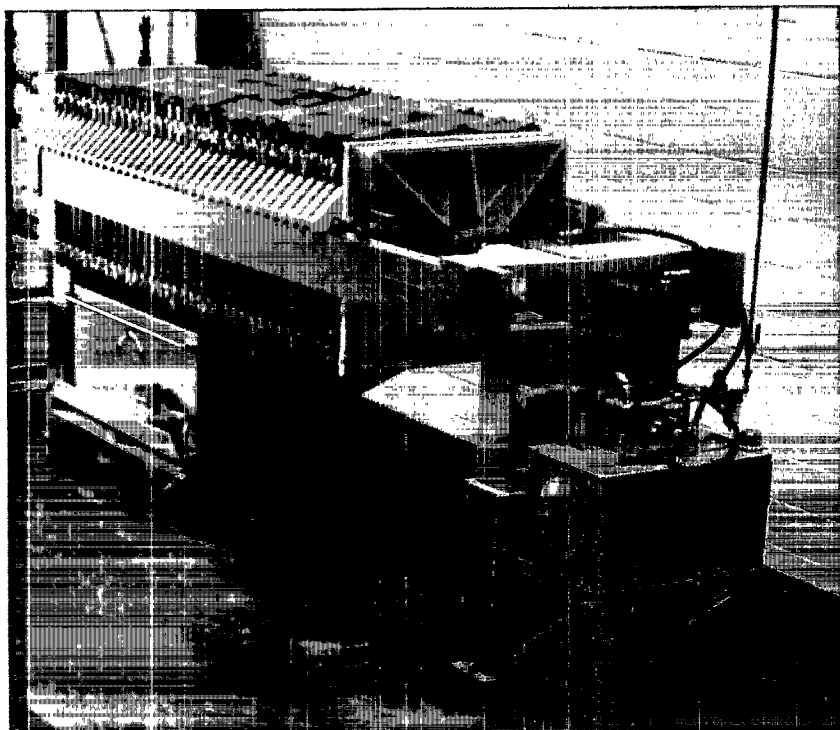
Hazardous Waste Delisting. RCRA regulations include a procedure, called delisting, by which specific hazardous wastes can be excluded from RCRA coverage even though they are listed in the RCRA regulations. A waste can be delisted when certain criteria are met, including conformance with the standards listed in Table 11. The advantages of delisting include lower waste disposal and recordkeeping costs. EPA requires that a minimum of four samples of a waste be analyzed in support of a delisting petition. The analytical data and other required information must be submitted to either an authorized RCRA state agency or to the Federal EPA. Specific delisting rules for states may vary from the Federal rules.

Many electroplaters and metal finishers have been successful in receiving a temporary delisted status for their wastewater treatment sludges. These sludges have been dewatered to the point where the toxic materials they contain do not leach out of the sludge cake under the conditions of the EP toxicity test.

Hazardous Waste Management

The rapidly escalating cost of solid and hazardous waste disposal virtually necessitates an effective waste management program. Because the wastewater treatment system sludge constitutes the most significant portion of the electroplater's solid and hazardous waste, this discussion will focus on the management of wastewater treatment sludges.

The cost of sludge disposal varies with three factors: the volume of sludge to be disposed of, the unit cost to transport the sludge to a licensed disposal site, and the unit fee charged by the disposal site to accept the sludge. Because the latter two factors are not likely to be under the control of the sludge generator, waste management is concerned primarily with reducing the volume of sludge generated. Figure 12 illustrates the relationship between the annual disposal cost, the amount of sludge disposed of, and the unit cost of disposal. The amount of sludge generated can be reduced in a number of ways:



Recessed chamber sludge dewatering filter press with sludge cart.

Reducing Waste Loads

Reducing the quantity of pollutants and the volume of wastewater before it is sent through a wastewater treatment system has two advantages: it reduces wastewater treatment costs and it reduces the volume of sludge generated. Although the effect of reducing wastewater flow is not usually as great as the effect of reducing the level of heavy metal pollutants in the wastewater, the volume of wastewater processed does influence sludge generation. Because of the high pH of most wastewater discharges, the greater the water volume treated, the greater the consumption of the alkali neutralizing agent (caustic, lime) and water conditioning agents (ferric chloride, aluminum chloride). These chemicals contribute to the quantity of sludge generated. In the case of lime, some portion normally remains undissolved and adds to the sludge volume. Conditioners such as ferric and aluminum chloride are converted to insoluble hydroxides during treatment, thereby increasing the volume of the sludge.

The effect of reduced pollutant loading on sludge volume is easier to determine. For example, a discharge of 1 lb (0.45 kg) of chromic acid anhydride to the wastewater will result in the precipitation of approximately 1 lb (0.45 kg) of chromium hydroxide during the treatment process. This amount of chromium hydroxide will add approximately 6 gal (23 l) of volume to the clarifier underflow, based on an underflow solids concentration of 2 percent by weight. Similar relationships exist for other metals used in plating operations.

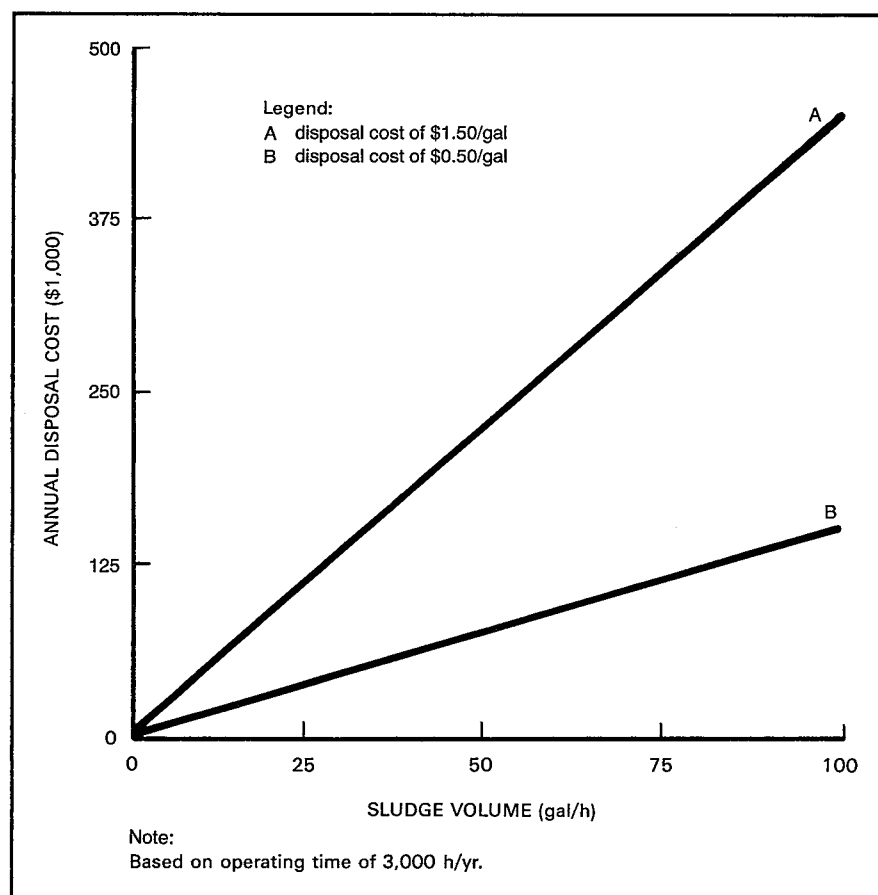


Figure 12. Annual Cost of Sludge Disposal

- By reducing the mass of pollutants entering the waste treatment system
- By reducing the wastewater volume entering the treatment system
- By using wastewater treatment techniques that generate minimal quantities of sludge
- By reducing sludge volume by mechanical dewatering.

To evaluate sludge volume reduction alternatives, the plant must first define its present and future disposal cost factors. Typically, disposal sites accepting metal hydroxide sludges base their charges on the volume of sludge. In some cases, the site will have one rate structure for fluid sludges and one for nonflowing sludges. As a rule, transportation costs are directly related to the sludge volume or weight.

Optimizing Waste Treatment Systems

The high cost of sludge disposal demands that the design of wastewater treatment systems consider the relative volumes of sludge generated by each of the treatment systems considered. Many of the newly developed treatment techniques offer improved pollutant removal capabilities compared with the capabilities of conventional treatment, but at the cost of significant increases in sludge generation. For this reason, the treatability studies conducted during the evaluation of the different treatment alternatives should address sludge generation and the dewatering properties of the resultant sludge.

For example, insoluble sulfide precipitation can reduce the metal concentration in many waste streams to lower levels than can hydroxide precipitation. However, because this process uses ferrous sulfide as the source of the sulfide ion, ferrous ions are liberated in the reaction and converted to ferrous hydroxide, which adds to the sludge volume. Figure 13 compares the sludge generation rates of an insoluble sulfide precipitation system and an insoluble sulfide polishing system with a conventional hydroxide system, using sodium hydroxide as the neutralizing agent, over a range of flow rates. Using the sulfide process as a polishing system to reduce the concentration of metals in the effluent after a conventional hydroxide precipitation/clarification sequence will achieve the same degree of metal removal as sulfide precipitation, but compared with the hydroxide process, will increase the volume of sludge generated only slightly. The trade-off, however, is that a polishing system will require additional hardware and have a higher initial cost. The savings in sludge disposal fees and reagent costs must justify the added expense of the polishing system.

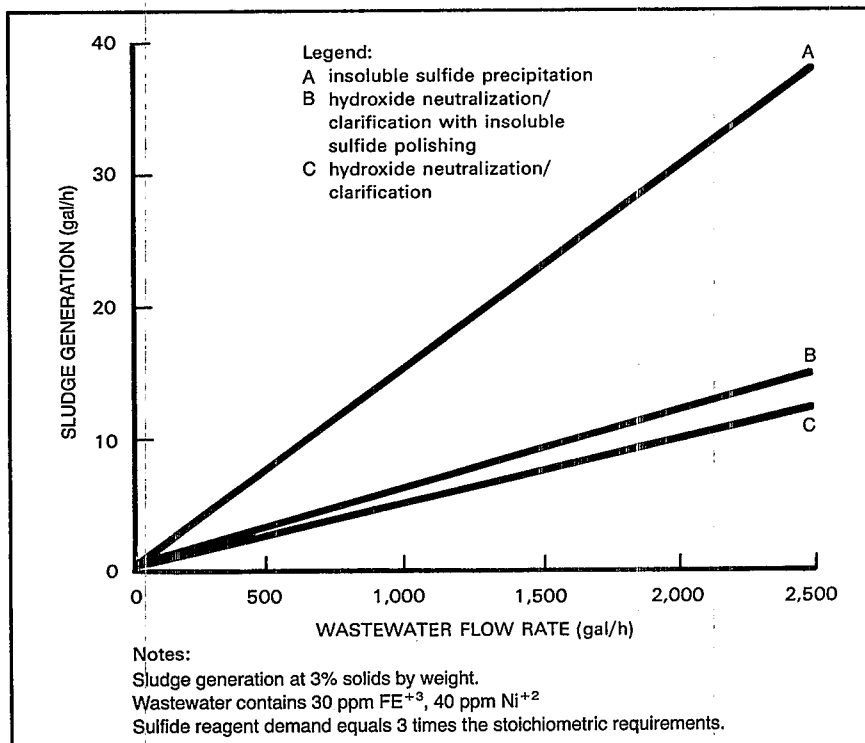


Figure 13. Sludge Generation Rates for Three Wastewater Treatment Systems

The choice of reagents for an existing treatment process can drastically affect the quantity of sludge generated. Lime and caustic soda are the two alkali neutralizing agents used most frequently. The advantages of lime include lower cost per unit of neutralizing capacity, sludge that settles and dewateres more readily, and the ability to reduce metals to lower levels in some applications (primarily because of the chelate-breaking capabilities of the calcium ions). Lime has disadvantages, however, in that it requires a higher investment in the reagent feed system, takes longer to react in the wastewater, and (according to one study) produces three to six times the bulk of sludge produced by caustic soda neutralization.

A relatively new reagent, sodium borohydride, may offer technical advantages over both lime and caustic. In EPA tests¹⁰, sodium borohydride produced a sludge mass equal to caustic treatment while removing metals to levels lower than lime. Additionally, sodium borohydride can simultaneously reduce hexavalent chromium. A disadvantage is the relatively high cost of sodium borohydride.

Sludge Dewatering

Since sludge disposal costs depend primarily on sludge volume, mechanical dewatering devices have been shown to produce considerable cost savings. Figure 14 shows the volume reduction achieved by dewatering as a function of solids concentration. As an example, consider 1,000 gallons of sludge at approximately 1 percent solids. Dewatering to 25 percent solids would reduce the sludge volume to about 32 gallons, a volume reduction of nearly 97 percent. Mechanical dewatering devices that have been used successfully to concentrate metal hydroxide sludge include pressure, vacuum, and compression filters, and centrifuges. These are described briefly below and in considerable detail in a recent EPA report¹⁶.

Pressure filters dewater sludge by pressurizing it and forcing the water out through a membrane. The simplest pressure filter in its construction and operation is the recessed filter plate press (shown in Figure 15); it is also the most popular mechanical sludge dewatering device in the industry today. Such filters most effectively dewater sludges that are very dilute or subject to wide variations in solids concentration. Low-pressure filters (80 to 150 psig) can achieve sludges of 20 to 40 percent solids, while high-pressure filters (150 to 225 psig) can attain 30 to 50 percent solids. As with all sludge filtration devices, the final solids concentration primarily depends on the length of time the sludge remains in contact with the filter and on the magnitude of the forces applied to the sludge.

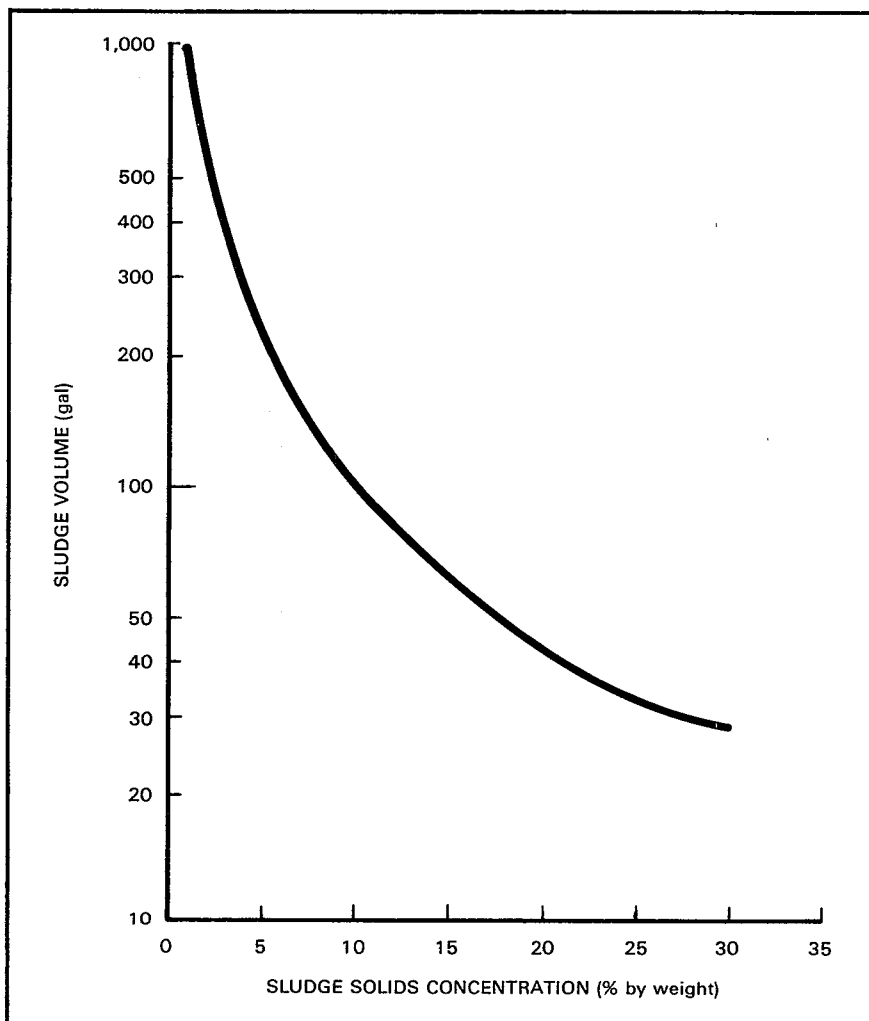


Figure 14. Sludge Volume as a Function of Solids Concentration

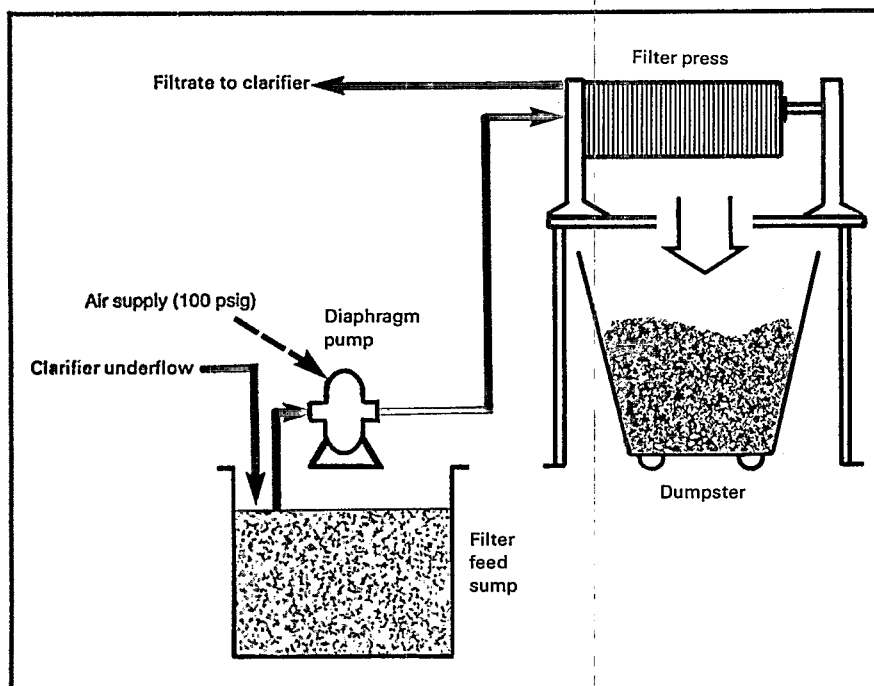


Figure 15. Low-Pressure Recessed Plate Filter Press

Vacuum filters dewater sludge by creating a vacuum which draws the water through a membrane. The rotary-drum filter is by far the most popular vacuum filter used in the industry. These filters perform best with feed solids concentrations above 3 percent by weight; sludges containing lower feed solids concentrations are usually thickened before vacuum filtration. Rotary-drum filters are often precoat with diatomaceous earth, particularly for use with dilute or otherwise hard-to-filter sludges. The precoat material represents an additional cost and adds to the quantity of solids to be disposed of, but in many cases this method significantly improves the solids concentration. Vacuum filters can usually attain 20 to 30 percent solids concentration, depending on the depth to which the drum is submerged and the rotational speed of the drum.

Compression filters dewater the sludge by squeezing it between water-permeable membranes. The units consist of a series of belts and rollers that gradually increase the compressive force applied to the sludge. This technique has proved effective mainly for dewatering highly compressible sludges characterized by large, delicate particle flocs typically associated with polyelectrolyte conditioning. The compression filter was developed to overcome the difficulty of dewatering this type of sludge by filtration. Compression filters consume less energy than vacuum filters or centrifuges, but are more mechanically sophisticated. Consequently, the relatively high capital cost of smaller units makes them unattractive for concentrating the lower sludge volumes typical of the plating industry.

Centrifuges dewater sludge in a manner similar to gravity thickeners, but they create an apparent gravity thousands of times more powerful by rapidly rotating the sludge. The increased gravity greatly accelerates the settling process and magnifies the compaction effect. Solids concentrations of 10 to 20 percent can be attained, depending on the nature of the sludge. The use of a centrifuge usually requires that the feed stream be conditioned with a polyelectrolyte to increase settling ability. Because of the need for polyelectrolytes and their limited ability to achieve high solids concentrations, centrifuges are losing favor to pressure filters for electroplating sludge dewatering.

The following example examines the economics of installing a recessed plate filter press (Figure 15) to dewater a dilute clarifier underflow from 3 percent solids (by weight) to 20 percent solids. Figure 16 compares the annual costs of disposing of the sludge at 3 percent solids with two higher concentrations. The figure shows two curves for sludge disposal at 20 percent solids by weight: one cost including filter press operation as well as dewatered sludge disposal (at \$1.00/gal) and the other, the cost of sludge disposal alone. Even with its operating costs included, the filter press reduces annual disposal costs at underflow rates exceeding 10 gal/h (57 l/h). For a plant disposing of its sludge at \$1.00/gal, the investment has a reasonable rate of return at 17 gal/h (95 l/h). Mechanical dewatering, then, is usually a cost effective approach to the problem of solid waste management.

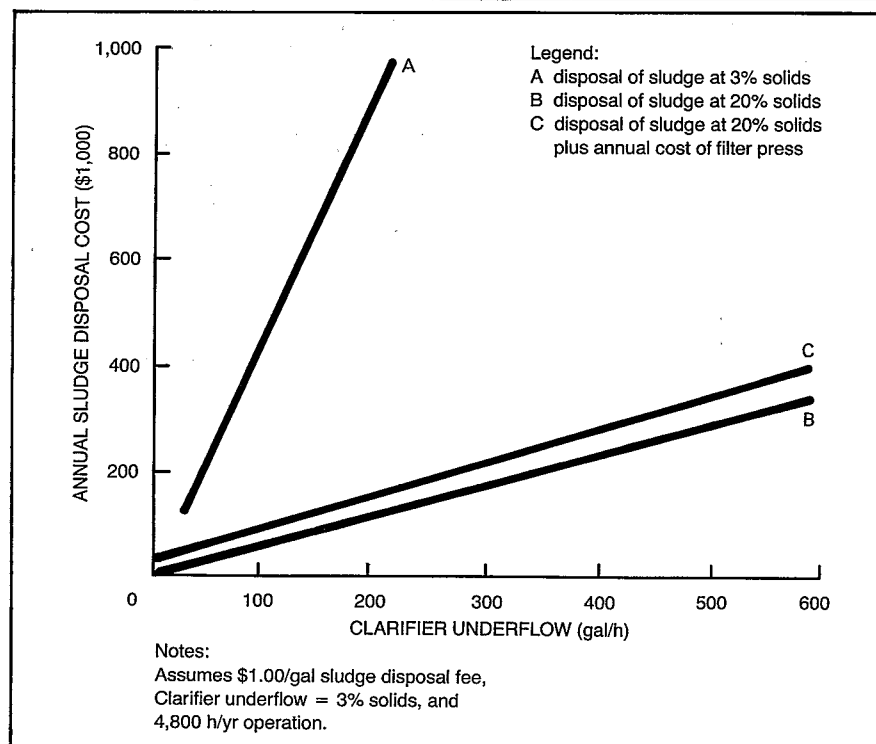


Figure 16. Sludge Disposal Costs with and without Filter Press

Plants generating very small sludge volumes (i.e., less than 17 gal/h) may find that the investment cost of sludge dewatering equipment cannot be justified by the limited quantities of sludge in need of disposal. Some hazardous waste disposal sites have some means of dewatering sludge. Plants generating small volumes of sludge may find it cost-effective to use these capabilities of the disposal facility since hazardous waste regulations promulgated in May 1985 prohibit the landfilling of sludges unless they have been dewatered or containerized.

6. Pollution Control Financing Alternatives

The Federal government has established tax incentives and has made financing alternatives available to ease the burden of complying with environmental regulations. The financing alternatives are available through several different government programs. The following provides an overview of the various programs and sources of more detailed information at the Federal level. Regional, local, and district offices of all of the Federal agencies listed below can be found in local telephone directories.

Income Tax Provisions

There are three categories of Federal income tax deductions for investments in pollution control facilities:

- Interest paid on the loan to finance the project
- Yearly cost of the pollution control project as determined by amortizing or depreciating its cost
- Investment credits.

Questions should be addressed to:

Internal Revenue Service (IRS)
1201 E Street, N.W.
Washington, DC 20224

IRS toll-free telephone assistance:
(800) 424-1040

IRS Tel-Tax (Recorded tax information on 140 topics available 24 hours a day, seven days a week):
Local IRS telephone

IRS Walk-in assistance: Local IRS office

For detailed instructions on the deductions mentioned above, the following publications should be consulted:

IRS Publication 334, *Tax Guide for Small Business*
IRS Publication 534, *Depreciation*
IRS Publication 572, *Investment Credit*
IRS Publication 535, *Business Expense*

Small Business Administration

The U.S. Small Business Administration (SBA) operates three programs to help small businesses which are independently owned and fall within SBA's definition of a small business finance pollution control project:

- The 7(a) Program
- Pollution Control Financing Guarantees
- The Section 503 program.

The 7(a) Program. To be eligible for funds under the 7(a) Program, the borrower must have been turned down by two institutional lenders. Financing may be used for the purchase of land, site preparation, engineering and design costs, purchase of equipment and machinery, construction, and working capital. Both direct loans and guaranteed loans are available. Direct loans are for amounts of up to \$150,000. Loans are guaranteed in amounts of up to 90 percent of the total loan amount or \$500,000, whichever is less. Details about this program can be obtained from any local or district office of the SBA, or from:

Office of Business Loans
U.S. Small Business Administration
1441 L Street, N.W.
Washington, DC 20416
(202) 653-6696

Pollution Control Financing

Guarantees. Guarantees are available to small businesses requiring financing of more than \$250,000. The maximum loan limit in this program is \$5 million. To be eligible, the business must have a minimum of five years' operating history and must show a profit in any three of the five years in operation. Funds may be used for the purchase of real estate, site preparation and construction, purchase and installation of equipment, and financing. Bonds are issued by a state or local authority, and the SBA guarantees payment. In the past, SBA was restricted by law to issuing guarantees only for taxable financings. A recent change in the law (PL 98-473, October 12, 1984) allows SBA to guarantee tax-exempt financings as well. Further details about this program can be obtained from:

Pollution Control Financing Branch
U.S. Small Business Administration
4040 N. Fairfax Drive, Suite 500
Arlington, VA 22203
(703) 235-2902

The Section 503 Program.

Participation in this program is through a Certified Development Company; these are corporations organized through SBA to issue loans for business and community development. Financing may be used to purchase fixed assets with a useful life of more than 15 years (i.e., land, equipment, facilities). These loans are for up to 40 percent of the total loan or \$500,000, whichever is less. Details about this program and application forms can be obtained from:

Office of Business Loans
U.S. Small Business Administration
1441 L Street, N.W.
Washington, DC 20416
(202) 653-6696

Economic Development Administration

The Economic Development Administration (EDA) finances the growth of businesses in redevelopment areas. Although the financing of pollution control equipment is not specifically covered by the EDA, such items may be eligible under this program. EDA-guaranteed loans may be used for the purchase of land, construction, equipment, and operating capital. The EDA will guarantee up to 90 percent of the total loan, but prefers to guarantee 75 percent or less. Minimum loan amounts are \$550,000, with a maximum of \$10 million. Further information can be obtained from:

U.S. Department of Commerce
Economic Development
Administration
15th & Constitution Avenues
Room 7844
Washington, DC 20230
(202) 377-5067

Farmers' Home Administration

Farmers' Home Administration (FHmA) loans are used to assist companies located in rural areas of the country with the purchase of land, facilities, supplies, and for working capital. Loans are available through conventional lenders and are guaranteed by the FHmA. Information about the loan application process and other details can be obtained from:

Farmers Home Administration
Business and Industry Division
14th and Independence Ave., S.W.,
Room 5420
Washington, DC 20250
(202) 475-4100

Other Sources of Financing

In addition to the programs operated on the Federal level, financing for the purchase of pollution control equipment can be obtained through private sources as well as through state and county governments. Information on these programs at the state and county levels is available from local authorities and EPA's Regional Small Business Liaison contacts listed in the following section.

7. EPA Sources of Additional Information

A number of regional and Federal EPA representatives can provide detailed information on environmental regulations and financial alternatives.

EPA Headquarters Office

General regulatory information:

U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460
(202) 382-4700

Effluent guidelines and standards:

Jeffrey Denit (WH-552)
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460
(202) 382-7120

Hazardous waste storage and disposal:

RCRA Hotline: (800) 424-9346.

Financial assistance:

Frances Desselle
Financial Assistance Coordinator
Office of Analysis and Evaluation
Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460
(202) 382-5373

Small Business Ombudsman
Environmental Protection Agency
(A149C)
401 M Street, S.W.
Washington, DC 20460
(202) 557-7015 or
(800) 368-5888

EPA Regional Offices

Region I (*Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont*)
Room 2203, JFK Federal Building
Boston, MA 02203

David Fierra
Water Division Director
(617) 223-3478

Lester Sutton
Small Business Liaison
(617) 223-5424

Region II (*New Jersey, New York, Puerto Rico, and the Virgin Islands*)
Room 900, 26 Federal Plaza
New York, NY 10007

William Muszynski
Water Division Director
(212) 264-2573

Kenneth Eng
Small Business Liaison
(212) 264-4711

Region III (*Delaware, Maryland, Pennsylvania, West Virginia, District of Columbia, and Virginia*)
841 Chestnut Street
Philadelphia, PA 19107

Greene A. Jones
Water Division Director
(215) 597-9411

Jim Burke
Small Business Liaison
(215) 597-3658

Region IV (*Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee*)
345 Courtland Street, N.E.
Atlanta, GA 30308

Bruce Barrett
Water Division Director
(404) 881-4450

H. Mack Rhodes
Small Business Liaison
(404) 881-4727

Region V (*Illinois, Indiana, Wisconsin, Michigan, Minnesota, and Ohio*)
230 Dearborn Street
Chicago, IL 60604

Charles H. Sutfin
Water Division Director
(312) 353-2147

Kathy Brown
Small Business Liaison
(312) 353-3299

Region VI (*Arkansas, Louisiana, New Mexico, Oklahoma, and Texas*)
First International Building
1201 Elm Street
Dallas, TX 75270

Myron O. Knudson
Water Division Director
(214) 729-2656

Carl Edlund
Small Business Liaison
(214) 767-2605

Region VII (*Kansas, Missouri, Nebraska, and Iowa*)
324 East 11th Street
Kansas City, MO 64108

Paul M. Walker (Acting)
Water Division Director
(816) 758-6401

Ron Ritter
Small Business Liaison
(816) 374-6201

Region VIII (*Colorado, Wyoming, Montana, North Dakota, South Dakota, and Utah*)
1860 Lincoln Street
Denver, CO 80203

Max Dodson
Water Division Director
(303) 327-4871

Charles Stevens
Small Business Liaison
(303) 837-3711

Region IX (*Arizona, California, Hawaii, Nevada, American Samoa, Guam, and the Trust Territories*)
215 Fremont Street
San Francisco, CA 94105

Frank M. Covington
Water Division Director
(415) 454-8115

James Thompson
Small Business Liaison
(415) 974-8015

Region X (*Alaska, Idaho, Oregon, and Washington*)
1200 Sixth Avenue
Seattle, WA 98101

Robert Burd
Water Division Director
(206) 399-1237

John Ybarra
Small Business Liaison
(206) 442-1233

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¹U.S. Department of Transportation. "Hazardous Material Table and Hazardous Materials Communications Regulations." *Code of Federal Regulations*, Title 49, Part 172.

²U.S. Environmental Protection Agency. "Standards Applicable to Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities." *Code of Federal Regulations*, Title 40, Parts 260-267.

³_____. "General Pretreatment Regulations for Existing and New Sources of Pollution." *Code of Federal Regulations*, Title 40, Part 403.

⁴_____. "Effluent Guidelines and Standards; Electroplating Point Source Category; Pretreatment Standards for Existing Sources." *Code of Federal Regulations*, Title 40, Part 413.

⁵_____. "Effluent Guidelines and Standards: Metal Finishing Point Source Category; Treatment Standards for Existing Sources." *Code of Federal Regulations*, Title 40, Part 433.

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⁶U.S. Environmental Protection Agency and American Electroplaters' Society, Inc. (co-sponsors). *Annual Conference on Advanced Pollution Control for the Metal Finishing Industry (1st), held at Lake Buena Vista, Florida on January 17-19, 1978*. EPA 600/8-78-010. NTIS No. Pb 282-443. May 1978.

⁷_____. *Conference on Advanced Pollution Control for the Metal Finishing Industry (2nd), held at Kissimmee, Florida on February 5-7, 1979*. EPA 600/8-79-014. NTIS No. Pb 297-453. June 1979.

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⁸U.S. Environmental Protection Agency. *Advanced Treatment Approaches for Metal Finishing Wastewaters. Part 1*. EPA 600/j-77-056a. NTIS No. Pb 277-147. Oct. 1977.

⁹_____. *Advanced Treatment Approaches for Metal Finishing Wastewaters. Part 2*. EPA 600/j-77-056b. NTIS No. Pb 277-148. Nov. 1977.

¹⁰_____. *Assessment of Emerging Technologies for Metal Finishing Pollution Control: Three case studies*. Contract No. 68-03-2907-09. (Prepared by Philip A. Militello).

¹¹_____. *Control and Treatment Technology for the Metal Finishing Industry: Ion Exchange*. EPA 625/8-81-007. (Prepared by Centec Corporation). June 1981.

¹²_____. *Control Technology for the Metal Finishing Industry: Evaporators*. EPA 625/8-79-002. (Prepared by Centec Corporation). June 1979.

¹³_____. *Controlling Pollution from the Manufacturing and Coating of Metal Products: Water Pollution Control*. EPA 625/3-73-009. (Prepared by Centec Corporation). May 1977.

- 14 _____ *Electrodialysis for Closed Loop Control of Cyanide Rinse Waters*. EPA 600/277-161. NTIS No. Pb 272-688. (Prepared by International Hydronics Corporation). Aug. 1977.
- 15 _____ *Electrolytic Treatment of Job Shop Metal Finishing Wastewater*. EPA 600/2-75-028. NTIS No. Pb 246-560. (Prepared by New England Plating Company). Sept. 1975.
- 16 _____ *Environmental Pollution Control Alternatives: Sludge Handling, Dewatering, and Disposal Alternatives for the Metal Finishing Industry*. EPA 625/5-82-018. (Prepared by Centec Corporation). Oct. 1982.
- 17 _____ *Evaporative Recovery of Chromium Plating Rinse Waters*. Project No. S803781-1. (Prepared by Advance Plating Company and Corning Glass Works). Feb. 1977.
- 18 _____ *An Investigation of Techniques for Removal of Cyanide from Electroplating Wastes*. EPA W00-12010-EIE-11/71. NTIS No. Pb 208-210. (Prepared by Battelle Columbus Laboratories). Nov. 1971.
- 19 _____ *Investigation of Treating Electroplaters' Cyanide Waste by Electrodialysis*. EPA R2/73-287. NTIS No. Pb 231-263. (Prepared by RAI Research Corporation). Dec. 1973.
- 20 _____ *New Membranes for Treating Metal Finishing Effluents by Reverse Osmosis*. EPA 600/2-76-197. NTIS No. Pb 265-363. (Prepared by Midwest Research Institute). Oct. 1976.
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