# Electroplating

## Industry Description and Practices

Electroplating involves the deposition of a thin protective layer (usually metallic) onto a prepared metal surface, using electrochemical processes. The process involves pretreatment (cleaning, degreasing, and other preparation steps), plating, rinsing, passivating, and drying. The cleaning and pretreatment stages involve a variety of solvents (often chlorinated hydrocarbons, whose use is discouraged) and surface-stripping agents, including caustic soda and a range of strong acids, depending on the metal surface to be plated. The use of halogenated hydrocarbons for degreasing is not necessary, as water-based systems are available. In the plating process, the object to be plated is usually used as the cathode in an electrolytic bath. Plating solutions are acid or alkaline and may contain complexing agents such as cyanides.

## Waste Characteristics

Any or all of the substances used in electroplating (such as acidic solutions, toxic metals, solvents, and cyanides) can be found in the wastewater, either via rinsing of the product or from spillage and dumping of process baths. The solvents and vapors from hot plating baths result in elevated levels of volatile organic compounds (VOCs) and, in some cases, volatile metal compounds, which may contain chromates. Approximately 30% of the solvents and degreasing agents used can be released as VOCs when baths are not regenerated.

The mixing of cyanide and acidic wastewaters can generate lethal hydrogen cyanide gas, and this must be avoided. The overall wastewater stream is typically extremely variable (1 liter to 500 liters per square meter of surface plated) but is usually high in heavy metals, including cadmium, chrome, lead, copper, zinc, and nickel, and in cyanides, fluorides, and oil and grease, all of which are process dependent. Air emissions may contain toxic organics such as trichloroethylene and trichloroethane.

Cleaning or changing of process tanks and treatment of wastewaters can generate substantial quantities of wet sludges containing high levels of toxic organics or metals.

## Pollution Prevention and Control

Plating involves different combinations of a wide variety of processes, and there are many opportunities to improve on traditional practices in the industry. The improvements listed below should be implemented where possible.

*Changes in Process*

- Replace cadmium with high-quality, corrosion-resistant zinc plating. Use cyanide-free systems for zinc plating where appropriate. Where cadmium plating is necessary, use bright chloride, high-alkaline baths, or other alternatives. Note, however, that use of some alternatives to cyanides may lead to the release of heavy metals and cause problems in wastewater treatment.
- Use trivalent chrome instead of hexavalent chrome; acceptance of the change in finish needs to be promoted.
- Give preference to water-based surface-cleaning agents, where feasible, instead of organic cleaning agents, some of which are considered toxic.
- Regenerate acids and other process ingredients whenever feasible.

*Reduction in Dragout and Wastage*

- Minimize dragout through effective draining of bath solutions from the plated part, by, for example, making drain holes in bucket-type pieces, if necessary.
- Allow dripping time of at least 10 to 20 seconds before rinsing.
- Use fog spraying of parts while dripping.
- Maintain the density, viscosity, and temperature of the baths to minimize dragout.
- Place recovery tanks before the rinse tanks (also yielding makeup for the process tanks). The recovery tank provides for static rinsing with high dragout recovery.

*Minimizing Water Consumption in Rinsing Systems*

It is possible to design rinsing systems to achieve 50–99% reduction in traditional water usage. Testing is required to determine the optimum method for any specific process, but proven approaches include:

- Agitation of rinse water or work pieces to increase rinsing efficiency
- Multiple countercurrent rinses
- Spray rinses (especially for barrel loads).

*Management of Process Solutions*

- Recycle process baths after concentration and filtration. Spent bath solutions should be sent for recovery and regeneration of plating chemicals, not discharged into wastewater treatment units.
- Recycle rinse waters (after filtration).
- Regularly analyze and regenerate process solutions to maximize useful life.
- Clean racks between baths to minimize contamination.
- Cover degreasing baths containing chlorinated solvents when not in operation to reduce losses. Spent solvents should be sent to solvent recyclers and the residue from solvent recovery properly managed (e.g., blended with fuel and burned in a combustion unit with proper controls for toxic metals).

## Target Pollution Loads

A key parameter is the water use in each process. Systems should be designed to reduce water use. Where electroplating is routinely performed on objects with known surface area in a production unit, water consumption of no more than 1.3 liters per square meter plated ($l/m^2$) for rack plating and 10 $l/m^2$ for drum plating should be achieved. The recommended pollution prevention and control measures can achieve the target levels listed below.

- Cadmium plating should be avoided. Where there are no feasible alternatives, a maximum cadmium load in the waste of 0.3 grams for every kilogram of cadmium processed is recommended.
- At least 90% of the solvent emissions to air must be recovered by the use of an air pollution control system such as a carbon filter.
- Ozone-depleting solvents such as chlorofluorocarbons and trichloroethane are not to be used in the process.

## Treatment Technologies

Segregation of waste streams is essential because of the dangerous reactions that can occur. Strong acid and caustic reactions can generate boiling and splashing of corrosive liquids; acids can react with cyanides and generate lethal hydrogen cyanide gas. In addition, segregated streams that are concentrated are easier to treat.

*Air Emissions*

Exhaust hoods and good ventilation systems protect the working environment, but the exhaust streams should be treated to reduce VOCs and heavy metals to acceptable levels before venting to the atmosphere. Acid mists and vapors should be scrubbed with water before venting. In some cases, VOC levels of the vapors are reduced by use of carbon filters, which allow the reuse of solvents, or by combustion (and energy recovery) after scrubbing, adsorption, or other treatment methods.

*Liquid Effluents*

Cyanide destruction, flow equalization and neutralization, and metals removal are required, as a minimum, for electroplating plants. Individual design is necessary to address the characteristics of the specific plant, but there are a number of common treatment steps. For small facilities, the possibility of sharing a common wastewater treatment plant should be considered. Cyanide destruction must be carried out upstream of the other treatment processes. If hexavalent chrome ($Cr^{+6}$) occurs in the wastewater, the wastewater is usually pretreated to reduce the chromium to a trivalent form using a reducing agent, such as a sulfide.

The main treatment processes are equalization, pH adjustment for precipitation, flocculation, and sedimentation / filtration. The optimum pH for metal precipitation is usually in the range 8.5–11, but this depends on the mixture of metals present. The presence of significant levels of oil and grease may affect the effectiveness of the metal precipitation process; hence, the level of oil and grease affects the choice of treatment options and the treatment sequence. It is preferred that the degreasing baths be treated separately. Flocculating agents are sometimes used to facilitate the filtration of suspended solids. Pilot testing and treatability studies may be necessary, and final adjustment of pH and further polishing of the effluent may be required. Modern wastewater treatment systems use ion exchange, membrane filtration, and evaporation to reduce the release of toxics and the quantity of effluent that needs to be discharged. The design can provide for a closed system with a minor bleed stream.

*Solid and Hazardous Wastes*

Treatment sludges contain high levels of metals, and these should normally be managed as hazardous waste or sent for metals recovery. Electrolytical methods may be used to recover metals. Sludges are usually thickened, dewatered, and stabilized using chemical agents (such as lime) before disposal, which must be in an approved and controlled landfill. The high costs of proper sludge disposal are likely to become an increasing incentive for waste minimization.

## Emissions Guidelines

Emissions levels for the design and operation of each project must be established through the environmental assessment (EA) process on the basis of country legislation and the *Pollution Prevention and Abatement Handbook*, as applied to local conditions. The emissions levels selected must be justified in the EA and acceptable to the World Bank Group.

The guidelines given below present emissions levels normally acceptable to the World Bank Group in making decisions regarding provision of World Bank Group assistance. Any deviations from these levels must be described in the World Bank Group project documentation. The emissions levels given here can be consistently achieved by well-designed, well-operated, and well-maintained pollution control systems.

The guidelines are expressed as concentrations to facilitate monitoring. Dilution of air emissions or effluents to achieve these guidelines is unacceptable.

All of the maximum levels should be achieved for at least 95% of the time that the plant or unit is operating, to be calculated as a proportion of annual operating hours.

*Air Emissions*

A 90% recovery of the quantity of VOCs released from the process is required.

*Liquid Effluents*

Electroplating plants should use closed systems where feasible or attain the effluent levels presented in Table 1.

*Sludges*

Wherever possible, the generation of sludges should be minimized. Sludges must be dewatered and stabilized and should be disposed of in an approved, secure landfill. Leachates from stabilized

**Table 1. Effluents from the Electroplating Industry**

*(milligrams per liter, except for pH)*

| *Parameter* | *Maximum value* |
|---|---|
| pH | 7–10 |
| TSS | 25 |
| Oil and grease | 10 |
| Arsenic | 0.1 |
| Cadmium | 0.1 |
| Chromium (hexavalent) | 0.1 |
| Chromium (total) | 0.5 |
| Copper | 0.5 |
| Lead | 0.2 |
| Mercury | 0.01 |
| Nickel | 0.5 |
| Silver | 0.5 |
| Zinc | 2 |
| Total metals | 10 |
| Cyanides (free) | 0.2 |
| Fluorides | 20 |
| Trichloroethane | 0.05 |
| Trichloroethylene | 0.05 |
| Phosphorus | 5 |

*Note:* Effluent requirements are for direct discharge to surface waters.

sludges should not contain toxics at levels higher than those indicated for liquid effluents. Where feasible, sludges may be reused, provided that toxics are not released to the environment.

*Ambient Noise*

Noise abatement measures should achieve either the levels given below or a maximum increase in background levels of 3 decibels (measured on the A scale) [dB(A)]. Measurements are to be taken at noise receptors located outside the project property boundary.

| | *Maximum allowable log equivalent (hourly measurements), in dB(A)* | |
|---|---|---|
| *Receptor* | *Day (07:00–22:00)* | *Night (22:00–07:00)* |
| Residential, institutional, educational | 55 | 45 |
| Industrial, commercial | 70 | 70 |

## Monitoring and Reporting

Equipment to continuously monitor pH should be installed to provide an indication of overall treatment reliability. For larger plants (with discharges of more than 10,000 liters per day), the effluent should be sampled daily for all parameters except metals. Sampling of metals should be carried out at least monthly and when there are process changes. For smaller plants (having discharges of less than 10,000 liters per day), monthly monitoring of all parameters except pH may be acceptable. Frequent sampling may be required during start-up and upset conditions.

Monitoring data should be analyzed and reviewed at regular intervals and compared with the operating standards so that any necessary corrective actions can be taken. Records of monitoring results should be kept in an acceptable format. The records should be reported to the responsible authorities and relevant parties, as required.

## Key Issues

The key production and control practices that will lead to compliance with emissions guidelines can be summarized as follows:

- Use cyanide-free systems.
- Avoid cadmium plating.
- Use trivalent chrome instead of hexavalent chrome.
- Prefer water-based surface cleaning agents where feasible, instead of organic cleaning agents, some of which are considered toxic.
- Minimize dragout.
- Use countercurrent rinsing systems; recycle rinse waters to the process after treatment.
- Regenerate and recycle process baths and rinse waters after treatment.
- Recycle solvent collected from air pollution control systems.
- Send spent solvents for recovery.
- Do not use ozone-depleting substances.
- Manage sludges as hazardous waste. Reuse sludges to the extent feasible but without releasing toxics to the environment.

## Sources

Cushnie, G. C., Jr. 1985. *Electroplating Wastewater Pollution Control Technology*. Park Ridge, N.J.: Noyes Data Corporation.

Nordic Council of Ministers. 1993. *Possible Ways of Reducing Environmental Pollution from the Surface-Treatment Industry*. Oslo.

Patterson, James W. 1985. *Industrial Wastewater Treatment Technology*. 2d ed. Boston: Butterworth.

UNEP (United Nations Environment Programme). 1992. *Environmental Aspects of the Metal Finishing Industry: A Technical Guide*. Paris.

World Bank. 1996. "Pollution Prevention and Abatement: Electroplating Industry." Draft Technical Background Document. Environment Department, Washington, D.C.