Simple Techniques for Source Reduction of Wastes from Metal Plating Operations

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ABSTRACT

There are many simple techniques available for source reduction of wastes from metal plating operations. They may be grouped into eight categories: reactive rinsing, counterflow rinsing, dragout minimization, dragout recovery, process modifications/operational changes, material substitutions, waste exchange opportunities and housekeeping improvements. A technical assistance project and financial incentive programs offered by Environment Canada are also described.

INTRODUCTION

Recently, waste reduction at source has emerged as an issue because of increasingly stringent provincial regulations and municipal sewer-use bylaws. In Alberta, for example, new provincial hazardous waste regulations, which came into effect April 1, 1988 prohibit the disposal of specific hazardous wastes in excess of defined concentrations at all landfills in Alberta. Examples include dioxins, certain solvents, PCBs, strong acids, cyanides and wastes containing heavy metals. Generators may store their wastes for only up to 365 days, and the amount that can be stored on-site by one generator can not be more than 10 tonnes at any one time. In Manitoba, new provincial regulations have established a cradle-to-grave tracking system for the movement of all hazardous wastes. Waste generators are required, beginning in 1988, to provide detailed information on the nature and quantity of the waste generated, and to inform the province of any major production changes. Failure to comply with the regulations can result in penalties, including fines not exceeding fifty thousand dollars or up to six months imprisonment. One can say that the time for waste reduction has come!

This paper describes simple techniques that can be used for waste reduction at source in the metal plating industry and introduces the services of the assistance program offered by Environment Canada's Western and Northern Region. The terms "waste reduction at source" and "source reduction of waste" are interchangeable. Source reduction techniques imply any measures that can reduce effluent discharge prior to treatment and disposal either on-site or off-site.
SIMPLE TECHNIQUES FOR WASTE REDUCTION AT SOURCE

There are many simple techniques available for source reduction of the volume and toxicity of wastes. In this paper, simple techniques imply any measures which are technologically simple, low risk and low cost, or are not technologically simple but well understood by all platers. For the purpose of discussions, they are grouped into the following eight categories:

**Reactive Rinsing**

Reactive rinsing is the reuse of rinsewater within a plating facility. This technique takes advantage of the nature of the contaminated rinse water to minimize water usage. Its application in various finishing processes are illustrated in Figures 1 and 2. In Figure 1, the combined rinse water in the alkaline-clean rinse tank is neutralized and its rinsing efficiency enhanced because of better removal of the soapy film on part surfaces. The service life of the acid dip solution is increased as a result. In addition, this will allow the fresh water-feed to the alkaline-clean rinse tank to be turned off. In contrast, Figure 3 is an example of misapplication of reactive rinsing; the pH of acid dip rinse can be as low as 2.5. Under pH 2.5-3.0, cyanide can be readily converted to hydrogen cyanide and evolved as a toxic gas.

**Countercurrent Rinse**

In recent years, conserving waste has become an opportunity to conserve evaporative losses. In this system, overflows up the product. The concentration in process.

Complete Mix depends on completely better mixing:

- Use agitation
- Introduce submerged perforated plate
- Use air agitation

The latter is of simple, inexpensive implementation (Figure 4). The
Countercurrent Rinsing

In recent years, counterflow rinsing has gained prominence as a means of conserving water and reducing the cost of wastewater treatment. It also provides an opportunity to recycle rinse water to the plating tank to replenish evaporative losses.

In this system clean water is added to the last rinse tank. The water overflows up the row of rinse tanks in a direction counter to the progress of the product. The amount of rinse water is a function of the maximum allowable concentration in the final rinse tank which will not interfere with the plating process.

Complete Mixing. It should be noted that the success of counterflow rinsing depends on complete mixing of rinse water taking place in the rinse tank. To get better mixing:

1. Use agitation.
2. Introduce fresh water feed into the bottom of the rinse tank through a submerged perforated distribution pipe or diffuser.

The latter is of particular importance when using long, narrow rinse tanks.

Air Agitation. Agitation improves rinsing efficiency. Air agitation is simple, inexpensive and efficient for inducing agitation in a rinse tank (Figure 4). The system comprises an air distribution line and an air blower or...
compressor. Air is introduced through a perforated pipe into the bottom of a tank. A blower is preferred over a compressor because the latter may introduce oil vapors into the agitated tank. Moreover, a blower has advantages of lower energy consumption and capital cost.

Dragout Minimization

Figure 5 illustrates the definitions of dragout and drag-in, and the use of a drip board between a plating bath and a rinse tank. The drip board should be positioned at an angle to allow liquid to return to the plating bath. Material for the drip board surface may be coated metal or plastic such as polyvinyl fluoride, polyvinyl chloride, polypropylene or polyethylene. During visits to seven metal plating shops (see "ASSISTANCE PROGRAMS"), it was noted that there were four types of drip boards being used by the metal plating industry. Their rating is given in Table 1.

![Diagram of dragout and drag-in](https://example.com/diagram.png)

**Figure 5** Dragout

**TABLE 1**

<table>
<thead>
<tr>
<th>Type of Drip Board</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>Unacceptable (Without drip board)</td>
</tr>
<tr>
<td>P</td>
<td>Marginal</td>
</tr>
<tr>
<td>P</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>P</td>
<td>Desirable</td>
</tr>
</tbody>
</table>

There are several techniques which can be used to reduce dragout:

- Tumble or rotate the parts (barrels) after withdrawal.
- Drill out all of the barrel holes to return them to original size.
- Proper design of racks for better drainage.
- Use an adequate draining time. Care exercised by an operator is very important in reducing dragout. To help reduce operator's fatigue, install a hoist delay timer on a manual hoist line, or dwell hooks or slotted racks over tanks on a hand-line to provide the time delay needed for adequate draining. The optimum draining time can be determined by trial and error.
Use the lowest possible metal concentration of a plating solution. For example, a standard chrome bath is operated at 250 g/L (CrO₃). However, satisfactory results can be obtained at 150 g/L except for some critical or complex applications. Dragout is reduced both in volume and concentration only at the expense of a longer plating time. It should be noted that chemical suppliers tend to recommend higher metal concentrations than necessary as illustrated in Table 2. Though the operating nickel concentrations were higher than the typical Watts nickel concentrations, the chemical supplier still recommended the addition of nickel salts.

### Table 2

Comparison of A Typical Watts Nickel Makeup with Nickel Plating Baths*

<table>
<thead>
<tr>
<th>Typical Watts Nickel Makeup**</th>
<th>Tank 1</th>
<th>Tank 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>NiSO₄·6H₂O</td>
<td>32</td>
<td>36.58</td>
</tr>
<tr>
<td>NiCl₂·6H₂O</td>
<td>6.0</td>
<td>12.97</td>
</tr>
<tr>
<td>H₃BO₄</td>
<td>4.0</td>
<td>3.40</td>
</tr>
</tbody>
</table>

*At Plant B (see "ASSISTANCE PROGRAMS")

**Excellent for current density of 43 amp/ft²; if at 21 amp/ft² the nickel sulfate and nickel chloride concentrations may be halved (2).

### Dragout Recovery (Dragout Tanks)

In the last section various means to minimize dragout were discussed. However, a certain amount of process solution will still cling to parts, barrels or racks. Here, a simple, low-cost dragout tank for dragout recovery is introduced.

Dragout tanks are a series of still rinse tanks after a process tank. The workpieces are rinsed in these tanks before they enter a flowing rinse (Figure 6). It should be noted that a dragout tank may be positioned directly before or after a plating bath, depending on the availability of space.

![Figure 6: Dragout Tanks](image)

Dragout tanks also serve the purpose of protecting the running rinse water from contamination. The more dragout tanks used, the lower the concentration of contaminants in the running rinse. Table 3 shows that Plant C (see "ASSISTANCE PROGRAMS") has substantially reduced its nickel loss by adding one dragout tank.

Operation of Dragout Tanks. The solution from the first still tank must be drained and replaced by the less contaminated solution from the second, and the second must be filled with deionized or distilled water.

The quality of water used to prepare bath solutions is of great importance in
plating processes. Some impurities in tap water may harm finishing processes. Thus, if tap water or ground water is used to make up for evaporative losses, water impurities will become concentrated with time, resulting in the need to more frequently dump bath solutions. The solution drained from the first dragout tank may be used to replace evaporative losses in the plating tank. For this reason, only de-ionized or distilled water should be used to fill the second dragout tank. This helps minimize problems of spots on dried plated parts resulting from dissolved solids.

**TABLE 3**

Effect Of Dragout Tank On Nickel Concentration In The Running Rinse

<table>
<thead>
<tr>
<th>Process</th>
<th>Ni Conc*, ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original (Without Dragout tank)</td>
<td>11.90; 10.70</td>
</tr>
<tr>
<td>Modified (With one Dragout tank)</td>
<td>0.90</td>
</tr>
</tbody>
</table>

*one grab sample for each data; Plant C

Dragout tanks are best applied after a heated plating bath, such as used for nickel, hard chrome, copper and gold, allowing the dragout to be used for the replenishment of evaporative losses.

Returning the dragout to the plating bath will not only recover the valuable raw chemicals, but also in turn minimize hazardous waste generation. Thus, it provides an income rather than a payout for environmental protection.

**Process Modifications/Operational Changes**

Process modifications and operational changes include any major and minor redesign of manufacturing processes for the purpose of waste reduction. For example:

- Install flow regulators.
- Redesign racks to improve drainage.
- Improve the rinsing efficiency by lifting the barrel momentarily out of the rinse tank, allowing it to drain and reimmersing it instead of being left immersed.
- Use warm water rinse after an electro-cleaning or alkaline-cleaning stage. It will help wash the soapy film off the part surface, thereby increasing the service life of the acid dip or pickling solution (Figure 1).
- Increase the anode area and the bath temperature, if possible, to avoid the build up of trivalent chromium in a hexavalent chromium plating bath.
- Reduce the build up of trivalent chromium in a hexavalent chromium plating bath by electrolysis using an extremely small cathode area. Knill and Chessin(3) suggested a lead-anode-to-cathode area ratio of 30:1, and adequate agitation at 135-140°F, using a cathode current density of 3-5 amp/in². This can be tried out over a weekend.
- Use atmospheric evaporators where dragout volume is greater than evaporative losses.
- Maintain bath heat at elevated temperature during non-normal operating hours to provide additional room (through evaporation) for dragout return. It involves no capital investment, but some increase in energy cost.
- Use electrolytic strippers to replace chemical baths, thus eliminating chemical dumps.
- Use water sealing instead of chemical sealing (e.g. sodium dichromate) for anodizing process.
- Convert a simple spray tank to a dip/spray rinse tank to enhance the rinsing efficiency. When using a dip/spray tank the part is first rinsed in the tank; when technique introduced.

**Installation**

Tank may be heated. Use of Rins...make up-liquid extension of tank.

In hot galv. workpiece can be rinsed; fresh back rinse is tank.

In the acid sulfuric acid tank small quantity in which little.

**Material Substitute**

Replace the Hg

Cyanide-Free II operate, and the solutions is reg...various provinces. Cyanide-free II replace cyanide II cyanide zinc bat...problems; the most type of material for the treatment net saving.

ASTM B-253 replace aluminum, one oper...while eliminating to plate nickel ov
Rinsing processes, in the need to first dragout tank. For this fill the second plated parts to avoid the valuable solution. Thus, it is reduced. For

Installation of Dragout Tanks. If space is not adequate, a small dragout tank may be hooked on to the front or rear end of a plating tank (Figure 7).

Use of Rinse Water as Bath Make-up Liquid. The use of rinse water as a make-up liquid for evaporative losses from a process tank can be considered as an extension of the counterflow rinsing concept described previously.

In hot galvanizing, the caustic rinse water which washes caustic off the workpiece can be fed back to the hot caustic tank to compensate for evaporative losses; fresh tap water is added only to the caustic rinse. The flow of feed back rinse is limited to the amount of evaporative losses in the hot caustic tank.

In the acid pickling step, the sulfuric acid rinse can be fed back to the hot sulfuric acid tank. If warm hydrochloric acid (70%) is used for pickling, only a small quantity of the acid rinse can be recycled back to the acid pickling tank in which little evaporation takes place.

![FIGURE 7 Installation of a Small Dragout Tank](image)

Material Substitutions

Replace the Hazardous Material with a less or non-hazardous alternative.

Cyanide-Free Baths. Cadmium and zinc cyanide baths are costly, dangerous to operate, and their wastes are expensive to treat. Disposal of the spent solutions is regulated under the Canada Transport of Dangerous Goods Act and various provincial and municipal regulations.

Cyanide-free processes for cadmium and zinc plating have been developed to replace cyanide baths. It has been the trend in the past decade to replace the cadmium zinc baths with non-cyanide zinc to avoid dealing with cyanide waste problems; the ratio is now better than 2:1 in favor of non-cyanide(4). This type of material substitution will eliminate the need for alkaline chlorination for the treatment of cyanide. Thus, using cyanide-free baths will result in a net saving.

ASTM B-253 recommends two cyanide-free nickel strike baths for plating on aluminum, one operated at ambient temperature, and the other at high temperature, while eliminating the cyanide copper strike. These solutions might also be used to plate nickel on zinc(5), e.g., zinc die castings.
Zinc castings are normally plated successively with cyanide copper, electroless nickel and chromium to provide corrosion protection and a decorative appearance. A cyanide copper strike coating promotes good adhesion of the main deposit; without it immersion coatings would be formed on zinc surfaces resulting in poor adhesion to zinc. Recent developments reportedly allow plating of nickel on zinc die castings while eliminating a cyanide copper strike. Baudrand and Steward(6) discussed a mild alkaline electroless nickel bath that can be plated directly on zinc die castings avoiding the need for a cyanide copper strike. Michael Aleksinas of Fidelity Chemical Products, Newark, NJ, also described(7) a mild alkaline electroless nickel process which can be applied directly on zinc die castings. This process uses a special activator/neutralizer after alkaline cleanup and prior to electroless nickel plating.

Trivalent Chromium Baths. A trivalent chromium bath has the advantages, as compared to a hexavalent state bath, of reduced dragout volume due to less concentrated bath solution; less sludge generated due to a lower metal content in the bath solution. Supreme Plating Ltd. in Edmonton, Alberta, Canada utilizes a trivalent chromium bath to plate car bumpers and auto parts. The bath contains 6 g/L of trivalent chromium and operates at ambient temperature and a current density of 50 amp/ft² using graphite anodes. Its throwing power is good. Spray mist is eliminated and no ventilation system is needed.

Non-Accelerated Amorphous Chromate Conversion System. Amorphous chromate conversion coatings are used by industry as pretreatments for organic finishes of aluminum as well as unpainted aluminum. They assist paint adhesion and promote corrosion protection. The chromate coating bath commonly contains ferricyanide, an accelerator. Recently the increasing concern for environmental pollution has led to the development of non-ferricyanide, non-accelerated, chromate conversion coating baths(8).

Chrome Free Conversion Coating Baths. The formulations used in this process may consist of any combination of titanium, zirconium, tannins, fluorides, phosphates and nickel compounds. They are now widely used as substitutes for chromate coatings on aluminum and its alloys to promote paint adhesion and corrosion resistance. A proprietary non-chromated conversion coating process(9) claims that, in addition to eliminating chromium from the plating line, it also shortens the processing sequence by eliminating rinse tanks. The process consists of a non-etching cleaning tank, followed by a water rinse, then the conversion coating; no rinse need follow the coating treatment. Prior to painting, workpieces are warm air or oven dried. This chrome-free, dry-in-place coating produces no drag-out from the coating tank thereby eliminating the need of drag-out treatment and disposal.

Use Low Temperature (50°C) Alkaline Cleaners to Replace Higher Temperature (70°C) Ones.

Jansen and Tervoort(10) recommended some low temperature cleaners which will not only reduce the costs of heating energy and cleaner chemicals, but also minimize the generation rate of waste due to the extension of the service life of cleaners.

Waste Exchange Opportunities

One company's waste may be another's raw material. For example, sulfuric and hydrochloric acids are commonly employed for removing oxide scale from steel and iron. The resulting spent pickling liquor may contain up to 7% free acid and 5% ferrous ion. It may be reused for the following purposes:

- Coagulant in wastewater treatment
- Phosphate control and sludge conditioning
- Treatment of complexed and chelated copper rinse waters
- Ferrous ion, when mixed with chelated copper, reduces Cu^{2+} to Cu^{+} at pH of 3 to 4; as the pH is raised to 9, Cu^{+} is precipitated as Cu(OH)_2.

In Ontario, one smelter is accepting dry metal sludge for extraction and recovery of high nickel or copper content.
Metal plating plants should examine the possibility of this type of waste reuse by other industrial users. A good place to start is to contact the provincial or national waste exchanges.

Housekeeping Improvements

Basic good housekeeping practices are the most significant first step a company should take in reducing wastes.

Reduction of Spills and Leaks. Spills, tank overruns and leaks are common problems for metal finishing operations. Steps should be taken to reduce their frequency and impact, for example:
- Train personnel in better handling and control of hazardous materials and wastes.
- Prevent further occurrences of spills by analyzing their cause.
- Fix leaks promptly.
- Institute a preventative maintenance program.

Removal of Dropped Parts in Plating Baths. This can be done daily using a wooden or plastic coated rake, or a magnet for iron parts. Dropped parts contribute to heavy metal buildup in a bath. Removing parts dropped not only reduces the rejection rate of plated workpieces resulting from build-up of dissolved metal, but also extends bath life. This, in turn, would reduce waste generation.

Removal of sediment from cleaner tanks and rinse tanks. Good housekeeping is a part of the answer for achieving quality cleaning and rinsing. It will also reduce the generation of waste water.

In addition to the above, there are other areas that may need attention such as inventory control and training of operating staff.

ASSISTANCE PROGRAMS

Generators of small quantities of hazardous waste are often not aware of the availability of waste reduction techniques. Furthermore, they often lack the capability to devise cost-effective waste management strategies. A technical assistance program was initiated in the fall of 1986 by the Western and Northern Region of Environmental Protection, Environment Canada. It is directed at small industries, the first being metal finishing operations. The program provides two major services in waste reduction: (1) field assessment and (2) training. In addition to the technical assistance program, Environment Canada also provides financial incentives in waste reduction.

Field Assessment

The field assessment focuses on practical options for reducing waste generation at source. Comprehensive waste audits are carried out by a project team during visits to selected metal plating shops. The steps used in the plant assessment process are illustrated in Figure 8. The purposes of a field assessment are:
- To identify sources of waste streams
- To characterize waste streams quantitatively and qualitatively
- To assess operational procedures
- To identify raw material/chemicals used in plating processes

The results of the waste audit are then used to provide recommendations for waste management alternatives to disposal. As of 1987, four metal plating shops (Plants A, B, C and D) participated in field assessments. They all have benefited from the resulting recommendations. For example, Plant C is a medium-sized job shop that operates a manual rack plating line providing nickel and chrome coating services on car bumpers and auto parts. The plant originally did not use a nickel dragout tank and was troubled with continual violation of the city sewer-use bylaw limit on nickel. Upon our recommendation, a dragout tank in conjunction with a better draining technique
was utilized. Consequently, the nickel concentration in the flowing rinse tank effluent was greatly reduced (Table 3) and the plant effluent was brought into compliance with the city's regulation. Now the plant is in the process of purchasing evaporators and a deionizer.

**Training**

Environment Canada has developed a 3-part video-tape training course on metal plating waste management(11). The first part is directed to plant owners/managers. The main objective of the first part is to assist them in understanding how to manage their wastes in a cost-effective way, and to make them aware of the value of training their employees.

Part one of the video-tape course deals with the following subjects:
- Requirements for pollution prevention
- Environment Canada guideline requirements
- Waste generation/pollution prevention
- Pollution sources
- Planning for pollution control
- In-plant controls for pollution prevention

The video-tape presentation offers the advantage of being able to reach a large group of individuals at one time. The students' workbooks can be used by attendees for future reference. A video-tape presentation alone, however, cannot be tailored to all regional specific needs. To address this shortcoming, we in the Western and Northern Region of Environment Canada incorporated other objectives that we wished to get across to plant owners/managers, first, to stress simple techniques for at-source waste reduction, and second, to make the platers aware of local regulatory requirements. The video-tape presentation was, therefore, supplemented with the following presentations and materials:
A case study presented by a waste treatment equipment supplier
Presentations on regulations by Alberta Environment and the cities of Edmonton and Calgary
Source reduction techniques
Information on two federal government financial incentive programs in waste reduction for pollution abatement
Presentation on the “On-Site” program for the temporary employment of technical staff to work on waste problems

The training session was held on November 17-19, 1987 in Edmonton, Alberta. It attracted 33 persons from all four western provinces of Canada.

Federal Government Financial Incentives

There are two federal government assisted financial incentive programs that may be applied to waste reduction, namely, the Development and Demonstration of Resource and Energy Conservation Technology (DRECT) and the Accelerated Capital Cost Allowance (ACCA).

Under DRECT, the federal government will pay up to 50% of the cost of developing and demonstrating prototype systems of promising new technologies that reduce pollution and save energy. ACCA is a tax incentive program. An eligible taxpayer may write off the cost of capital equipment of processes installed for the prime aim of preventing and controlling air and water pollution over two years instead of the usual depreciation period.

SUMMARY AND CONCLUSION

There are various simple techniques that can be used to reduce waste at source. These simple techniques represent sound approaches for solving the waste disposal problems faced by the metal plating industry as provincial regulations and municipal sewer use by-laws become more stringent.

A technical assistance program in waste reduction was initiated by Environment Canada's Western and Northern Region in the fall of 1986. It offers assistance in plant waste assessment and training on how to reduce waste. Four metal plating plants have benefited from the waste assessment component. To date, one training course which attracted 33 platers has been held on metal plating waste management. The program demonstrates that government and industry can work together in a constructive way to solve waste management problems. Environment Canada also administers two financial incentive programs for pollution control and prevention.

ACKNOWLEDGEMENT

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REFERENCES


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