Chapter 4.4
Metal Finishing: Cleaner Production Fact Sheet and Resource Guide

Purpose

This fact sheet offers basic information on the important adverse environmental impacts of metal finishing, as well as associated health and safety impacts. **Metal finishing** includes both **electroplating** and **coating operations,** as well as their supporting processes (polishing, cleaning, degreasing, pickling, etching, etc.). The purpose of metal finishing is to prevent corrosion and wear, change electrical properties, enhance bonding for adhesives and coatings, and provide a decorative finish for metal products.

This fact sheet also discusses opportunities for mitigating these impacts, with an emphasis upon "cleaner production" strategies that may also provide financial benefits to micro- and small enterprises (MSEs). In addition, it provides a substantial, annotated list of resources for organizations seeking more information.[1]

This fact sheet has been prepared for (1) **business development services (BDS) providers**, which offer services such as management training or marketing support to MSEs, and (2) **intermediate credit institutions (ICIs)** and **direct lenders** that provide financial credit to MSEs. It is intended to be used in concert with other sections in Part III of the *Environmental Guidelines for Small-Scale Activities in Africa: Environmentally Sound Design for Planning and Implementing Development Activities*, which is USAID Africa Bureau's principal source of sector-specific environmental guidance.

Why Focus on Cleaner Production for Mitigation?

Cleaner production (CP) is a preventive business strategy designed to conserve resources, mitigate risks to humans and the environment, and promote greater overall efficiency through improved production techniques and technologies. Cleaner production methods may include:

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[1] USAID cleaner production fact sheets are available for the following subsectors that are likely to have substantial adverse impacts on the environment and/or worker health: brick and tile production; leather processing; small-scale mining; food processing; wood processing and furniture making; metal finishing; and wet textile operations.

- substituting different materials
- modifying processes
- upgrading equipment
- redesigning products

In addition to environmental, health and safety benefits, many CP techniques provide opportunities to substantially reduce operating costs and improve product quality. MSEs can profit from CP through more efficient use of inputs and machinery, higher-quality goods that command higher prices, and reduced waste disposal costs. Improved safety measures can also help MSEs avoid costly accidents and worker absences.

Experience has demonstrated that, with assistance, MSEs can often identify cleaner production opportunities that produce a positive financial return, sometimes with little or no investment. Many enterprises that change to CP methods may reap substantial financial and environmental benefits, indicating that CP should be the first option considered in addressing MSEs' environmental problems.

However, CP options with clear financial benefits are not equally available to all businesses. Further, such options may not completely mitigate environmental problems. In some cases, improving environmental performance may require businesses to use methods or approaches that offer no measurable financial return. Businesses typically undertake such measures if required by law or as part of a commitment to the community.

Important Environmental Issues Addressed by This Fact Sheet

- Use of hazardous chemicals
- Solid and hazardous wastes
- Air pollution
- Water use
- Wastewater

Adverse Environmental Impacts and Mitigation Opportunities

Several key environmental issues associated with metal finishing are listed in the box at left and discussed below. For each issue, the fact sheet provides a list of questions to aid in the assessment of individual MSEs.

These questions are followed by a number of mitigation strategies that can be considered. Where possible, cleaner production strategies are emphasized. The strategies presented typically represent a range of available options, from profitable activities that require no investment to other activities that may increase MSEs' costs.

❑ *Use of Hazardous Chemicals*

Metal finishing operations routinely use various hazardous chemicals, including solvents for cleaning the metal parts, acids and bases for etching them, and solutions of metal salts for plating the finish onto the desired form (substrate).

Most coating processes require the metal surface to be thoroughly cleaned beforehand, because surface contaminants greatly diminish the quality of the finished product. Both cleaning and plating processes generally occur in a "bath"—that is, a tank in which parts are dipped into a solution of chemicals.

Preparing the surface of the metal for treatment involves the removal of greases, soils and oxides. Cleaning agents used for this purpose include detergents, solvents, acidic solutions and caustics.

Finished metal parts are often further coated with some combination of paint, lacquer or ceramic coating. These coatings can themselves contain toxic solvents and heavy metals.

Chemicals used may include the following:

- acids (sulfuric, hydrochloric, nitric, phosphoric)
- toxic metals (cadmium, nickel, zinc, chromium, lead, copper) and compounds which contain these metals
- solvents (1,1,1-trichloroethane, methylene chloride, tetrachloroethylene, methyl ethyl ketone [MEK], toluene, xylene)
- cyanide compounds.

These chemicals may be toxic to humans and animals, cause cancer in both humans and animals, easily catch fire, and/or persist in the environment for a long time, entering the food supply. In particular, hexavalent chromium is highly toxic to humans, causing kidney damage and increasing the risk of lung cancer in humans. It is also highly toxic to aquatic animals at very small doses. Both workers and local communities are at risk from exposure to these chemicals, particularly those that persist in ground and surface water supplies for long times.

In general, cleaner production can reduce the environmental harm caused by using hazardous chemicals and improve the financial performance of the production process. Cleaner production options in this area are simple techniques, including pre-cleaning, production/inventory planning, substituting less hazardous chemicals and/or processes, and reusing or reclaiming "dirty" chemicals. These methods are described in detail below.

Key Questions to Consider:

- What chemicals are used at the facility?
- How are your chemicals stored?
- How do you manage use of chemicals in your facility? Do you keep an up-to-date inventory? Do you limit employees' access to chemicals?
- Which processes use chemicals? What quantities of chemicals do they require?
- Can any of the chemicals be replaced with less hazardous chemicals?
- How frequently do you have chemical spills at your facility? What do you do to protect against such spills?
- Can you reuse any chemicals?

- Can any chemicals used for specific purposes be replaced with more multi-purpose chemicals?

Selected Mitigation Strategies:

- **Avoid keeping outdated chemicals.** Chemicals may lose their effectiveness if used past their expiration date, resulting in poor-quality products and wasted bath solutions.

  Recently purchased chemicals should be used after older chemicals (a “first in, first out” policy) in order to prevent accumulation of expired stock. Creating an inventory control system will prevent waste by ensuring that all chemicals are used in order of arrival in the storeroom.

  Label all chemical containers with the name of the chemical, the date it arrived at the storeroom, the name of the manufacturer/distributor, and any appropriate hazard warnings. The manufacturer, and in some cases the distributor, may be able to provide a Material Safety Data Sheet (MSDS), which includes necessary warnings as well as details about proper safety equipment and procedures for handling the chemical. Assistance providers may also be able to find MSDSs via the Internet.

- **Conduct employee trainings** in the proper handling of chemicals, the reasons for using safer techniques, and emergency response. Trained employees will be better able to operate baths at peak efficiency, minimize spills, and improve the consistency of solutions.

  Training can also minimize the number of “bad baths” in which the entire solution must be changed out, which wastes time, materials and water, and may require workers to reprocessi of metal parts. Ensure that only trained employees are responsible for mixing bath solutions and setting flow levels.

- **Reduce the need for chemicals**.
  - Reduce the use of rust inhibitors (a toxic cleaning agent) by ordering metal parts to be delivered only at the time that they are needed, and also by storing them away from moisture if possible. This reduces the chances that they will rust.
  - Pre-clean parts (wipe them with rags, squeeze them, blow air or plastic pellets on them, vibrate them with abrasive media) before applying liquid or vapor degreasing solvents. This can reduce the amount (and cost) of solvents required and extend the life of degreasing solutions. Cold cleaning with mineral spirits can also help reduce the use of solvents by removing oil before vapor degreasing.

- **Optimize solvent-handling procedures.** There are a number of ways to reduce the amount of solvents used throughout a facility; several require little or no investment.

- Solvents left from “upstream” (earlier) processes can be reused in “downstream” (later) machine operations. For example, solvents used for final wash during equipment cleaning can be reused as paint thinner, eliminating the need to purchase paint thinners.
- Rotating the treated metal parts before removing them from the degreaser will allow all condensed solvent to flow back into the degreasing unit, reducing the need to refill (top off) solvents.
- Covering degreasing baths when they are not in use will reduce evaporation of solvents; firms can spend less on solvents and lower the risk of toxic exposures to workers.
- Alkali washes can be used instead of solvents in degreasing operations. This way, wastes from alkaline cleaners can be chemically treated to reduce toxicity and then discharged into the sewer, which minimizes cleaning costs. (See the description of wastewater treatment systems below.)
- Extend the life of cleaning solutions and reduce costs by filtering the cleaning solutions to remove sludge buildup. Refresh the solution by topping it off with fresh solution and emulsifiers. For small operators, a single mobile filtration unit can service all caustic and acid solutions. Use cleanable polystyrene or metal filters in the filtration unit and clean the filters by blowing compressed air over them.
- Use blast media to air-strip paint for line-of-sight stripping, instead of using solvents. Stripping paint using plastic blast media requires only low pressures and does minimal harm to the part substrate. Plastic blast media can be recycled, generate less waste than sand blasting, and can be cheaper and faster than chemical stripping methods.[2] Blast stripping should be performed only in well-ventilated spaces such as a walk-in booth or a large room. As with solvent-stripping methods, workers should wear respirators to protect themselves from airborne particulates and hazardous emissions.
- Recycle solvents onsite. Use gravity to separate a solvent/sludge mixture and reclaim the clear solvent for equipment cleaning. If reclaimed solvent is pure enough, it can also be used for formulating primers and base coats of paint. For larger volumes of solvents, recycle by using batch distillation. This works well for recovering isopropyl acetate, xylene, and paint thinner from cleanup operations. Residue from solvent recovery processes can be blended with fuel and burned in a combustion unit. Burning is safest for local communities as long as controls are used to capture toxic metals from the air emissions before they are released into the atmosphere. **Do not burn residue without such controls.** Residue

[2] Northeast Waste Management Officials' Association, 1998.

from the burning must still be disposed of properly, as it will be toxic.

- **Use process substitution** to reduce hazards to workers, communities, and the environment.
  - Zinc alloy plating, such as zinc-nickel or zinc-cobalt, can be used to provide corrosion protection instead of cadmium plating, which is highly toxic and carcinogenic. Alkaline zinc solutions can be used with existing equipment, although zinc solutions that do not contain cyanide require more thorough parts cleaning to be as effective as cadmium cyanide solutions. If cadmium plating is necessary, use bright chloride, high-alkaline baths, as they are less toxic than cadmium cyanide solutions.
  - Because cyanide is highly toxic to humans, use cyanide-free systems for zinc plating when possible. Cyanide-free systems include zinc chloride (acid) baths and zinc alkaline systems.
  - Zinc chloride baths have higher operating efficiencies, offer energy savings through improved bath conductivity, and result in better quality of product because hydrogen embrittlement is reduced. (This is a type of metal deterioration that reduces metal strength and ductility.) Zinc chloride baths, however, require that traditional steel tanks be lined with an acid-resistant material, such as hard rubber or polypropylene.
  - Zinc alkaline systems can be used in traditional steel tanks and produce good brightness, but require tighter operational controls to ensure an efficient process.
  - Replace cyanide cleaners with trisodium phosphate or ammonia. Use non-fuming cleaners such as sulfuric acid and hydrogen peroxide instead of chromic acid cleaner.
  - Use trivalent chromium instead of hexavalent chromium, as it is less toxic to humans and aquatic animals, creates less sludge, and is less viscous, therefore causing less drag-out (see below). Trivalent chromium also uses the same equipment as hexavalent chromium, so it requires no infrastructure changes. Unfortunately, trivalent chromium can only be used for a plating thickness no greater than 0.003mm. Trivalent chrome baths may also require additives to correct color differences.
  - For the copper bright-dipping process, use a sulfuric acid/hydrogen peroxide dip instead of cyanide and chromic acid dips. This reduces the toxicity of the bath and allows recovery of copper from the solution.

- **Consider options to reduce drag-out.** Drag-out is the residual solution that adheres to a part when it is removed from a process bath. Drag-out reduces the concentrations of chemicals in the plating bath, requiring more chemical inputs to maintain operating conditions. Methods to reduce drag-out include:
    - *Drainage from baths*: Install rails above process baths to rack pieces for drainage before rinsing. Add drain holes to plated parts to prevent bath solutions from pooling in racked items. Allow 10–20 seconds of drip time before rinsing.
    - *Change bath conditions*: Operate baths at lowest possible concentration to reduce drag-out loss. Using wetting agents to decrease the surface tension of the solution will also help prevent the solution from clinging to the parts. Increasing bath temperatures to make the solution less viscous can also reduce drag-out, but be sure that the higher temperatures do not reduce the effectiveness of any brightener being used. If MSEs choose to increase bath temperatures to reduce viscosity, they should insulate the tanks to reduce heating costs.
    - *Redesign processes*: Insert a drag-out recovery tank before the rinsing stage to minimize metal concentrations in the wastewater. Keep the drag-out that has been recovered from different process steps segregated so it can be used to top off plating tanks. This also streamlines the plating process and reduces drips on the floor.
- **Reduce chemicals needed in painting operations**.
    - Increase transfer efficiency of spray-painting by switching to a high-volume low-pressure (HVLP) system. This can increase transfer efficiency by 30 to 60 percent and thereby reduce supply costs for paint. Siphon-fed HVLP systems produce a fully atomized spray pattern with even surface coverage. Kits for converting conventional siphon sprayers to HVLP sprayers are inexpensive and practical to set up in small operations. All HVLP systems should be used in an enclosed space for maximum efficiency. **Workers should always wear respirators when using spray guns to keep them from inhaling overspray and hazardous vapors.**
    - Schedule paint jobs to start with light colors and end with dark ones so as to minimize cleaning between colors. Also, paint all products of the same color at the same time.
    - Scrape out paint cups and tanks before rinsing with solvent; this will make the solvent go further/last longer.

❑ *Hazardous and Non-Hazardous Waste Generation*

Metal finishing operations have many sources of non-hazardous and hazardous waste, including depleted or contaminated process baths, spent etchants and cleaners, waste from strip and pickle baths, exhaust scrubber solutions, degreasing solvents, and miscellaneous solid wastes (absorbants, filters, empty containers, etc.). Spills and accidental bath discharges, in particular, are an easily correctible source of hazardous waste.

Surface preparation for metal coating generally involves removing soils and imperfections such as oxidation, rust, corrosion, heat scale, tarnish, smut and old paint. The process of removing these flaws generates waste oils and/or greases, as well as waste solvents and cleaners. Clean-up of spray guns, hoses and other paint equipment generates paint sludge and waste solvent. Also, expired chemicals and paints are waste materials that require special disposal considerations.

Cleaner production can help reduce the amount of hazardous and non-hazardous wastes generated by (1) preventing spills and leaks, (2) retraining employees, and (3) maximizing the efficiency of operations to use fewer inputs. These methods are discussed in detail below.

Key Questions to Consider:

- What types of wastes does the facility generate?
- Do these wastes contain hazardous chemicals and/or toxic metal concentrations?
- How are you disposing of these wastes? How much does it cost to dispose of these wastes?

Selected Mitigation Strategies:

- **Use inventory controls.**
    - Ensure materials are labeled with expiration dates; use a first-in, first-out policy to minimize the amount of expired materials.
    - Secure storage areas, and grant access to only a few designated employees.
    - Require a one-for-one exchange policy, where workers must return an empty container in order to receive a new container. This will control the number of open containers, reducing the risk of spills, contamination and wasted materials.
- **Prevent spills**.
    - To prevent losses due to spills, purchase chemicals in the smallest possible quantities. When economic needs require purchasing chemicals in bulk, use spigots or pumps to transfer materials from large storage containers to smaller “working” containers to minimize drips and spills.
    - Keep containers tightly sealed at all times to prevent spills and evaporation of volatile chemicals.
    - Material storage areas should have a spill containment system such as a concrete pad with earthen berms enclosing the area.

- Install drainboards between tanks. (A drainboard is a board that is placed over the lips of two adjacent tanks to catch drag-out.) Ensure that the drainboard is tilted to allow drag-out to flow back into the earlier tank in the process.
- Prevent and contain spills and leaks with drip trays and splash guards around processing equipment.

- **Prevent leaks**. Create regular inspection and maintenance schedules for process equipment and filters. Prevent leaks by frequently inspecting piping systems, racks, storage tanks, tank liners, air sparging systems, and automated flow controls.
- **Make sure process controls are accurate**. Setting up schedules for calibrating all temperature controls , speed controls, and pH meters is a no-cost, preventative measure to ensure that operating conditions meet production requirements, reducing the number of substandard parts as well as energy, water, and raw materials usage.
- **Hold training sessions** to instruct employees on the proper handling of chemicals in order to reduce spillage and to minimize leaks and evaporative losses, which reduces supply and clean-up costs. Training can include low-cost, effective techniques such as:
    - proper use of spouts, funnels, and drip pans during material transfer.
    - use of drainboards to reduce drag-out.
    - maintaining liquids in tanks at the correct levels to reduce spilling from overflows.
    - use of containment berms to contain spills.
- **Prevent substandard parts.**
    - Sort for substandard parts and set them aside before electroplating or painting to prevent unnecessary operations.
    - Preparing surfaces well is key to preventing parts from failing to meet coating requirements; 80 percent of coating adhesion failures can be attributed to improper surface preparation.[3]
- **Reduce contamination of baths.**
    - Reduce contamination of bathwater, and thereby reduce the costs of replacing it with new bathwater, by ensuring that any dropped parts and tools are immediately retrieved. Locate rakes near baths to help pull dropped items out of the bathwater.
    - Clean racks between baths to minimize contamination.
    - Install a rain cover for outdoor tanks so that rain will not dilute chemicals.

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[3] See Northeast Waste Management Officials Association, 1998

- In areas with "hard water" (water with high concentrations of calcium, magnesium, chloride, or other soluble minerals), use softened, distilled, or deionized water for rinsing in order to reduce contaminant build-up in baths. This will result in less drag-out and generate less sludge.
- Use electrowinning to remove unwanted metal contaminants from plating solutions, such as copper contaminating zinc-and nickel-plating baths. Electrowinning involves placing a sheet of metal in a bath and running a low current through it. This allows the copper, for example, to attach to the metal plate, leaving the rest of the solution intact. Although small amounts of the plating metals will be removed along with the copper, generally the cost of replacing them is offset by savings from extending the overall life of the bath.

- **Reduce waste in painting operations.**
  - Use various sizes of paint-mixing and sprayer cups to make it easier to prepare only the amount of paint needed.
  - Use old paint as a base coat or primer.
  - Prevent nozzle tips for spray containers from clogging by inverting the can and spraying the nozzle to clear any residual paint. Repair clogged aerosols by cleaning or replacing the nozzle tip.
- Ensure that a spray gun's air supply is free of water, oil and dirt. Prevent spray gun leaks by submerging only the fluid control portion in cleaning solvents.

❑ *Air Pollution*

Vapor degreasing operations and hot plating baths generate used solvents that emit volatile organic compounds (VOCs). VOCs can cause serious health problems for workers, and they also contribute to air pollution in the lower and upper reaches of the atmosphere. Poor handling practices can result in the loss of as much as 30 percent of solvents and degreasing agents. This can be a significant cost, as these chemicals would otherwise be re-used. VOCs are also emitted during paint application, curing and drying.

In general, some sort of pollution control investment will be necessary to fully control air emissions from metal finishing facilities. Cleaner production can help to reduce air pollution by preventing solvents from escaping into the air (i.e., volatilizing) and improving the efficiency of pollution control systems. These methods are described in detail below.

Key Questions to Consider:

- What types of air emissions are generated at the facility?
- What methods are being used to control these emissions?

Selected Mitigation Strategies:

- Cover the degreasing unit during idle or down times to prevent solvent from volatilizing.
- Use a speed of 10 feet per minute or less to remove parts from solvent in order to minimize disturbance of the “vapor line”—the volume of air above the surface of the solvent that is saturated with solvent vapor. Rapid movement of the parts or basket disrupts the vapor zone, which allows new air to mix in with the vapor and then to escape the degreaser or bath, taking some of the vapor with it. Increasing the freeboard height above the vapor level to 50–100 percent of tank width will also help keep air from mixing with the vapor and reduce loss of solvent.
- Exhausts should be treated to reduce VOCs and heavy metals before venting to the atmosphere. Carbon filters can both reduce VOC levels and allow employees to recover solvent using steam stripping and distillation.
- Use mist collection and scrubbing systems to control vapors and mists from process baths.
- Use noncaustic paint removers such as alkaline or non-phenolic strippers to reduce phenol emissions.
- Use waterborne, powder, UV-curable, or high-solids paints instead of solvent-borne options. If solvent-based coatings must be used, consider alternative application technologies such as roller/curtain coating; tumbling, barreling, and centrifuging; or HVLP sprays.

❑ *Wastewater Problems*

Metal finishing, especially electroplating, generates large quantities of wastewater, primarily from rinsing between process steps. Because of the hazards to the community associated with the chemicals involved in metal finishing operations, wastewater should always be treated before disposal into ground or surface waters. Improperly treated wastewater can contaminate drinking water and irrigation supplies, with long-term consequences for the health of the local population, including employees.

Cleaner production can best help reduce impacts of wastewater by reducing the toxicity of the wastewater at the source. Once options for reducing source pollution are used, however, it will still be necessary to build or share use of a wastewater treatment plant. In order to be effective, wastewater treatment plants need to be properly designed for the types of wastes to be treated and the volumes of wastes generated. Operating such plants can be costly, although in areas where water is scarce or expensive, treating wastewater may help pay for itself by permitting re-use of water in facility operations.

Key Questions to Consider:

- What are the sources of wastewater at the facility?
- What types of contaminants are in the wastewater?
- How is the wastewater being treated before disposal?
- What options exist for reducing the volume or toxicity of wastewater generated?

Selected Mitigation Strategies:

- A waste treatment plant should treat wastewater to destroy cyanide, equalize flows, neutralize pH, and remove toxic metals.
- Separate waste streams. If cyanide and acidic wastewaters mix, it can generate lethal hydrogen cyanide gas. Also, nickel solutions must be separated from cyanide and ammonium solutions in order to allow nickel to precipitate out of solution.
- Treat degreasing baths separately, since the oils and grease in the wastewater will interfere with any metal precipitation processes.
- Use a reducing agent such as a sulfide to reduce wastewater containing hexavalent chromium, which is water-soluble, to trivalent chromium, which is insoluble. Add lime to the wastewater to precipitate out the chromium, and dispose of the solids in a sanitary landfill.
- Use sodium sulfides and iron sulfates to remove metal from rinsewater instead of tartarates, phosphates, EDTA and/or ammonia.
- Sludge from water treatment operations must be treated before disposal in order to control metals. Use electrolytic methods to recover metals from the sludge when metal concentrations are high. Sludges should be thickened, dewatered, and stabilized with lime before disposal in a controlled landfill. Oxidize chromium acid wastes with sodium bisulfite and sulfuric acid. Use magnesium oxide instead of caustic soda to adjust pH.

❑ *Water Use*

Metal finishing requires water in almost every stage of the process. Many metal finishing businesses have yet to seize major opportunities to reduce their water use. Often, limited water resources in an area must satisfy the needs for public drinking water, sanitation, irrigation, river transport and industrial needs. Inefficient use of these resources for metal finishing can leave insufficient or highly polluted waters in lakes, rivers and wetlands, degrading their ability to perform crucial economic and ecological functions. Water efficiency also has numerous financial advantages for an MSE, most notably the decrease in the water bill and in wastewater treatment costs. There are various cost-effective ways for metal finishing enterprises to reduce their water use that could provide substantial savings.

Key Questions to Consider:

- What type of rinsing technique is currently being employed?
- Is fresh water used in every new bath? Could some water be reused?
- Is there a system in place that measures the number of liters or gallons of freshwater used at various stages of the metal finishing process?

Selected Mitigation Strategies:

- **Ensure the proper design of rinse tanks** in order to improve rinsing efficiency, reduce water use, and reduce drag-out. Tanks should be the smallest size necessary for all parts/products that will be used in them, in order to reduce water usage. Using a static rinse tank before a running rinse tank will reduce drag-out in the running rinse tank, using less water for the same degree of cleanliness.

  Carefully placing water inlets and outlets on opposite ends of the tank will maximize water mixing in the tank, improving the effectiveness of the rinse. Inlet flow baffles, diffusers, distributors or spray heads can also help control the injection of freshwater into the rinsing tank and aid in mixing the water. Also, adding air blowers, mechanical mixing, or pumping/filtration systems can improve mixing by agitating tank water. Mechanical agitation is preferable to air agitation, however, since air blowers can introduce contaminants like oil into the bath.

- **Consider alternatives to tank rinsing.** Tank rinsing may not be the most water-efficient solution for rinsing certain types of parts. Consider spray rinsing instead of immersion for flat-surfaced parts. Ultrasonic rinsing works well for cleaning parts with small crevices or irregular shapes.

- **Employ a flow control technique.** Three effective flow control techniques are flow restrictors, flow cut-off valves, and conductivity meters and controllers. Flow restrictors ensure that excessive water is not fed to the process line. Flow cut-off valves are simple mechanisms that shut off water flow to rinse tanks when the process lines are not in use. Conductivity meters and control valves reduce rinse water flow and retain a set standard of water purity in the tank (electrical conductivity increases as the concentration of contaminant ions increases).

- **Measure usage at individual production points.** Install an inexpensive flow meter or accumulator on the main water feed line (leading to the process line) or on individual rinse tanks. Flow meters indirectly conserve water by allowing careful monitoring of usage and can identify optimum water usage (or excessive waste), leaks, and system failures.

- **Implement an alternative rinsing configuration.**

  Counter-current rinsing: This involves having rinse water circulated through a series of rinse tanks. Fresh water (preferably deionized) is fed into the rinse tank farthest from the process tank and overflows to the rinse tank closest to the process tank. The work piece is dipped in the cleanest water last. Counter-current rinsing uses significantly less water than a single flowing rinse. **Two counter-current rinse tanks can reduce water use by 90 to 97 percent.**

Reactive rinses and reuse: This system diverts the overflow from an acid rinse to an alkaline rinse tank. The reuse of acid rinse baths for alkaline cleaner rinses makes the alkaline cleaner rinse more effective, typically reducing water consumption by 50 percent.

Spray rinsing: Spray rinsing reduces the water needed for final rinsing by spraying drag-out back into its process tank or into a concentrated holding tank. Spray rinsing works best for flat sheets, or in conjunction with immersion rinsing for irregular objects.

- **Change the mechanics of the rinsing process.** Rinsing is more effective when the parts are dipped into the rinsing tank multiple times than when parts are dipped once and agitated while submerged. **Dipping parts twice in rinse baths is 16 times more effective at reducing drag-out than dipping once.**[4]
- **Re-use treated wastewater for minor rinsing steps,** such as after alkaline cleaners and acid pickling steps. Note: Caution should be exercised in re-using wastewater that has been conventionally treated (via hydroxide precipitation) as it can introduce high amounts of dissolved solids into the plating line.

[4] Source: *CP Manual for the Metal Finishing Industry*, 1998.

References and Other Resources

References consulted in preparing this fact sheet:

- The International Cleaner Production Information Clearinghouse (ICPIC) at http://www.uneptie.org/PC/cp/library/icpic.htm.

- The ICPIC was developed by the UN Environment Programme's Division of Technology, Industry, and Economics (DTIE) for the effective promotion of CP worldwide. The ICPIC contains a compilation of CP case studies, CP contacts, profiles of CP-related national policies and CP publications. Case studies used in preparing this fact sheet include:
  - EP3: Pollution Prevention Assessment for a Metal Finishing Facility http://www.p2pays.org/ref/10/09356.htm
  - Toxic Waste Reduction in Chrome Plating http://www.p2pays.org/ref/10/09381.htm
  - Cleaner Production for Reducing Water Consumption at a Metal Plating Industry http://www.p2pays.org/ref/10/09110.htm
  - Eco-efficiency at a Metal Finishing Factory in the Czech Republic http://www.p2pays.org/ref/10/09160.htm

- Management Options for Old Paint and Paint-Related Materials (1995). Minnesota Technical Assistance Program (MnTAP) Fact Sheet. http://www.p2pays.org/ref/01/00609.pdf

  This fact sheet provides information on how to effectively reduce and manage wastes from painting operations. These include (1) ignitable wastes, such as solvents and other cleaners; paints and paint thinners; and adhesives and glues, and (2) toxic wastes with heavy metals.

- National Metal Finishing Resource Center. http://www.nmfrc.org/

  The National Metal Finishing Resource Center (NMFRC) is an Internet-based organization established in 1995 under a program jointly funded by the U.S. Commerce Department's National Institute of Standards and Technology (NIST) and the U.S. Environmental Protection Agency (USEPA). Their site is a comprehensive collection of environmental and technical resources for pollution prevention in metal finishing, including a searchable technical database containing over 5,000 articles, papers and reports; specifications (with index) used in metal finishing; shop, supplier and people directories containing over 6,000 entries; and online calculators designed for finishing needs.

  Their "Ask the Expert Question-and-Answer Archives" on wastewater treatment were used in creating this fact sheet. http://www.nmfrc.org/wwarchive/aug02b.cfm

- North Carolina Department of Environment and Natural Resources, Division of Pollution Prevention and Environmental Assistance. http://www.p2pays.org/

- This Web site offers an extensive collection of resources on CP and pollution prevention for a variety of industry sectors. The page on waste reduction in electroplating (http://wrrc.p2pays.org/industry/electroplating.htm) houses an excellent online collection of technical resources for the metal plating industry. Several "Fact Sheets" linked to this Web site that were used in preparing this CP fact sheet include:
  - Water Efficiency, Industry-Specific Processes: Metal Finishing. http://www.p2pays.org/ref/04/03097.pdf
  - Water Conservation for Electroplaters: Counter-Current Rinsing http://www.p2pays.org/ref/01/00051.htm
  - Pollution Prevention Tips: Drag-out Management for Electroplaters http://www.p2pays.org/ref/01/00222.pdf
  - Ben Graves. Never Dump Cleaner. http://www.p2pays.org/ref/02/01366.htm
  - Virginia Waste Minimization Program (1995). Fact Sheet: Waste Reduction for Metal Finishers, 1 (4). http://www.p2pays.org/ref/11/10308.htm

- Northeast Waste Management Officials' Association (1998). *Pollution Prevention in Metal Painting and Coating Operations: A Manual for Pollution Prevention Technical Assistance Providers.* http://www.p2pays.org/ref/01/00777/toc.htm

  The Northeast Waste Management Officials' Association (NEWMOA) designed this manual to provide environmental assistance staffers with a basic reference on metal finishing-a single publication to jump-start their research on pollution prevention for companies with which they are working. The manual is explicitly designed to be useful both to assistance professionals with experience working with metal platers and to those who have never encountered metal finishing before. The USEPA Pollution Prevention Division funded this manual as a model of a comprehensive packet of information on a single industry.

- Pallen, Dean (1997). *Environmental Sourcebook for Micro-Finance Institutions.* Asia Branch, Canadian International Development Agency. http://www.microfinancegateway.org/files/1914_Pallen_Dean.pdf

  This sourcebook describes the environmental impacts of a variety of important MSE sectors. It is designed to help micro-finance institutions improve the environmental performance of their lending activities, and offers guidance for improving MSEs' economic performance as well.

- Pennsylvania Department of Environmental Protection (1997). *Pollution Prevention Opportunities for Painting and Coatings Operations.* http://www.p2pays.org/ref/01/00151.pdf

  This fact sheet describes alternatives for reducing releases of volatile organic compound (VOCs) from solvents, as well as good operating practices for painting operations.

- U.S. Environmental Protection Agency (1994). *Guide to Cleaner Technologies: Alternative Metal Finishes.* EP/625/R-94/007. http://www.p2pays.org/ref/02/01052.pdf

  This guide presents information on process alternatives that can reduce or eliminate generation of some wastes and emissions from metal finishing operations. It is particularly applicable to firms that apply cadmium and chromium finishes, as well as to finishers that use cyanide-based baths or copper/formaldehyde solutions.

Additional Useful Web sites

- Business Assistance. Metal Finishing Industry Resources
  http://pprc.org/hubs/toc.cfm?hub=24&subsec=7&nav=7

  This site catalogs a variety of metal finishing resource sites. It maintains links to several metal finishing trade associations as well as a database of current research projects. A joint project of the Business Assistance Programs in Alaska, Idaho, Oregon and Washington, the site is funded by a grant from USEPA.

- http://www.svti.sk/CleanVOC.htm is an annotated guide to resources available on the Internet for metal finishers.