3.4G 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 those 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 Section 3.4 of the *Environmental Guidelines for Small-Scale Activities in Africa: Environmentally Sound Design for Planning and Implementing Humanitarian and Development Activities*, USAID Africa Bureau's principal source of sector-specific environmental guidance.

Why Focus on Cleaner Production for Mitigation?

Cleaner production 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:

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

In addition to environmental, health and safety benefits, many cleaner production techniques provide opportunities to substantially reduce operating costs and improve product quality. MSEs can profit from cleaner

[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.

production through more efficient use of inputs and machinery, higher quality, 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 frequently identify cleaner production opportunities that produce a positive financial return, sometimes with little or no investment. Many enterprises that change to cleaner production methods may realize substantial financial and environmental benefits, indicating that cleaner production should be the first option considered in addressing MSEs' environmental problems.

However, cleaner production 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.

Adverse Environmental Impacts and Mitigation Opportunities

Several key environmental issues associated with metal finishing are listed in the box at right 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 key 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 MSE costs.

Important Environmental Issues Addressed by This Fact Sheet

- Use of Hazardous Chemicals
- Solid & Hazardous Wastes
- Air Pollution
- Water Use
- Wastewater

Use of Hazardous Chemicals

Metal finishing operations routinely use various hazardous chemicals, including solvents for cleaning, acids and bases for etching, and solutions of metal salts for plating the finish into 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), and
- cyanide compounds.

These chemicals may be toxic to humans and animals, cancer causing for both humans and animals, flammable, 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 employee 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 loose 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 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) detailing necessary warnings as well as proper safety equipment and procedures for handling the chemical.)

- **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, water, and may require reprocessing of parts. Ensure 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) used by ordering 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 chance of rusting.
  - Pre-clean parts (wipe with rags, squeeze, blow air or plastic pellets, vibrate 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 solvents by removing oil before vapor degreasing.

- **Optimize solvent handling procedures.** There are several ways to reduce the amount of solvents used throughout a facility that require little or no investment.
  - Solvents can also be reused from upstream operations in downstream 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 parts before removing from degreaser will allow all condensed solvent to flow back into degreasing unit, reducing the need to refill (top-off) solvents.
  - Covering degreasing baths when not in use will reduce solvent losses to the air, both reducing solvent costs and 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 discharged to the sewer, which minimizes cleaning costs. (See description of wastewater treatment systems below.)
  - Extend the life of cleaning solutions and reduce costs by filtering the cleaning solutions to remove the sludge build up. Refresh the solution by topping up 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 filters by blowing compressed air over them.

- Use blast media to air strip paint instead of solvent stripping techniques for line-of-sight stripping. Plastic blast media paint stripping uses low pressures and does minimal harm to the part substrate. Plastic blast media can be recycled, generates less waste than sand blasting, and can be cheaper and faster than chemical stripping methods[2]. Blast stripping should only be performed in well-ventilated spaces such as a walk-in booth or a large room. As with solvent stripping methods, workers should wear a respirator to protect 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 should be blended with fuel and burned in a combustion unit. Burning is safest for local communities with controls for toxic metals.

- **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 higly 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-resistance lining, 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 for process efficiency.
    - 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

[2] Source Northeast Waste Management Officials' Association. *Pollution Prevention in Metal Painting and Coating Operations - A Manual for Pollution Prevention Technical Assistance Providers*. 1998

    viscous, therefore causing less drag-out. Trivalent chromium also uses the same equipment as hexavalent chromium so 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 for the copper recovery from solution.

- **Consider options to reduce drag-out.** Drag-out is the residual solution that adheres to a part upon removal from a process bath. Drag-out reduces the concentrations of 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. Reducing solution viscosity by increasing bath temperatures can also reduce drag-out, but this approach must be balanced with the operating conditions necessary for brighteners to be effective as well as with increased energy costs. 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 drag-out from different process steps segregated for topping 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% and thereby reduce supply costs of 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 prevent inhalation of overspray and hazardous vapors.

  - Schedule paint jobs from light to dark colors to minimize cleaning between colors.

  - Scrap paint cups and tanks before rinsing with solvent.

  - Paint all products of the same color at the same time.

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 wasted materials that require special disposal considerations.

Cleaner production can help reduce the amount of hazardous and non-hazardous wastes generated by preventing spills and leaks, retraining employees, and 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[3] between tanks that are tilted to allow drag-out to flow 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 calibration schedules on all temperature, speed controls, and pH meters is a no-cost, preventative measure to ensure that operating conditions meet production requirements, reducing the number of sub-standard 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 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; maintenance of liquid levels in tanks to reduce over-flow spills; and use of containment berms to contain spills.
- **Prevent sub-standard parts.**
  - Sort for substandard parts before electroplating or painting to prevent unnecessary operations.
  - Good surface preparation is key to preventing parts that fail coating requirements. 80% of coating adhesion failures can be attributed to improper surface preparation[4].
- **Reduce contamination of baths.**
  - Reduce contamination of baths and thereby reduce costs in maintaining new bathwater by ensuring immediate removal of dropped parts and tools. Locate rakes near baths to help retrieve dropped items.
  - Clean racks between baths to minimize contamination.
  - Install a rain cover for outdoor tanks to prevent dilution.
  - In areas with “hard water” (high concentrations of calcium, magnesium, chloride, or other soluble contaminates), use a water softener, distilled water, 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 to remove copper from zinc and nickel plating baths. Electrowinning involves placing a sheet of metal in a bath and running a low current through it. This would allow the

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[3] A drainboard is a board that is placed over the lips of two adjacent tanks to catch drag-out.
[4] See Northeast Waste Management Official’s Association, 1998

copper 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 bath life.

- **Reduce waste in painting operations.**
  - Use various sizes of paint-mixing and sprayer cups 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 spray gun 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 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% of solvents and degreasing agents. This can be a significant cost, as they 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 (volatizing) 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 downtimes to prevent solvent from volatilizing.
- Use a speed of 10 feet per minute or less to remove parts from solvent 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 and causes air to mix in with the vapor and escape the degreaser or bath. Increasing the freeboard height above the vapor level to 50-100% of tank width will also help prevent air mixing and reduce loss of solvent.

- Exhausts should be treated to reduce VOCs and heavy metals before venting to the atmosphere. Carbon filters can reduce VOC levels and allow for solvent recovery by 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 instead of phenolic ones 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 high-volume low pressure (HVLP) sprays.

Wastewater

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.

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. There can be substantial operating costs associated with treating contaminated rinse water, although in areas where water is scarce or expensive, treating wastewater may be cost-effective, as it can permit 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 wastewaters 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 level of oils and grease in the wastewater will affect the effectiveness of 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.
- Use sodium sulfides and iron sulfates to remove metal from rinsewater instead of tartarates, phosphates, EDTA, and ammonia.
- Sludge from water treatment operations must be treated before disposal 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 large opportunities to further reduce water use. Often, limited water resources in an area must satisfy the needs for public drinking water, sanitation, irrigation, river transport, and industrial needs. Use of these resources can leave insufficient or highly polluted waters in lakes, rivers, and wetlands, degrading the crucial ecological functions they perform. Water efficiency also has numerous economic advantages, most notably: operation costs decrease when the water bill is reduced and wastewater treatment costs decline. There are various cost effective water reduction options for metal finishing processes that could provide substantial savings.

Key questions to consider:

- What type of rinse water 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 quantifies the 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 minimum size necessary for all parts/products to reduce water usage. Using a static rinse tank before a running rinse tank will reduce drag-out in the running rinse tank, requiring less water used 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 freshwater injection into the rinsing tank and aid in tank mixing. 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 serve to shut-off water flow to rinse tanks when the process lines are not in use. Conductivity meters and control valves will reduce rinse water flow and retain a set water purity standard 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 to process line or on individual rinse tanks. Flow meters indirectly conserve water by allowing for careful monitoring of usage and can identify optimum water utilization (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%.

  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 renders the alkaline cleaner rinse more effective and water consumption is halved.

  Spray Rinsing: Ultimately, spray rinsing reduces the water needed for final rinsing by spraying drag-out back into its process tank or into a concentrated holding tank. As a result, the result is that less water will be needed for final rinsing. 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[5].

- **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 conventionally treated wastewater (via hydroxide

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

precipitation) due to the introduction of high dissolved solids into the plating line.

References and Other Resources

References consulted in preparing this fact sheet:

CP Manual for the Metal Finishing Industry. 1998. Developed by the UNEP Working Group for Cleaner Production and the CRC for Waste Minimisation and Pollution Control Ltd on behalf of the Queensland Department of Environment and the Brisbane City Council.
http://geosp.uq.edu.au/emc/cp/res/Metal%20Finish/Metal%20Finish_manual.htm

The Cleaner Production manual for the Metal Finishing industry was developed by the UNEP Working Group for Cleaner Production and The CRC for Waste Minimisation and Pollution Control Ltd on behalf of the Queensland Department of Environment and the Brisbane City Council. The project was completed in April 1998. The manual provides information about Cleaner Production opportunities within the Metal Finishing Industry, to point the way towards greater profitability and improved environmental performance. It focuses on those aspects which are most achievable in the short and medium term, and which require limited or no capital expenditure.

The International Cleaner Production Information Clearinghouse (ICPIC) at http://www.emcentre.com/unepweb/index.htm.

The ICPIC was developed by the UNEP DTIE for the effective promotion of Cleaner Production (CP), worldwide. The ICPIC contains 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.emcentre.com/unepweb/tec_case/metal_28/process/p14.htm
Toxic Waste Reduction in Chrome Plating
http://www.emcentre.com/unepweb/tec_case/metal_28/process/p19.htm
Cleaner Production for Reducing Water Consumption at a Metal Plating Industry
http://www.emcentre.com/unepweb/tec_case/basicm_27/house/h1.htm
Eco-efficiency at a Metal Finishing Factory in the Czech Republic
http://www.emcentre.com/unepweb/tec_case/metal_28/house/h3.htm

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

This fact sheet provides information on how to effectively reduce and manage these wastes from painting operations include ignitable wastes, such as solvents and other cleaners, paints and paint thinners, and adhesives and glues; or 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 US Commerce Department's National Institute of Standards and Technology (NIST) and the Environmental Protection Agency. Their site is a comprehensive collection of environmental, technical, and pollution prevention metal finishing resources 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 On-line 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 website offers an extensive collection of resources on Cleaner Production (Pollution Prevention) for a variety of industry sectors. Their site Waste Reduction in Electroplating website http://wrrc.p2pays.org/industry/electroplating.htm houses an excellent on-line collection of technical resources for the metal plating industry. There are several "Fact Sheets" linked to this website that were used in preparing this CP fact sheet:

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. *Fact Sheet: Waste Reduction for Metal Finishers*. Vol. 1 Issue 4. 1995. http://www.p2pays.org/ref/11/10308.htm

Northeast Waste Management Officials' Association. *Pollution Prevention for the Metals Finishing Industry - A Manual for Pollution Prevention Technical Assistance Providers*. 1997
http://www.p2pays.org/ref/03/02454.htm

The Northeast Waste Management Officials' Association (NEWMOA) designed this manual to provide environmental assistance staff with a basic reference on metal finishing. The purpose of the manual is to enable assistance providers to rely on a single publication to jump start their research on pollution prevention for metal finishers with whom they are working. The manual is explicitly designed to be useful to assistance professionals with experience working with metal platers and those who have never encountered metal finishing before. The U.S. Environmental Protection Agency Pollution Prevention Division funded this manual as a model of a comprehensive packet of information on a single industry.

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

The Northeast Waste Management Officials' Association (NEWMOA) designed this manual to provide environmental assistance staff with a basic reference on the metal coatings process. The purpose of the manual is to enable assistance providers to rely on 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 to assistance professionals with experience working with metal coating operations and those who have never before encountered this process. The U.S. Environmental Protection Agency Pollution Prevention Division funded this manual as a model of a comprehensive packet of pollution prevention (P2) information on a single industry.

PA Department of Environmental Protection. Pollution Prevention Opportunities for Painting & Coatings Operations. 1997. http://www.p2pays.org/ref/01/00151.pdf

This fact sheet describes alternatives for reducing VOC releases from solvents as well as good operating practices for painting operations.

Pallen, Dean (1997). Environmental Sourcebook for Micro-Finance Institutions. Asia Branch, CIDA.
http://www.acdi-cida.gc.ca/cida_ind.nsf/8949395286e4d3a58525641300568be1/0d80b65c5f18111c85256707006e7747?OpenDocument

The Environmental Sourcebook for Micro-Finance Institutions (MFIs) is designed to help MFIs improve the environmental performance of their lending activities. The sourcebook describes the environmental impacts of a variety of important MSE sectors, and offers guidance for improving both the environmental and economic performance for various MSE sectors.

US 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 the generation of some of these wastes and emissions from metal finishing operations. It is particularly applicable to firms that apply cadmium and chromium finishes, as well as finishers that use cyanide-based baths or copper/formaldehyde solutions.

Additional Useful Websites

Business Assistance: Metal Finishing Industry Resources http://www.pprc.org/pprc/sbap/metalfin.html
This site catalogs a variety of metal finishing resource sites. The site maintains links to several metal finishing trade associations as well as a database of current research projects. It is a joint project of the Business Assistance Programs in Alaska, Idaho, Oregon and Washington and is funded by a grant from the U.S. Environmental Protection Agency.

Cleanerproduction.com offers two catalogs of sites relevant to the metal finishing industry: http://www.cleanerproduction.com/industries/metalplating.html and http://www.cleanerproduction.com/industries/metal%20products.html. The site is run by Hamner and Associates LLC, based in Seattle, Washington USA and Manila, Philippines.

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