PART 2 CLEANER PRODUCTION IDEAS

1. Simple Cleaner Production Options

1.1 Housekeeping

Housekeeping improvements represent the simplest way to reduce pollution cheaply and usually without purchasing additional equipment. Housekeeping improvements discussed in this section include preventative maintenance, inventory control, spill prevention, preventing contamination of bath solutions, waste segregation and staff training.

1.1.1 Workshop Tidiness

One major aspect of good housekeeping simply involves keeping the workplace clean and free of clutter. This can greatly reduce the risk of accidents and damage to stock or equipment and can also help create a smooth work flow throughout the facility. For example, keeping stock in a designated inventory area can reduce the risk of it becoming accidentally damaged by forklifts. In the case of hazardous products, this can prevent spills in non-bunded areas.

Maintaining a smooth flow of work can greatly increase the efficiency of the operation. By planning where materials are stored and used they can be easier to get when needed. Also wastes can be more easily segregated.

1.1.2 Preventative Maintenance

Leaks in pipes and equipment can add up to huge losses of resources, and an example of the extent of water loss from leaking pipes is provided in the following table.

Table 1: Water loss from leaks (at pressure 4.5 bar)

Leak size (mm)	Kilolitre/day	Kilolitre/year
0.5	0.39	140
1	1.2	430
2	3.7	1,300
4	18	6,400
6	47	17,000

Preventative maintenance will minimise leaks, spills and other potential losses of resources. A regular schedule for cleaning and maintenance with inspection logs to follow up on repairs is a good management option.

Key areas for maintenance and inspection are pumps, flanges, filters, anodes, cathodes, meters, flow restrictors, sensors, tanks and tank liners. Malfunctions should be dealt with as soon as they are discovered.

1.1.3 Inventory Control

To reduce the volumes of hazardous materials stored on site at any one time, consider a 'just-in-time' purchasing system. A 'just-in-time' system can generally work very successfully if your supplier can provide a quick turn-a-round on orders, otherwise a system for recording the stocks of materials may be required.

To control the distribution of hazardous and expensive chemical additives, consider locking stores and having a system where workers can only exchange empty containers for new supplies on a one-for-one basis. This will help avoid stockpiling or misuse of products and provide the possibility of returning containers/

1.1.4 Spill Prevention and Control

The best way to reduce spills is to train staff about the proper handling of materials. Clear procedures should be in place for mixing chemicals and the responsibility for handling and mixing chemicals should be limited to a small number of staff who are trained in the procedures. As well as reducing spills, this will also improve the consistency of formulations.

By using drain boards or splash guards on the tanks, drainage from the dripping pieces is directed back into process baths and prevent it falling on the floor. Providing adequate freeboard in tanks will also greatly reduce spills to the floor.

A significant area of loss for galvanising plants is from zinc splatter during the dipping process. This can be reduced in many cases by installing hoods. This can be seen over leaf in Example 1.

Example 1: Installing Galvanising Hoods at Newcastle Galvanising (Graham Group)

Newcastle Galvanising made some significant savings by installing a hood system to reduce zinc splatter. It has thereby reduced the demand of zinc by around 7%. Zinc is a high cost material - around $1,450 to $2,600 per tonne.

It has also saved on time required to scrape zinc off the walls - a messy process that could only recover about 75% of the splatter.

Worker safety has also improved significantly. Workers no longer have to be evacuated from the process area during the dipping which improved productivity and worker morale. Further, the hood system is ventilated reducing the fumes that are emitted to the environment.

Source: EnviroNet Australia, Cleaner Production Case Studies

The Full Case Study is available in Section 3 - Case Study 21

1.1.5 Staff Training

A trained workforce is often an overlooked part of the company's pollution prevention plan. Training not only helps avert or limit accidents, it also empowers workers and makes them feel more valued by their company. Consider providing training for general housekeeping requirements and also for spill response.

1.2 Production Planning

1.2.1 Process Layout

Improving process layout can greatly affect waste generation, particularly for electroplating operations. Many small plating shops typically have only one set of rinse baths which service the entire plating process. This means that operators must walk back and forth between the various plating tanks and the rinse tanks. This results in greater processing time, the dripping of solutions onto the floor, and the worker possibly contacting the solution.

By streamlining the process and adding a set of rinse baths directly adjacent to each plating bath, operators can move through the process in one direction allowing for smoother work flow. It also means that drag-out can be kept segregated and returned back to the plating tank to top up the volume. An example of the potential savings available from layout changes can be seen in the Case Study 19 in Part 3 of this manual. A summary of this case study is also shown in Example 2 over page.

Overhead racks allow for greater production throughput, but also provide greater control over aspects such as drain times and rinse cycles. As will be discussed later in section 1.5.2, controlling these aspects can greatly reduce waste generation. Automation of overhead racks provides even greater benefits and may be considered by larger businesses where it can be justified by larger throughput.

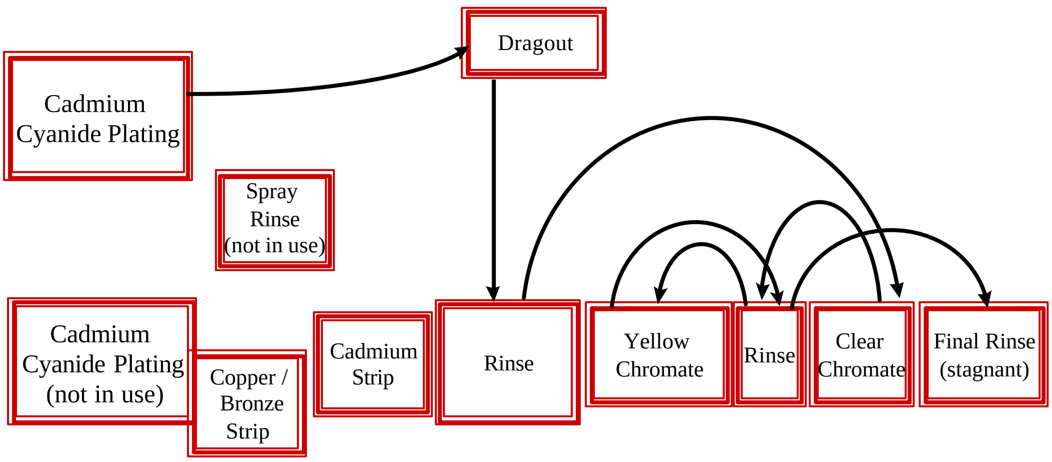
1.2.2 Forward Planning and Production Scheduling

Carefully inspecting parts before they are coated can help avoid processing parts that have a high likelihood of becoming rejects. Provide staff responsible for racking parts with clear quality guidelines so they can identify potential rejects before they are processed.

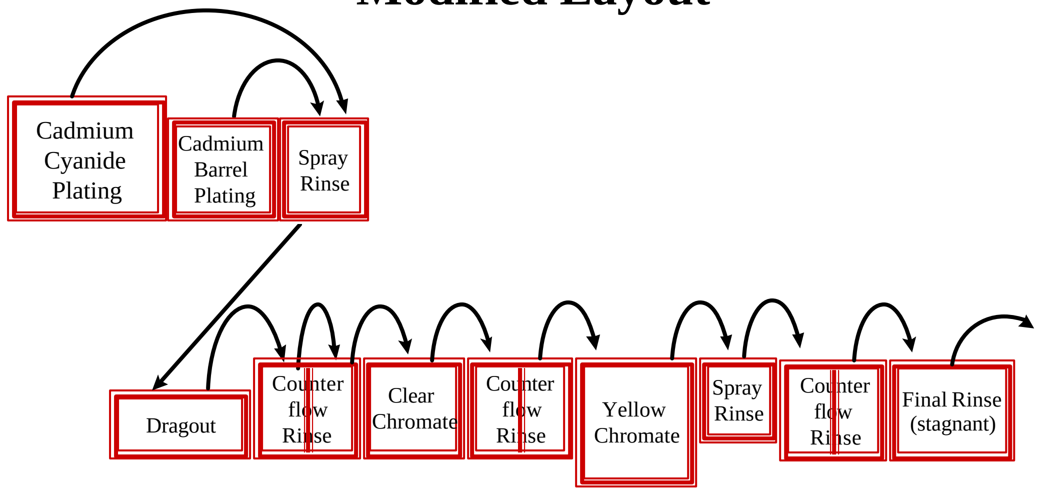
Forward planning and fine tuning production schedules can also have an impact on waste generation, particularly for powder coating operators. By painting all products of the same colour at the same time, the need to clean equipment between batches is reduced. If batches are processed from lighter to darker shades, the residues from lighter batches may be used in the formulations for the darker batches. This also reduces the need to clean equipment.

Example 2: Improving Bath Layout: Example from an Cadmium Electroplating Line

Original Layout



Modified Layout



The changes resulted in reductions in cadmium cyanide drag-out by 490 litres/year, chromate conversion drag-out by 3,300 litres/year and rinse water by 870 litres/year. The demand for filter cake in the wastewater treatment system also decreased by 1,090 kg/year.

The capital investment for these changes was $US 4,520 which included two new rinse tanks, 2 spray tanks and labour. The changes however resulted in annual savings of $US 2,620, and the project paid for itself in 1.7 years. The changes also resulted in a reduced number of worker footsteps need for the plating line from 58 to 21..

Source: Merit Partnership Pollution Prevention Project for Metal Finishers, Modifying tank layouts to improve process efficiency, 1996.

The Full Case Study is available in Section 3 - Case Study 19.

1.3 Cleaning & Pre-treatment

Metal parts need to be cleaned to remove the multitude of possible surface contaminants before being coated. A list of possible contaminants is provided in Table 2. Most coating process require very thorough cleaning regimes as surface contaminants greatly affect the quality of the finished product. Cleaning process can also act to pre-treat metal surfaces to allow for better adhesion of the coating on the metal surface.

Table 2: Possible contaminants found on metal parts

- pigmented and non-pigmented metal drawing compounds
- polishing and buffing compounds
- greases, metallic soaps, abrasives and waxes
- cutting and grinding fluids
- rust (metal oxides)
- oxidation and scale
- heavy metal salts
- quenching, rust protection, lube oils and hydraulic fluids
- metal chips, dust, carbonaceous deposits
- paint and inks
- rosin and terpenic compounds
- fluxes

(Source: Enviroene, 1989).

For electroplating processes, cleaning is most commonly undertaken in caustic or acidic soak tanks. Steel and brass are dipped in caustic cleaning solutions containing emulsifiers and surfactants to remove and dissolve the oils and solids present. The cleaning baths can also incorporate an electrical current or heat as part of the cleaning process. Aluminium surfaces are cleaned with acidic strippers since caustic is very corrosive to aluminium. Plastics are generally etched with acid which as well as cleaning provides an etched base onto which the metal can adhere.

For galvanising, scale and rust are removed by pickling in sulphuric or hydrochloric acid. The item is then immersed in a flux solution, usually consisting of 30% zinc ammonium chloride with wetting agents, maintained at about 65^{o}C. The flux solution removes the oxide film which forms on the highly reactive steel surface after acid cleaning, and prevents further oxidation before galvanising.

For anodising, cleaning is typically undertaken with a non-etching, alkaline soak cleaner. The item is then immersed in a deoxidising etch solution containing sulphuric acid and chromic acid for 2-5 minutes to remove any oxide film and permit the anodising process to occur uniformly.

In Queensland, the use of solvents as cleaning agents is very limited. This has principally been a result of work place health and safety and environmental requirements for limiting or eliminating the use of solvent based products. Therefore across the industry alkaline (caustic) and acid based solutions are the principal agents used for cleaning and pre-treatment. Such solutions have a limited life and are generally dumped after a certain time, from 1 month to 6 months depending of the throughput. Consequently acid and alkali wastes account for the largest volume of liquid waste generated from the industry (see **Error! Reference source not found.**), and disposal is a considerable operating cost for most businesses.

It is worth considering ways in which the life of cleaning solutions can be extended in order to reduce the amount of waste generated from this part of the process.

1.3.1 Avoiding the requirement to clean

It may be possible to avoid cleaning to some extent through the following means:

- Having parts delivered 'just-in-time' to avoid the use of rust inhibitors.
- Requesting suppliers to supply parts that are easier to clean.
- Avoid the routine degreasing of all parts, and only degrease parts that really need it.
- Reduce the number of different cleaning agents you use by selecting those with a wide range of applications.

1.3.2 Physical cleaning methods

Many surface finishing operations are moving towards physical cleaning methods such as scraping, scrubbing or blasting techniques to reduce the use of cleaning solutions. Physical methods can include:

- using rags to wipe off excess oil
- blowing with air
- plastic pellet blasting systems for paint stripping
- fine blasting systems (sodium bicarbonate or solid carbon dioxide) (USAEP, 1997).
- vibrating apparatus with an abrasive media (e.g. glass or steel balls for brass; silk and carbide pads for nickel parts; rotating brush and pumice for copper)
- heating / burning / pyrolysis

For paint stripping, blasting systems with collection devices, for example, can eliminate up to 99 percent of the waste sludge that would have been generated using conventional chemical solvent stripping techniques.

Vibrating apparatus with abrasive media (e.g. glass or steel balls for brass; silk and carbide pads for nickel parts; rotating brush and pumice for copper) can replace pickling processes.

Pre-cleaning by mechanical means in combination with chemical cleaning will also extend the life of cleaning solutions.

1.3.3 Extending the Life of Cleaning Solutions

Avoiding the requirement to clean and using physical cleaning methods will be able to reduce cleaning wastes to some extent, but most businesses with continue to rely on the use of chemical cleaning baths to achieve a quality finish.

Probably the most effective way to reduce the generation of cleaning wastes is to extend the life the cleaning solutions. This can be achieved by filtering the cleaning solutions to remove the sludge build up and rejuvenating the solution by topping up with fresh solution and emulsifiers.

The action of the cleaning solution on the metals parts produces a sludge which collects in the cleaning tank. In the case of alkaline cleaning baths, the caustic reacts with the grease and oil contaminants producing a soap-like sludge. The sludge gradually builds up in the bath until it becomes so supersaturated with the sludge that the bath is ineffective, at which point it is generally dumped and replaced.

The life of the bath can be greatly increased by filtering the solution to remove suspended solids. To compensate for the depletion of cleaning agent and emulsifiers, the bath should also be topped up as required.

Filtration systems are available as in-tank units or as units external to the tank and the smaller units are suited to small scale businesses. For operations with high throughput the filtration units may be run continuously, however for smaller operations they need only be run for a few hours a day. It is also possible to use a single mobile filtration unit to service all cleaning solutions, caustic and acid.

External filtration systems have not been very popular in the past because of problems associated with corrosion and leaking plumbing and clamps etc. There are now in-tank systems available which eliminate these problems.

Replacing the filter media generates a solid waste that adds to operating costs. Some filters use a cleanable and reusable filter medium, so this should be considered when selecting the most appropriate filter system.

It has been reported by some Brisbane companies using systems that the life of cleaning solutions can be extended up to 5 years before they need to be dumped. Given the costs involved in disposing of these solutions, significant savings are possible.

Example 3: Extending the life of cleaning solutions for electroplating businesses

A small scale electroplating shop in Brisbane (name withheld) spends around $5,000 (or more) every year disposing of spent cleaning solutions. In addition to this, around $3,000/year would be spent to replace these chemicals.

For around $2,000 - $3,000, a combined in-tank filter and oil skimmer can be purchased to filter the cleaning solutions and extend the life of the cleaning solution. It is estimated that filtration could extend the life of the cleaning solutions up to 5 years. The cleaning solutions would still need to be topped up with chemicals to maintain the cleaning capacity of the cleaner.

The cost benefits of this are summarised below.

Current operating cost for cleaners	*$8,000/yr*
Cost of filter	*$3,000*
Pay back period	*4.5 months*
New operating costs for the cleaners (chemicals to top up cleaner + 1 disposal every 5 years)	*$1,260/yr*
Savings	***$6,740/yr***

Source: The UNEP Working Group Centre for Cleaner Production.

6.3.4 Component Parts Washers

Parts washers can be used to remove contaminants, oil and grease with a water and detergent combination. Washer units come in sizes from 300 - 1500 litres and most have a purifying/recycling system that allow the detergent or solvent solution to be recycled.

Aqueous parts washers can replace other cleaning systems using hazardous cleaning agents, and the detergent solutions used in these systems are typically biodegradable and may be suitable for discharge to sewage treatment plants.

The use of parts washers in the United States has increased since the enforced withdrawal of many hazardous degreasing agents. The cost for these washers has decreased as they become more commonplace in metal cleaning and preparation. The current practice is to make the parts washers as closed-loop and low maintenance as possible.

Parts washers can also use non-aqueous solutions such as solvents or mineral spirits, however from a cleaner production perspective the use of solvents should be avoided. Where solvents are used, parts washers reduce evaporation of the solvent, reduce worker exposure to hazardous substances and also allow for reuse which decreases the amount of cleaner needed.

1.3.4 Bacteriological cleaners

Biological cleaning systems or "bug cleaners" are being developed in Sweden as an alternative to chemical based cleaning. The method is in the early days of development, but may find a use in large scale galvanising operations. They require a large scale digester and the cleaning process is very slow. With further development they may find wider applications.

1.3.5 Ultrasonic cleaning

Ultrasonic cleaning can achieve high levels of cleanliness for metal surfaces and is capable of removing extremely small particles. It can remove debris from parts with complex geometries more quickly than immersion dipping processes. They are usually very small units varying in size from 20 - 140 litre capacity, and are therefore most applicable to small component applications such as jewellery. The other down side is that they are very expensive, however it is expected that ultrasonic cleaning may become available to a wider number of applications in the future.

1.3.6 Pyrolysis for Powder Coating

For the powder coating industry, paint stripping with solvent paint strippers, such as methylene chloride can be replaced with a pyrolysis process. Pyrolysis is controlled burning that occurs in an oven that operates at around 400 ^{o}C. The pyrolysis products are then ducted to an afterburner prior to discharge. An example of where pyrolysis has successfully replaced solvent stripping is described in Case Study No. 14 in Part 3.

1.4 Control of Bath Conditions

Monitoring and control of bath conditions at optimum levels will optimise efficiency, reduce wastage of materials and energy, and reduce drag-out. Sensors can be used to control process temperature, humidity, pH, flow rates and contamination levels, and sensor technology has advanced to the point where computers can now be used to assess conditions. Improvements in technology and reduction in costs have made analytical sensors, PC interfaces and process control systems more attractive.

The following sections describe some of the key parameters in controlling bath conditions.

1.4.1 Chemical concentrations

Maintain baths at the minimum chemical concentration to achieve necessary product quality. Undertake monitoring in-house rather than relying on chemical suppliers to advise on chemical requirements as some may set higher than necessary limits. By experimenting and lowering levels to just above the point when defects start to occur, chemical costs and the costs associated with disposal or treatment can be reduced. Reduced chemical concentration also reduces drag-out.

1.4.2 Bath Temperature

The temperature of a bath can have an impact on the efficiency of the process, and the amount of drag-out. At higher temperatures, the viscosity of the bath is lower, and therefore drag-out is reduced. On the other hand, higher operating temperatures also mean higher energy costs, and possibly the break down of brighteners. It could be worth investigating this trade-off to see if altering bath temperature, either up or down, could save money either in heating costs or in drag-out chemicals.

1.4.3 Prevent heat and vapour loss

There are number of ways to reduce heat loss and vapour loss from tanks:

- Heated tanks should be insulated to minimise heat loss. Use covers while baths are not in use.
- Floating balls and satchels are commonly used to minimise heat and vapour losses, and can have a pay back period of only a few months.
- Chemical mist suppressants can also be used in some applications to prevent vapour loss.

A study undertaken by the Industrial Technology Institute (1997) indicated that by using suppressants, the concentrations of chromium in the head space above a tank can be reduced to as low as 0.9% of the level when suppressants are not used. Also, the use of poly-balls (1-3/8 inch polypropylene plastic balls) can reduce air-borne concentrations of metals by 13% of the concentration without the balls. The study also showed that there was no significant benefit of using both the suppressants and balls as the concentrations were not significantly lower than from using suppressants alone.

1.4.4 Preventing Contamination of Plating Solutions

The build up of contaminants gradually reduces the efficiency of bath solutions, resulting in the need to dump solutions. The build up of contaminants, such as a cyanide bath contaminated with carbonate, also increases drag-out by as much as 50% because of the increase in solution viscosity. Some simple corrective technologies are available to extend the life of the bath solutions by removing the contaminants.

- Filtration

  Filtration systems are available as in-tank units or as units external to the tank, and the smaller units are suited to small scale businesses.

- Electrowinning

  Electrowinning removes unwanted metal contaminants from the solution leaving the desired metals in the plating solution, for example, to remove copper from zinc and nickel plating baths. When the copper content becomes too high, a sheet of metal is placed in the bath through which a "trickle current" is run. At this low current, copper plates out, but the bath additives remain mostly unaffected. While some of the plating metals (zinc, nickel) are removed, the savings realised by extending the bath life can justify this.

- Using deionised or distilled water

  Using deionised or distilled water instead of tap water for the make up of plating baths reduces the build up of contaminants in these solutions, resulting in less sludge build up and also reduced drag-out problems. Tap water contains contaminants such as calcium, iron, magnesium, manganese, chlorine, carbonates, and phosphates, so the use of deionised or distilled water eliminates the introduction of these contaminants.

- Mechanical agitation versus air agitation

  Air agitation is likely to introduce contaminants such as oil from the compressor and carbon dioxide into the bath and for this reason, mechanical agitation may preferable. If air is to be used however, ensure the air is filtered to remove any contaminants.

1.5 Reducing Drag-out

Drag-out, is the solution dragged from the process tank to the rinse tank, is the primary source of contaminated rinse water in the metal finishing industry. Reducing drag-out can:

- reduce contamination and therefore increase the life of rinse waters;
- extend the life of process baths;
- reduce the demand for new chemical and water inputs; and
- reduce the cost of treatment to remove harmful or regulated contaminants before the water is reused or discharged.

A concern of many plating shops is that making changes to reduce drag-out, such as increased drain times, conflicts with process throughput objectives. Often missing from this argument however is the full cost considerations of losing process solution and the need to spend more money on treatment.

This section provides ideas for reducing drag-out, and examples are also provided in Case Studies Nos. 1, 10 and 24 in Part 3.

1.5.1 Withdrawal and Drainage Time

The faster an item is removed from the bath, the thicker the film on the workpiece and the greater the drag-out volume. Also, the quicker the drain time the more drag-out that is carried over to the rinse tank. It has been reported (Hagler Bailly Consulting, 1995) that the effect of withdrawal is so significant that most of the time allocated for draining a rack should instead be used for withdrawal.

Increasing the drainage time after parts are removed from baths can significantly reduce the volume of drag-out, and this has been demonstrated in a number of studies.

- A trial in the United States showed that a drain time of at least 10 seconds reduces drag-out by greater than 40%, compared to the three second industry average (IAMS, 1996).
- A trial in Hong Kong showed that drainage times longer than 15 to 20 seconds reduced drag-out by 75% without adversely affecting the quality or quantity of product (Hong Kong Government Industry Department, 1995).

This can often be done without slowing down the whole process, as rinsing is typically not the rate-determining-step in the process. By analysing the whole process and identifying the rate-determining-step, other operations may be slowed down to maximise the draining time.

Example 4: Reducing drag-out at Whitco, Brisbane

Whitco in Brisbane have recently increased the drain time for their electroplating line to 5 seconds in an attempt to reduce the amount of metals carried over into rinse waters. Prior to this change operators where draining the racks for a minimum amount of time (about 2 second).

A trial undertaken as part of this project examined the decrease in drag out that could be achieved as a result of this increase drain time. In the chrome plating line for example, the trial demonstrated that the amount of solution carried over to the drag-out tank was reduced by a factor of 1.5.

The result of this will be less carry over of metals and chemicals to the wastewater treatment system, and consequently less use of treatment chemicals. Staff at Whitco are expecting to see significant savings in chemical use at their treatment plant, maybe up to 50%, particularly for chemicals such as sodium metabisulphite and sodium hypochlorite which are used to treat chromium and cyanide respectively.

Source: Prepared by the Centre for Cleaner Production as part of this project.

1.5.2 Workpiece Orientation and Hanging Racks

Drainage times can be increased without increasing the demands on workers time by using hanging racks and automated rinse processes. These systems can greatly increase throughput which may allow shops to take on more work.

Hang parts on the rack so that they are free draining. Liquid should be allowed to follow the quickest route back to the process tank rather than carrying it to the next. Tilt parts to avoid pockets where chemicals can collect and avoid positioning parts directly over one another.

Where practical, rotate items as they are removed from the bath to avoid retention of solution on the parts.

1.5.3 Product Modification

Minor changes to the product can reduce drag-out. Racking holes are commonly added to pieces to enable them to be hung. These should be positioned to promote drainage while not impacting on the structural integrity of the item. Holes can also be added to eliminate pockets where solution can collect. This can significantly reduce drain times (IAMS, 1996).

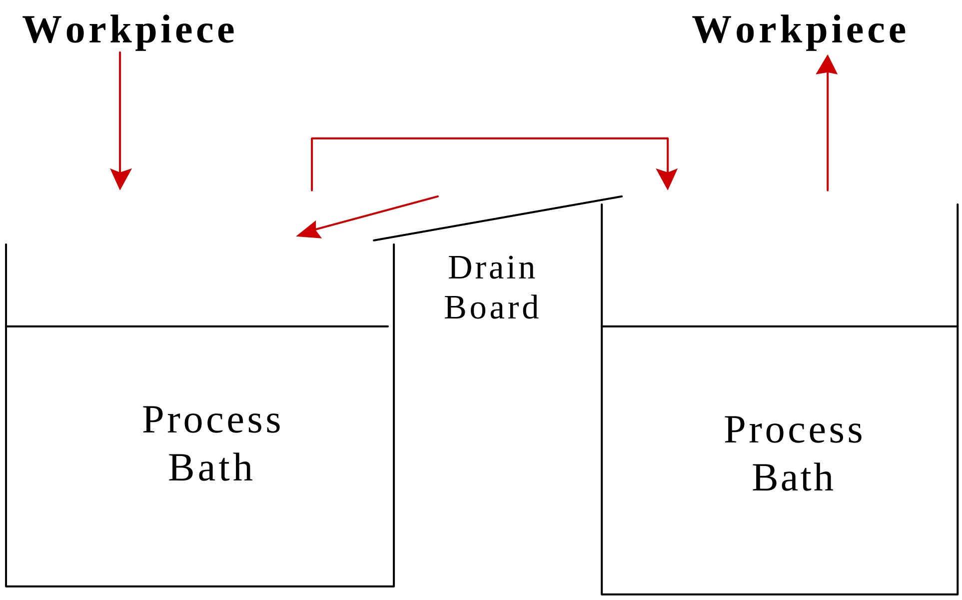
There are a number of structural features that can increase the amount of drag-out, such as folded or lapped spot-welded seams. These form thin recesses which draw liquid into them due to capillary forces. Reducing the number of pieces in an assembly and using butt welds can help reduce this effect.

1.5.4 Drain Boards and Drip Trays

Drain boards (see Figure 1) are widely used throughout the metal finishing industry to capture plating solutions. These boards are suspended between process tanks and are constructed of plastic, or plain or teflon-coated steel. Solutions drip on the boards and drain back into their respective processing tanks.

Place a drain board over the lips of two adjacent tanks to catch drag-out. Slope the board back to the first tank (this also keeps the solutions off the floor and out of the sewer).

Figure 1: Drain Boards



1.5.5 Wetting Agents

Surfactants and other wetting agents can help reduce drag-out by as much as 50%, by reducing the surface tension of the solution. (Hagler Bailey Consulting). However wetting agents can create foaming problems and may not be compatible with wastewater treatment systems. Therefore experimentation will be necessary to determine the most suitable wetting agent.

1.5.6 Air Knives

Air is blown across the surface of the work pieces as they are withdrawn from the process or rinse tank, pushing the liquid back into the tank. In some applications this rapid dry method may cause quality problems.

1.5.7 Return of drag-out to the plating bath

The direct return of drag-out to the plating bath is the simplest form of metal recovery and is practised very widely in the industry. The first tank after the plating tank is referred to as the ‘drag-out tank’ or a ‘still rinse’ and collects the majority of the material dragged out. This solution is used to ‘top up’ the plating bath to compensate for evaporative loss. As well as the problem of contaminant build up described previously, the volume of drag-out solution collected is generally more than that needed to compensate for evaporative loss in plating tank, and so the plating tank may need to be operated at a higher temperature to accommodate all the drag-out solution. Evaporation can be used to eliminate this problem.

1.6 Improved Rinsing Techniques

The best rinsing system is a compromise between obtaining acceptable rinse efficiency and using the minimum amount of water. Traditionally the industry has used water generously to achieve a good rinse. However there are a number of ways to achieve a good rinse by using vastly less water.

By minimising water used for rinsing you can save on two fronts. Firstly you save when buying the water in the first place, and secondly you save on treating and disposing of the resulting wastewater.

This section contains a description of the ways to use less water for rinsing while maintaining good rinse efficiency. A case study of the benefits that can be achieved by improving rinsing techniques is described in Example 5.

Example 5: Reducing Wastewater at Methven Tapmakers

Methven Tapmakers reduced the amount of water used in the plating shop by around 42% by installing water meters and through staff awareness training. The savings made through the following changes have been more than $12,000 per year.

- reducing the number of water inlets;
- installing water meters on the three remaining inlets;
- inter-linking tanks so that water can be reused in subsequent tanks if it is not contaminated (see counter-current rinsing);
- teaching staff about the value of water;
- turning off inlets when the tanks are not in use.

Installation costs for the meters and connections were about $560. The modifications were done during a regular maintenance period so resulted in no loss of production. Water costs have been reduced from $75 to $41 per day.

Source: EnviroNet Australia, Cleaner Production Case Studies

The Full Case Study is available in Section 3 - Case Study 20

1.6.1 Agitation

Since most plants use hand operated racks, agitation can be achieved by moving the racks manually. Rinsing is more effective if the pieces are raised and lowered in and out of the tank rather than agitating while submerged. Double dipping the pieces in the same bath has been shown to be 16 times more effective in reducing drag-out than a single dip.

Air sparging with compressed air is often not an efficient agitation technique, and often results in air stripping of the solution. Vortex mixers with recirculation of a side-stream from the rinse tank are reasonably effective, but use of a propeller type agitator results in the highest efficiency.

1.6.2 Spray rinsing and fog-sprays

Spray rinsing employs a spray nozzle to spray rinse water onto the workpiece as it drains above the process tank. It is best suited to the rinsing of flat sheets, however it can be used in conjunction with immersion rinsing for irregular shaped objects.

For heated tanks, spray nozzles can be sized and water flow rates adjusted so that the spray water balances the evaporative losses.

Fog tanks and fog sprays are a variation of spray rinsing, combining the water spray with air pressure to produce a fine water mist. The fog captures the chemicals and returns them to the process bath.

Spray tanks or fog tanks are used in those situations where the mist water would lead to undesirable dilution of the process solution.

With respect to rinsing efficiency, a spray rinse is approximately equivalent to half a dip rinse, and uses between 1/8 and 1/4 the water used in dip rinsing. These systems are represented in Figure 2.

1.6.3 Static and running rinses

Some smaller plants can get away with only a small number of static rinse baths to achieve adequate rinsing. However for plants with higher production throughput, it is more common to have running rinses, where a constant feed of water is supplied to the tank to keep the contaminant concentration low.

A single running rinse arrangement requires large volumes of water to achieve good rinsing. Water use can be reduced by using one or more static rinse tanks prior to the running rinse. This can be seen in Figure 3.

Figure 2: Fog tanks and fog sprays

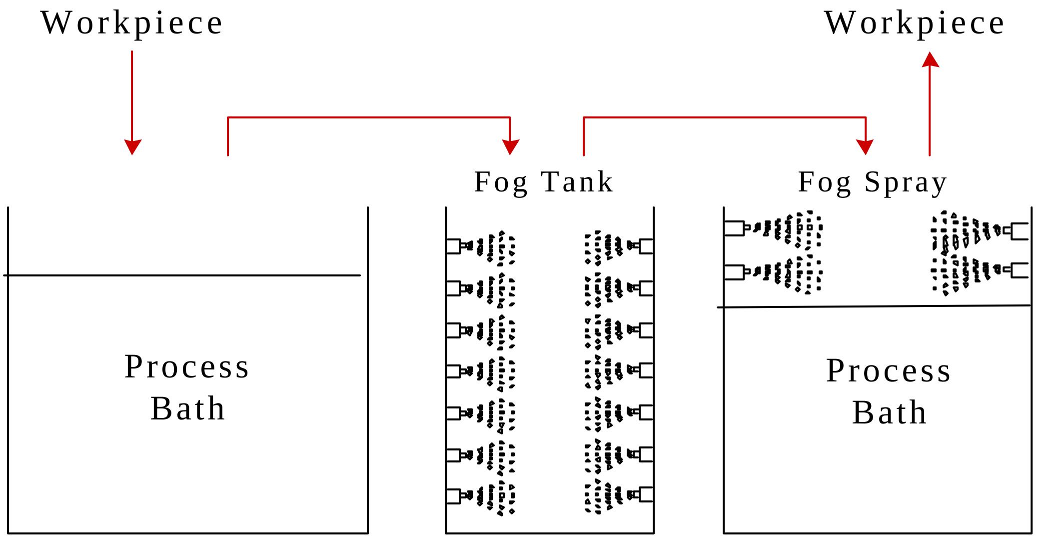
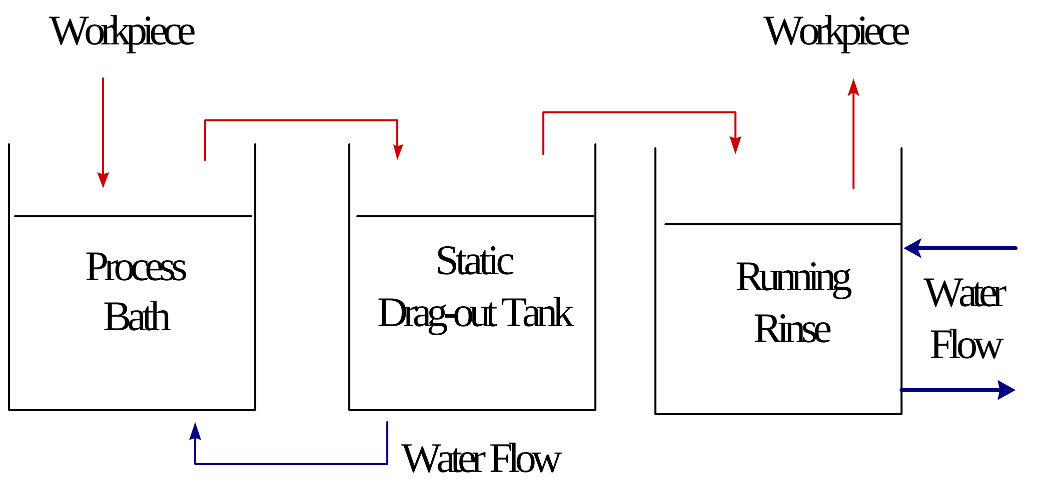


Figure 3: Static and Running Rinses



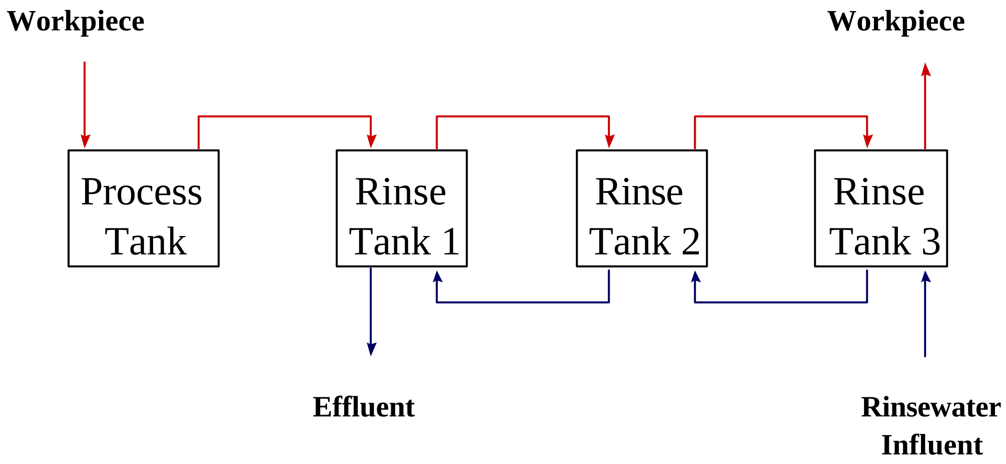
1.6.4 Counter-current rinsing

Counter-current rinsing can further reduce the demand for fresh water by returning drag-out to the process tank. Fresh water is fed into the final rinse tank and overflows backwards through the flowing rinse tanks until it reaches the rinse tank immediately after the plating tank.

Often the overflow from this first rinse tank discharges to the drain or a treatment system. However, if the process tank operates at a temperature high enough to cause sufficient evaporation, the overflow may enter the process tank, thereby reclaiming much of the drag-out. Overflow to the process tank is only practical when deionised (DI) water is used for rinsing (IAMS, 1996).

A multistage counter-current rinse system uses up to 90% less rinse water than a conventional single-stage rinse system and is depicted in Figure 4.

Figure 4: Counter-Current Rinsing



(Source: Ohio EPA, 1994).

1.6.5 Controlling water flow

The simplest and cheapest way to control water flow is to turn off water to rinse tanks when they are not in use. However this can be difficult to enforce, so you may need a system that does not rely on human action.

Simple in-line flow restrictors can limit the water flow rate, and are very cheap (around $10). However, because restrictors are non-adjustable they may be unsuitable in some job shops where the variety of materials being plated requires variable flow rates.

Where variable flows are required, automated metering systems can be used to control flow with reasonable accuracy. These can either operate based on preset flows for specific operations or control the flow using conductivity sensors. The conductivity sensors measure the concentration of contaminants in the rinse water and adjust the flow accordingly; the higher the conductivity, the higher the flow. An example of the benefits that can be gained through flow control is described in Example 6 over page.

1.6.6 Avoiding the need to rinse

The rinse between a soak cleaner and an electrocleaner may be eliminated if the two baths are compatible.

Example 6: Reducing Rinse Water Use with Conductivity Control Systems

This example from the Merit Partnership in the United States demonstrates the potential benefits of installing conductivity control systems to control the inflow of water to rinse tanks.

The group installed control devices at nine sites at an average cost of $1,600 per device, including parts and labour. The total cost across all sites was $14,500.

Water use at these sites reduced dramatically by around 42%, from 1,960 kilolitres/month to 1,125 kilolitres/month. The resultant monthly savings were around $280 for water in and $110 for wastewater discharge. The demand for WWTS chemicals also reduced from around $4,000 to $3,200 / month.

The total savings were around $14,300/year, resulting in a pay-back period of just over 12 months.

Source: Merit Partnership Pollution Prevention Project for Metal Finishers.

The Full Case Study is available in Section 3 - Case Study 18

1.7 Techniques for Rinse Water Reuse and Metal Recovery

The concept of a "zero discharge" system is becoming a viable option for the industry. It is based on the theory that water and metals contained in the liquid waste streams can be recovered and reused again in the process. As the costs for treating and disposing of wastewaters to sewer become more and more expensive, there will come a time when it is more cost effective to treat and reuse the water than to treat and dispose.

Treated wastewaters can potentially be recycled back to non critical processes such as rinsing, cleaning, pickling tanks or for floor cleaning. Considering that up to 90% of all water use in electroplating is used for rinsing operations, considerable gains can be made through recycling of this valuable resource.

Some of the techniques described in this section also allow for metals to be recovered from waste streams. However, metal recovery can be in conflict with source reduction efforts. Firstly, the goal of source reduction is to have low drag-out concentrations, however many of the metal recovery technologies perform best when concentrations are high. Secondly recovery technologies result in additional wastes such as spent filters, membranes, cathodes and resins etc.

Therefore operators should consider carefully the technical feasibility, the full environmental impacts and quality implications before investing in recovery systems. They may prove to be only feasible for those waste streams that are expensive to dispose of and which have high replacement cost.

Example 7: Zero wastewater discharge system at Southern Maine Industries Corporation

By installing zero wastewater discharge / closed-loop systems in its new facility, Southern Maine Industries (SMI) realised the following benefits:

- 99% reduction in water purchasing;
- Elimination of wastewater discharges;
- Significant reduction in hazardous waste generation;
- Reuse of 760 litres of drag-out per day.

This clearly demonstrates the principle of zero discharge processes in metal finishing operations.

The wastewater treatment system cost approximately $US160,000 to install. Savings (mainly due to cost avoidance) were around $US100,000 giving a pay-back period of around 1.6 years.

Source: Maine Department of Environmental Protection

The Full Case Study is available in Section 3 - Case Study 27

Treating and recycling wastes to reclaim water or to recover the metals usually require capital investment in treatment system such as those described in this section. The types of recovery technologies that are in use in the US for this purpose are shown in Table 3. This information was gathered from a survey of 318 platers and reported in document profiling the US metal finishing industry prepared by WRITAR.

Table 3: Recovery technologies in use in the US.

Recovery Technology	% of businesses where it is in use
Ion exchange	25.0 %
Atmospheric evaporators	22.3 %
Electrowinning	19.0 %
Vacuum evaporators	7.2 %
Reverse osmosis	1.8 %
Electrodialysis	<1.0 %

Source: Waste Reduction Institute for Training and Applications Research (WRITAR), "Profile of the Metal Finishing Industry", 1997

Powder Coating operations are have significant potential to achieve minimal or zero discharges, as shown in the Case Study described in Example 12.

1.7.1 Electrolytic Recovery or Electrowinning

Electrolytic recovery captures metals in solution by plating them out on a thin starter sheet made of the metal to be recovered or a stainless steel blank, which serves as a cathode in the tank. The product of this process is a solid metallic slab, which can be reclaimed or used as an anode back in the plating tank. This technique requires rinse water segregation to prevent contamination of the anode with mixed metals.

The benefits of electrolytic recovery are shown below in Example 8. Other examples can be seen in Case Studies 2, 8 and 21 in Part 3.

Example 8: Electrolytic Recovery at Email

The Dorf Design division of Email Kitchen and Bathroom Products Pty Ltd has installed electrolytic recovery equipment to recover nickel and gold from the drag-out tanks, and chrome from the bright dipping process.

The total capital cost of these initiatives was $67,800 with annual savings of between $43,190 and $50,190. This represents a pay-back period of between 1.4 and 1.6 years.

The savings realised were largely from gold recovery ($15,000-$22,555), nickel recovery ($3,530), reduced sludge generation ($14,500, and reduced sodium metabisulphite usage for chrome treatment ($9,660).

Source: Victorian Environment Protection Authority
The Full Case Study is available in Section 3 - Case Study 9

1.7.2 Reverse osmosis

Reverse osmosis involves forcing liquid through a membrane which is impermeable to most dissolved salts, using a high pressure. Its advantages include the ability to process dilute solutions, to produce purified waste streams suitable for reuse, and lower energy requirements than evaporation systems. The purified water can be returned to the rinse tanks and the recovered metal salts are used to replenish the plating tank.

It is used most commonly to purify rinse water from acid nickel baths. It is not suitable for solutions with a high oxidation potential, such as chromic acid, and if organics are present it must be augmented with an activated charcoal filter.

Capital costs can average about $30,000 and annual operating costs are about 1/3 of capital costs. Examples of where reverse osmosis has been successfully applied are described in Case Study 25 in Part 3.

1.7.3 Ion exchange

Ion exchange removes both positively and negatively charged metal and chemical ions from the solution by passing the rinse water through resin beds. Once the bed has reached its capacity, the metals are recovered in concentrated solution and the resin is regenerated for reuse. The disadvantage of this technology is that it is a complex process requiring careful operation and maintenance, the wastestreams must be segregated in order to recover metals, and it generates an additional wastewater load from the regeneration and washing process. Capital costs can range from $5,000 to $500,000 and annual operating costs are about 25% to 50% of capital cost.

Examples of where Ion Exchange and other deionising systems have been successfully applied are described in Case Studies 1, 12, 19, 22, 24 and 25 in Part 3. A specific example is also shown in Example 9 below.

Example 9: Deionising Units at Cougar Lighting Co

Cougar Lighting Company investigated a proposal to implement a closed loop deionising unit to purify electroplating water. This unit is designed to recycle 85% to 90% of water, eliminating the flow of heavy metals and waste to sewer.

The expected savings and benefits of this system include:

- reduced annual water consumption from 2.6 million litres to 600,000 litres.
- about $8000 per year saved from reductions in water and chemicals used, and waste disposal, on a capital investment of $11,817.
- recycling of water leads to large savings in worker time on tedious wiping.

Source: EnviroNet Australia

The Full Case Study is available in Section 3 - Case Study 6

1.7.4 Electrodialysis

Electrodialysis is a membrane process whereby wastewater passes through an ion selective membrane system which removes both anions and cations. Electrodialysis can achieve higher concentrations than reverse osmosis or ion exchange, however it also recovers contaminants and fails to recover other important bath contents such as brighteners and additives. Capital costs can range from $10,000 to $50,000 with operating costs between 15% and 30% of investment.

1.8 Alternative processes

This section provides some examples of techniques which are alternatives to traditional metal finishing processes, and which can provide significant reductions in waste treatment costs. Examples of where these techniques have been successfully applied are described in Case Studies 3, 13 and 14 in Part 3.

1.8.1 Non-cyanide plating systems

Cyanide is widely used in the plating industry but its high toxicity requires that wastewaters containing cyanide need an additional treatment step of cyanide oxidation. Therefore changing to non-cyanide systems can result in cost savings of around 10% due to the savings at the wastewater treatment stage.

Zinc plating is the area in which the most success has been achieved in cyanide replacement, through the introduction of zinc chloride (acid) baths and zinc alkaline systems.

Zinc chloride (acid) baths are becoming widely accepted in the industry. As well as the obvious benefit of reduced wastewater treatment costs, they have the advantages of higher operating efficiencies, superb brightness and appearance, substantial energy savings through improved bath conductivity and less hydrogen embrittlement. To tolerate the acidic conditions, traditional steel tanks need to be lined or replaced, however the additional cost is off-set by the savings from reductions of waste treatment costs and safety hazards.

Zinc alkaline systems are the least expensive of all the zinc plating baths, can be used in traditional steel tanks and also produce good brightness. These systems do not tolerate variations in operating conditions and if operated outside the tight operating window, efficiency and quality can be affected. However zinc alkaline may prove to be the more feasible of the two non-cyanide systems because of the ease of changeover using existing tanks.

Technologies to replace other cyanide systems such as copper, brass, gold and silver exist but generally have not demonstrated the success rates that zinc cyanide replacements have.

There has been a perception that replacing cyanide solutions with non-cyanide solutions requires upgrading degreasing and cleansing techniques, as non-cyanide solutions requires a thoroughly cleaned surface to ensure high quality plating. However the tolerance of non-cyanide systems has improved greatly since their initial introduction.

Example 10: Conversion to Alkaline Non-Cyanide Zinc Plating at CP Plating, Brisbane.

CP Plating has replaced the cyanide system because of the costs and hazards associated with the use of cyanide plant processes high volumes of steel for zinc plating in lengths up to six meters. The process line is typical for the industry with an electrocleaner, hydrochloric acid pickles(2), caustic desmutter, and two zinc plating tanks. One of the zinc tanks is an acid chloride (potassium chloride) and the other was a cyanide solution (50 g/l cyanide), which has since been replaced with an alkaline zinc solution. The process and rinse tanks are approximately 12,000 litres and the plating tanks are 22,000 litres.

The following is a summary of the company's experiences in changing from a zinc cyanide process to an alkaline zinc process.

- The zinc alkaline system was preferred because it could be accommodated in the existing unlined steel cyanide tank. The use of acid chloride solutions would require a new acid resistant tank.
- Since the major constituent of the alkaline zinc solution is caustic soda, it is simple and comparatively cheap.
- It is extremely expensive to dispose of the old cyanide solution (approximately $2.50 per litre) and in this situation, the volume to be disposed of was beyond the capacity of the treatment facility.
- It was necessary to provide a dissolution tank for the zinc metal since zinc metal is not placed directly in the plating tank as in cyanide and other processes.
- As the process is slightly more temperature sensitive, additional cooling capacity was also needed.
- Since the efficiency of the alkaline bath is significantly lower than for cyanide, there is increased mist generation, resulting in greater need for mist control chemicals, which has been significant.
- This lower efficiency does lead to a significant savings. Due to better resulting distribution, there is a reduction in zinc metal usage as the deposit is far more uniform.
- Effluent treatment cost is also lower as there is no cyanide to destroy and the costly biannual decarbonating is no longer required.

While it is too early for the company to provide detailed costing, it appears that there has been an overall reduction in plating operating cost.

Source: Chris Burgess, CP Plating

Example 11: Electrophoretic Plating at Gainsborough Hardware Industries

Gainsborough Hardware Industries used conventional electroplating processes to provide surface finishes on their range of door furniture.

The popular gold finish required the use of gold cyanide plating solutions, with the subsequent problems of specialised waste treatment.

Gainsborough replaced the gold cyanide system with an electrophoretic plating process, which has achieved savings of the order of $54,000 per annum from reduced waste disposal and trade waste costs.

Source: EnviroNet Australia

The Full Case Study is available in Section 3 - Case Study 10

1.8.2 Replacing hexavalent chromium with trivalent chromium in chrome plating

Use of trivalent chromium as a substitute for hexavalent chromium has a number of advantages:

- eliminates the health risk from exposure to hexavalent chrome,
- less sludge is created in the plating tanks,
- eliminates the step of reducing hexavalent chromium to trivalent chromium in the wastewater treatment,
- drag-out is reduced because the solution is also less viscous than hexavalent chromium and bath concentration is much lower, and
- trivalent chrome uses the same equipment making it a "drop-in" replacement.

Plating thickness with trivalent chrome is limited to 0.003 mm; thicker coatings exhibit cracking and other quality problems. Thus the technique is usually unsuitable for hard chromium coatings, which may be 0.508 mm or more in thickness.

In the United States substitution with trivalent chromium has been slow because the plating quality is considered lower than using hexavalent chromium. Automobile manufacturers continue to demand the high quality, high-gloss finish that hexavalent chromium delivers. (USAEP, 1997). However in applications which do not require very high quality chrome finishes, this substitution could be considered.

Colour tones of trivalent chromium coatings are different from those of hexavalent chromium, however additives to the trivalent chromium bath can often correct the difference.

1.8.3 Electroless Plating Bath Life Extension

Electroless plating is a form of plating that does not rely on electrical current to force metals to plate out, instead it relies on the natural differences in electric potential of metals.

The main problem associated with this process is that bath solutions become contaminated with by-products of the chemical reaction. The by-products interfere with the plating process causing a decrease in bath efficiency over time. Once the solution becomes inefficient, it is generally dumped and replaced with fresh solution.

From a Cleaner Production perspective, this form of plating does not appear to be a favourable alternative, due to the limited life of the bath and the requirement to dispose of the spent solution. However in those instances where it used, the process can be improved by extending the life of the solution through the addition of chemicals, generally reducing agents such as hypophosphate. The reducing agents force the bath to become unstable causing the contaminants to plate out, usually onto steel wool. It has been reported that this can potentially increase the life of an bath up to tenfold and reduce the volume of waste generated by up to 90%. (USAEP).

Electroless plating has very limited application in Queensland and therefore life extension technology is not expected to be greatly in demand.

Example 12: Closed Loop / Zero Discharge Spray Booth System for Powder Coating Operations

Carramar Lighting are looking to implement a closed loop / zero discharge spray booth system for their powder coating operation. The innovative system will allow the operator to rack individual lengths of shaped aluminium (instead of 40 or 50 lengths) for pretreatment and powder. A three-way valve redirects the alkaline cleaner, rinse water and chromate/phosphate back to the original separate holding tanks.

This system is expected to cost $80,000 and will save around $9,000 a year. The pay-back period is around 9 years.

Source: EnviroNet Australia

The Full Case Study is available in Section 3 - Case Study 4

1.9 Wastewater Treatment

According to the Cleaner Production philosophy, treatment and disposal of waste should be considered as the very last option once all opportunities for avoidance, reduction and recycling have been exhausted.

For the metal finishing industry however it is appreciated that some waste will be generated even when significant gains have been made to avoid and reduce the volumes. This is particularly the case for wastewaters which generally require treatment prior to being discharged to the council sewage system.

Some Queensland operators that generate wastewaters have managed to avoid the requirement to have a wastewater treatment system. This could be because of their small size or because they manage to meet discharge limits without treatment. However, with ever tightening discharge limits it will become more difficult to avoid the requirement to treat wastewaters.

For those operators who are facing the probability of having to install a wastewater treatment system, you should first consider all the options for reducing wastes discussed in previous sections of this guide before deciding on the treatment system that is best for your operation. In this way you may be able to defer the need to have a treatment system, or you may be able to reduce the size of plant for your reduced waste stream.

Most operators in Queensland employ a neutralisation and precipitation process to remove metals from the wastewater, resulting in the formation of a sludge which is transported to a suitably licenced faciltiy as a hazardous waste.

The costs of treating wastewaters and disposing of the resulting sludge is quite expensive. In Queensland the current disposal cost for sludge to a licenced treatment facility is $260 - 280/tonne. Add to this the transport costs, and the total cost for disposal can be thousands of dollars a year.

As well as paying to dispose of sludge from the treatment process, there are also charges for discharging the treated effluent to sewer, through Trade Waste charges. Currently sewer discharge fees in Queensland are based on the volume of effluent discharged. However in other States, charged are calculated based on load of contaminants (such as metals) as well as volume. This form of charging may well be introduced into Queensland in the future, which means that there would be potential savings to be made by reducing metals in the effluent.

It is therefore worth investigating ways to improve treatment to get the best value out of your treatment dollar, and this section provides a few ideas.

1.9.1 Waste Segregation

Segregation of waste streams from the different plating lines will greatly improve the ultimate treatment efficiency. Each stream is treated separately to precipitate or neutralise the problem contaminant before being recombined for discharge. If all the waste streams are treated together, the different contaminants can interfere with each other.

For example always keep nickel solutions away from cyanide and ammonium solutions. Nickel chelates with cyanide and ammonia, making precipitation of the nickel from the wastewater stream very difficult.

Example 13: Stream Segregation at Medford Plastics

Medford Plastics Company found that their treatment system was not successfully reducing the nickel concentrations from their plating line wastewaters. At that time, wastewater from all their plating lines (copper, nickel and chromium) were combined before treatment.

Segregating the electroless nickel before the treatment phase allowed the company to treat this stream separately and effectively meet council regulations.

Stream segregation is becoming a significant trend in the industry and is critical to reducing the costs of treatment and is also providing greater opportunities for reuse and recycling.

The Full Case Study is available in Section 3 - Case Study 17

Other examples of approaches to wastewater treatment systems are also described in Case Studies in Part 3.

1.9.2 Batch treatment versus continuous treatment

Small operations tend to have batch treatment system in place because they have smaller volumes of wastewater to treat, and can contain it in the treatment tanks. However some larger operations have used continuous treatment to avoid the large storage capacity that would be required for a batch process.

Batch treatment processes should be used wherever possible because it gives much greater control over the treated wastewater discharged to sewer. With a batch process, each batch is monitored and if acceptable, is discharged. This batch by batch check is not possible with a continuous process and so it is not possible to guarantee that the treated wastewater is within discharge limits because it will have been discharged.

1.9.3 Improving precipitation processes

The sludge that is produced from wastewater treatment at most metal finishing operations must be disposed to a licenced treatment or disposal facility, because the metals contained in the sludge can leach from the sludge and cause pollution problems. Brisbane City Council and licenced treatment facilities require sludges to pass leachability standards (referred to as TCLP (toxicity characteristic leaching procedure) and to be dewatered before being disposed to a licenced secure landfill. Leachability standards for landfills across the state vary depending on the type of landfill (lined or unlined) and the conditions imposed by the licensing authority. If the leachability is within the standard, it can generally be disposed to a secure (lined) landfill. If it is outside the standard, it must be treated at a licenced treatment facility, at significantly greater cost.

There are a number of products on the market which can improve the leachability of the sludge. These products use magnesium oxide in place of the traditional pH adjusting agents such as caustic soda. As well as adjusting the pH to promote the precipitation of the metals, the magnesium also chelates with the metals, fixing them in the sludge.

The example below demonstrates how these products can be used to greatly reduce the cost of sludge disposal.

Example 14: Reduced Sludge Disposal at CP Plating.

CP Plating has started using a magnesium oxide based product in its treatment plant to precipitate the metals from the wastewater.

Prior to changing to the product, the company was sending the sludge to a treatment facility at a cost of $260-280/tonne. Using the magnesium oxide product, the company can now send its sludge to a secure landfill and only pay $42 / tonne in charges.

As well as this, the company now dries the sludge and has thereby reduced the weight of sludge disposed from 30 tonnes to 10 tonnes per year.

The total combined savings from using the magnesium oxide product and drying the sludge are as follows:

Before the changes:	30 tonne / yr @ $260 / tonne	**$7,800/yr**
After the changes:	10 tonne / yr @ $42 / tonne	**$ 420/yr**

Note that these figures do not include transport costs which have also reduced significantly.

Source: Chris Burgess, CP Plating

1.10 Innovative New Technologies

This section provides a brief discussion about clean technologies that have been identified from literature sources, mainly from the United States. Although these technologies may not have found their way to Australia yet, they have been proven as viable technologies elsewhere, and are therefore worthy of consideration.

Clean technologies are manufacturing processes or technologies that reduce pollution or waste, energy use, or material use in comparison to the technologies that they replace.

1.10.1 Sulphuric / Boric Acid Anodising (SBAA)

The SBAA process is a direct replacement for the chromic acid anodising process used on aluminium production pieces. The SBAA process consists of a sulphuric / boric acid anodising bath and a chromate sealer bath. The SBAA process contains a small amount of chromium in a separate sealer bath in which the parts are dipped after the SBAA process. The rinse waters still contain metals and acids that must be pre-treated, but the overall level of chromium needing treatment is much less than conventional means. Therefore SBAA offers a significant reduction in the treatment of chromic acid, as well as a reduction in toxic air emissions from the chromium plating. SBAA operating costs are similar to existing chromium plating operations. In the United States, reduction in allowed chromium levels are expected to make SBAA a more prevalent alternative to conventional anodising in the next 5-10 years. (USAEP)

1.10.2 Electrodialysis Technologies for Bath Solutions

Electrodialysis is a process that maintains a low metal ion concentration in the anodising bath solution by transporting metal ions with an electrical current and capturing them where they collect as a concentrated sludge.

When anodising aluminium for example, bath solution must be changed and disposed of when the aluminium concentration reaches 80 - 100 grams/litre. Electrodialysis technologies can extend indefinitely the useful life of the anodising bath solution, and allows the metals to be reclaimed and reused. Additionally, controlling the metal ion concentration in the anodising solution improves the production quality. The sludge must be removed from the unit and the cathode changed on a regular basis to ensure effective metal removal.

In the United States, most companies have been slow to accept this technology due to moderately high capital costs for equipment, but also because locating companies that will recover and reclaim metals from the sludge has proved difficult. As disposal costs increase, electrodialysis will prove more economically feasible. (USAEP)

1.10.3 High Velocity Oxy-Fuel (HVOF) Thermal Spray Technology

High Velocity Oxy-Fuel spray technology is a dry process that produces a dense metallic coating. It uses a fuel/oxygen mixture in a combustion chamber, where the metal powder is melted and continually fed into a gun using a carrier gas (argon) and propelled at high speed at the item being coated. The metal powder is available in many compositions, including nickel, chrome carbide, and tungsten carbide. Uniform coating thicknesses of up to 0.25 inches can be achieved.

This process produces a dense metallic coating whose physical properties are equal to or surpass those of hard chrome plating with hexavalent chromium. The only waste stream produced is overspray, and this is currently dealt with using a water curtain filter system or a particulate air filter. Since the overspray contains only pure metal or alloy, it is feasible to reclaim it as a raw material.

In the United States, HVOF is steadily gaining acceptance and the pay-back period has been estimated to be 2-4 years, depending on the size of the operation. (USAEP)

1.10.4 Ion Vapour Deposition

Ion Vapour Deposition (IVD) is an evaporative process that gradually builds a film onto metal surfaces, and is an alternative to electroplating. It is most suited to decorative-coating and tool coating.

The key benefit of the technology as an alternative to electroplating is that it virtually eliminates all rinse waters. One limitation however is that the coatings do not work well where lubrication is required, therefore would not be a good choice for fastener parts. It also has limited success in applications that involve coating annular-shaped objects.

Despite the limitations, IVD technologies are expected to continue to replace aqueous plating operations in the United States. (USAEP, 1977)

1.10.5 Electrolytic Recovery for Metal Cyanide Recycling

Wastewater generated from the rinsing of metal cyanide-plated parts contains metals and cyanide-containing compounds. These waste streams require pretreatment prior to disposal, typically with hazardous chemicals, including acids, alkalis, and chlorine-containing chemicals. Electrolytic recovery technology uses and electrical current to plate out the metals and oxidise the cyanide in the rinse waters.

The metal is recovered from the electrolytic recovery unit (ERU) as a foil that can be returned to the cyanide bath as an anode source, and cyanides are partially oxidised to cyanates. These systems can remove more than 90% of metal ions and oxidise up to 50% of the cyanides.

Since these systems run in a batch mode, few process changes are required, and the pay-back period is estimated to be 2 years for an operation that generates more than 1,000 kilolitres per year.

Electrolytic recovery is only feasible for highly concentrated metal wastewaters, as removal efficiency decreases as concentration decreases. Typically, it has not been widely used in the industry in the United States, but has been used to recover the more valuable metal (silver and gold).

2. The Future of Metal Finishing

Like most developed countries, Australia will continue to face stringent environmental controls, and the development and adoption of new and innovative 'Clean Technologies' will be necessary to ensure that the industry can achieve the current and pending discharge limitations.

In the United States, environmental concerns have been the primary driving force for research and development in this industry. Material suppliers are aggressively pursuing alternative technologies, and cyanide, cadmium and hexavalent chrome alternatives are receiving most attention. (WRITA, 1997)

Literature from the United States has predicted trends in clean technology advancement for the short, medium and long term future.

Short term trend: Growth in Powder Coating

Powder coating is likely to be an increasingly popular finishing technology for years to come. It has already made major inroads into liquid coating markets and has penetrated traditional decorative plating markets as well. Advances in powder technology and delivery systems continue to open up new applications. The desirability of powder coating is based on the near elimination of water wastestreams and VOC releases as well as superior materials use efficiency.

Medium term trend: Expansion of Physical and Chemical Vapour Deposition

Vapour deposition technologies are "dry" finishing processes for metal plating. Several technologies are currently available to transport metals in a vapour state to a part to achieve a solid metal coating. It is currently limited to very specific, high-tech applications, however future developments to accommodate larger parts and higher production rates hold the promise for a substantial reduction in water wastestreams in metal finishing operations.

Long term trend: Next Generation Technologies

Advances in material science will one day allow for the finishing of parts by radically different methods, or reduce the need for finishing through alternative substrates. Four classes of emerging technologies are:

- non-aqueous liquid baths which use solutions other than water (eg. alcohol)
- physical bonding where metals are deposited through physical rather than electrochemical means
- "nanotechnologies" which is the use of laser technology to place metals onto surfaces
- alternative substrates such as ceramics and plastics which reduce the need for metal finishing

3. Conclusions

This project has demonstrated several facets of the Cleaner Production conundrum in the metal finishing industry in Queensland.

Firstly, there is a considerable amount of scope for implementing Cleaner Production ideas in the industry, despite or because of the small scale of operations here.

Secondly, the industry is hungry for information about the options available and the viability of the different options.

Thirdly, the industry has the capacity and the will to work with regulators to solve problems and save money.

Fourthly, there is a plethora of information globally about this industry and the environmental considerations which is being transferred to our State.

In conclusion, it appears the industry here is little different from that in other states and many other countries. There is a tremendous set of drivers for environmental change, for enhanced compliance, for better occupational health and safety and for improved quality. Cleaner Production can bring about financial savings, enhanced compliance and better quality products. There are the gains to be made, and not at a great price.