PART 1: BACKGROUND

1. Metal Finishing Industry in Queensland

The metal finishing industry in Queensland is concentrated in Brisbane and South East Queensland, with only a handful of businesses operating out of other major centres such as Bundaberg, Maryborough, Toowoomba, Cairns, Gladstone and Townsville. It is estimated that there are approximately 130 businesses in the South East Queensland region, and roughly 20 in other areas.

The industry consists principally of galvanising, electroplating, powder coating and anodising operations. The most numerous of these are powder coaters, followed by electroplating businesses. In comparison, galvanising is only represented by a small number of businesses, but has the largest production capacity of all the industry sectors. Similarly, the anodising industry is dominated by a small number of businesses (see Table 1).

Table 1: Number of metal finishing businesses and approximate production capacity in Queensland

Industry Type	Approx. number of business in Brisbane region	Relative scale of production (1 - 10)
Powder coating	100	4
Electroplating	20	10
Anodising	5	4
Galvanising	4	10

* A relative scale of production has been provided in the absence of production data.

There is very limited information about the profile of the metal finishing industry in Australia, however very comprehensive statistical information is available for the US, and is considered to be strongly indicative of the industry in Australia. This information, which is presented over leaf has been quoted directly from a document titled "Profile of the Metal Finishing Industry", prepared by the Waste Reduction Institute for Training and Application Research.

Profile of the United States Metal Finishing Industry

The metal finishing industry is a highly fragmented group of relatively small companies. Most companies are comprised of a single facility. The number of metal plating and related facilities decreased 4.3% over a ten year period from 1982 to 1992, while coating and related facilities increased 19.5% over the same period.

A 1993 report on environment and competitiveness in the metal finishing industry notes that only 10-15% of the companies in the industry are job shops. Most metal finishing activities occur in captive shops within larger manufacturing operations. Industries such as furniture and fixtures, primary metals industries, machinery, fabricated metal products, electrical and electronic equipment, and transportation equipment are particularly dependent on metal finishing and may have at least a portion of their metal finishing accomplished "in-house".

Equipment use data for plating operations generated by the survey showed that 37.4% of respondents used barrel plating, 30.9% were rack only, 27.6% had both types of operations, and 4.1% were reel to reel. The survey also reported that 16.7% of shops used automatic hoist, 40.7% used manual hoist, 25.7% were handline operations, 8.7% return type, and 4.1% side arm.

The regulatory framework has been the primary force in the gradual decline of classes of metal finishing like cyanide based systems and cadmium plating and will continue to create "winners and losers" in metal finishing. The result is often a renewed interest in new applications of older process technologies which, for example has been a positive for the nickel plating industry. Likewise technical advances in powder coating technologies have not only captured painting segments but also resulted in inroads into a number of decorative plating markets as well.

The seven most commonly operated plating processes are shown in Table 1. Note that many experts believe that the non-cyanide and cyanide treatments have been under-reported in this survey. A typical job shop operating cost breakdown is shown in Table 2.

Table 1

Plating type	% of shops using
Nickel	42 %
Non-cyanide zinc	39 %
Copper cyanide	38 %
Cadmium cyanide	30 %
Electroless nickel	30 %
Decorative chrome	29 %
Tin acid plating	27 %

Table 2

Operating area	% of total costs
Labour	28.0 %
Materials	14.4 %
Environmental	5.1 %
Health & safety	2.5 %
Overhead and profit	50.0 %

Source: Waste Reduction Institute for Training and Application Research.

2. Waste Generated from the Industry

Like most industry sectors, the metal finishing industry generates wastes which have the potential for human and environmental harm. A summary of the common wastestreams generated by the industry, and their sources, is provided in Table 2.

Table 2: Summary of wastes generated from the Metal Finishing Industry in Queensland.

Waste Type	Source
Air emissions	
Mists containing metals and acids	All finishing activities
Particulates	Metal polishing, pyrolysis, powder coating
Fumes	Acids / alkalis
Volatile organic compounds (VOC)	Solvents, paint strippers
Liquid wastes	
Wastewaters containing metals, cyanide and process chemicals	Rinsing, equipment cleaning, spills
Acids (nitric, sulphuric, hydrochloric, hydrofluoric)	Acid cleaners, pickling, etching, bright dipping
Alkalis	Caustic cleaners, etching solutions
Plating solutions containing metals (cadmium, zinc, nickel, copper, chromium)	Contaminated plating solutions which are no longer efficient
Ion exchange resin reagents	Demineralisation of process water
Solid wastes	
Precipitated metal sludges	Wastewater treatment
Filters and filter sludges	Filtering of cleaning and plating solutions
Oily / greasy rags	Pre-cleaning
Metal polishing residues	Polishing of metals prior to plating
Paint residues	Powder coating
Packaging and general wastes	

For an electroplating shop, for example, the major proportion of environmental management costs is spent on the wastewater treatment system. The cost of treatment chemicals can be over half the annual operating costs of the wastewater treatment systems, and the total annual operating costs for wastewater treatment is often one half or more of the original capital cost of the system. (WRITAR)

As a result, the emphasis of this manual is on liquid waste generation, as it is an area where the most significant economic and environmental gains can be made be made.

2.1 Air emissions

Air emissions from metal finishing activities mainly consist of two classes: volatile substances, referred to as Volatile Organic Compounds (VOC), which evaporate to atmosphere and contribute to overall air pollution, and fine dust mists that contain cyanide, acids, metals, ammonia and overspray from aerosols. These are also emissions of particulates from ovens and other processes.

In the local vicinity these emissions may place pressure on the air quality, particularly in a city such as Brisbane which is experiencing and will continue to experience rapid growth and expansion of industrial activities. It is therefore important that individual businesses attempt to reduce air emissions as much as possible so that the combined effects of industry as a whole do not push air pollution beyond tolerable thresholds.

2.2 Wastewaters Discharged to Sewer (Trade Waste)

Of the 130 or so metal finishing businesses in the Brisbane region, approximately 60 discharge wastewater to the sewer under Trade Waste Agreements with the Brisbane City Council. Small powder coating operations do not generate wastewater as a rule, and therefore account for the remaining 70 or so businesses.

The volume of the wastewater discharged to sewage systems from this industry in SE Queensland is estimated to be 90,000 kilolitres per month. In comparison with many other industry sectors, the volume of wastewater produced by metal finishing industries is generally small (Tay, 1993). However the wastewater can potentially be highly toxic in nature because of the presence of heavy metals such as Copper, Nickel, Zinc, Cadmium, Chromium and Cyanides.

The heavy metals contained in industrial wastewater cause problems downstream at sewage treatment plants for a number of reasons. Firstly, they are not easily removed from the wastewater stream and will be present in the effluent that is discharged to waterways, possibly causing adverse impacts on aquatic life. Secondly, heavy metals can inhibit the biological treatment processes at the sewage treatment plant, reducing the treatment efficiency of the plant. Finally, heavy metals tend to accumulate in sewage sludges, greatly reducing the reuse options for the sludge, such as composting for use as a soil improver or for use in mine site rehabilitation.

The sludges then become a liability for council and the community rather than an asset.

To control the amount of metals entering the sewage treatment system, councils impose acceptance standards for heavy metal concentrations and daily mass loads. The concentration limit for metals commonly discharged from metal finishing operations (Chromium, Copper, Nickel and Zinc) in Brisbane is currently 10mg/l and daily mass loads vary between 30 - 75 g/day depending on the metal. It is anticipated that these limits will become tighter in the future as the ability to dispose of metal contaminated sludges becomes even more difficult. Most premises currently rely on pre-treatment to remove metals to acceptable levels prior to discharge.

Information currently available suggests that a significant proportion of metals discharged to treatment plants (STPs) in industrial areas of SE Queensland originates from metal finishing industries. Table 3 shows the approximate percentages of metal loads that are attributed to metal finishing discharges.

Therefore attempts by the industry to reduce the mass loads of metals discharged to sewer will have a very significant impact on the levels of metals discharged to STPs, and hence to the environment.

Table 3: Percentage of total loads of metal discharges to STPs that are attributed to metal finishing

Metals	Proportion of total industrial waste stream from the industry (%)
Cadmium	1.5%
Chromium	44.9%
Copper	45.3%
Lead	4.4%
Nickel	72.0%
Zinc	43.3%

2.3 Hazardous Liquid Wastes

Other more hazardous liquid wastes that cannot be discharged to the sewer are also generated from the industry. They are regarded as hazardous because they are either toxic, accumulate in the environment or because they do not readily biodegrade and require special treatment prior to disposal. Treatment often involves neutralisation and/or fixation to render them inert. The types and volumes of hazardous liquid wastes generated from the industry are shown in Table 4 and the trend in generation over the last 4 years is shown in Figure 1. Please note that the figures contained in Table 3 are indicative only as the volumes also include wastes associated with painting activities associated with steel and pipe fabrication.

Table 4: Types and volumes of hazardous liquid waste generated by metal finishing industries in Brisbane.

Type of Liquid Waste (Willawong treatment class)	Volume generated from metal Finishing industry (KL / year) [1]	Percentage of this waste stream which originated from the metal finishing sector (%)
Acid / Alkali / Metal wastes (Class 4)	1920	33 %
Galvanising acids (Class 7H)**	1199	75 %
Soluble heavy metal wastes, eg.Chromate (Class 7A)	321	36%
Solids requiring treatment (Class 7K)	219	7%
Soluble oils (Class 7J)	173	5%
Other * (Class 7X)	95	3 %
Oily wastes containing phenol (Class 7I)	21	9 %
Cyanide wastes (Class 7B)	2	data not available

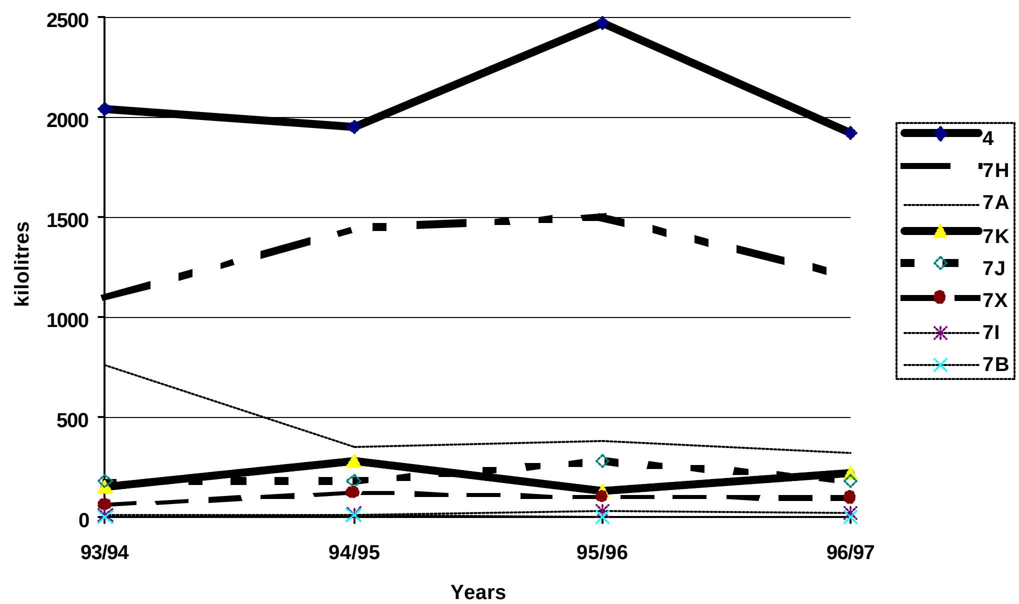
* Class 7X consists of Classes 4 & 7A but are charged at a higher rate

** Large volumes also sent to Sydney

[1] Figures for 1996/7 period

Acid / alkali / metal wastes are generally acidic or alkaline (caustic) cleaning solutions which have metal concentrations greater than the limits allowable for other categories. Chromate and cyanide bearing solutions are generally spent plating solutions. Galvanising acids are hydrochloric acids containing metal residues from the galvanising process. Soluble oils are generally lubricants that are used in metal cutting, drilling and polishing etc and phenols are preservatives often contained in oils. Solids requiring treatment are generally thick sludges containing heavy metals.

Figure 1: Trend in hazardous liquid waste generation from the metal finishing industry between 1993 and 1996.



Key

4	Acid / Alklali / Metal wastes	7J	Soluble oils
7H	Galvanising Acid	7X	Other
7A	Soluble heavy metals	7I	Phenols
7K	Solids requiring treatment	7B	Cyanide

The volume reduction in Class 4 wastes in 1996/97 was due to efforts by a major discharger to meet new discharge standards. The drop in Class 7A wastes in the years following 1993/94 was due to the strategy of a major discharger to concentrate its waste.

Galvanising generates the largest volume of hazardous liquid waste (principally acid), but is represented by only a small number of operators. In comparison, electroplating accounts for a larger proportion of the operations in the Brisbane region but collectively produces a lower quantity of liquid wastes. However, the wastes generated by this sector are more hazardous, containing various heavy metals which may cause a problem downstream at the sewage treatment plants. It should also be considered that the metal content in these wastes is potentially quite a valuable commodity.

The metal finishing industry accounts for a significant proportion of some of the hazardous liquid wastes streams collected in SE Queensland, particularly galvanising acids (75%), acid/alkali/metal wastes (36%) and soluble heavy metal wastes (36%). Therefore attempts by the industry to reduce the volumes generated will have a noticeable impact on volumes generated for the region as a whole.

2.4 Hazards to Human Health and to the Environment

Many of the chemical substances and metals used and handled in the industry are hazardous, both for workers and for the environment. There is a wealth of information available on the effects of these substances on humans, and a summary is provided in Table 5.

In the environment, all metals are present in trace quantities and are in fact essential for life processes, however if they are present in larger quantities, they are toxic. Metals, being elements, cannot be metabolised, so if they enter a waterway they accumulate to levels which are toxic to aquatic life. As a result, governments place very strict standards on the maximum levels of metals permitted to be discharged. Substances of particular concern in the metal finishing industry are chromium and cyanide, and these are discussed further below.

Chromium

One of the major concerns in the metal finishing industry has been the use of chromium. Hexavalent chromium has been widely used in the industry because of its finishing qualities. However, it is extremely toxic and a known carcinogen. Trivalent chromium is naturally occurring whereas the hexavalent form is generally produced by industrial processes (ATSDR, 1989). Trivalent chromium compounds are considerably less toxic than the hexavalent compounds and are neither irritating nor corrosive.

The trivalent chromium process has been available for 20 years and is considered less toxic and more environmentally friendly because of the lower toxicity of trivalent chromium and the lower content of chromium in the plating solution. Over the last few years, several competitive plating processes based on trivalent chromium have been developed. Some of these processes yield a deposit that more closely resembles the plating produced by a hexavalent solution, albeit at a slightly higher cost and requiring more careful control of plating conditions (OECA, 1994).

Cyanide

Exposure to large amounts of all forms of cyanide, either by touching, breathing or ingesting, can harm the brain, lungs, and heart, and cause coma and death.

In terms of environmental harm, the free cyanide found in electroplating wastewater is one of the most toxic contaminants in the industry.

Consequently, there is a trend away from the use of cyanide, and much research has been undertaken into the development of non-cyanide processes. Non-cyanide zinc is an example of a replacement technology that has successfully replaced cyanide based processes, however, there are still a number of metals (e.g silver, brass, bronze) where viable alternatives are unavailable. (EPA, 1997).

Table 5: Health impacts of substances used in the Metal Finishing Industry

Substance	Potential Impacts
Chromium Compounds	Health Rating = 4 (Extreme - Cancer Causing) * Hexavalent chromium compounds are corrosive and cause chronic ulceration and perforation of the nasal septum when inhaled. They also cause chronic ulceration of other skin surfaces. Trivalent chromium compounds are naturally occurring and are considerably less toxic than the hexavalent compounds and are neither irritating nor corrosive. Chromium will convert from hexavalent to trivalent form naturally over a long period of time in the presence of organic matter. Chromium is non-volatile and is very insoluble in water. Therefore, is spilled on land is tends to stay in the top five centimetres. Chromium is highly persistent in water, with a half-life of greater than 200 days. It is toxic to plants at concentrations higher than 0.2 to 0.4 percent. The Chronic Aquatic Toxicity Limit for chromium is 1 ppm. In water chromium is typically present in particulate form as sediment. Chromium can bio-accumulate in plants and animals. Acute toxic effects (those seen two to four days after contact) may include the death of animals, birds, or fish, and death or low growth rate in plants. Chromium is more toxic in soft water than in hard water. Chromium (VI) has high acute toxicity to aquatic life, and chromium (III) has moderate acute toxicity to aquatic life. Chronic toxic effects may include shortened lifespan, reproductive problems, lower fertility, and changes in appearance or behaviour. Chromium (III) and chromium (VI) both have high chronic toxicity to aquatic life. Chromic acid has been found to retard the digestion process at sewage treatment plants are relatively low concentrations (5 ppm).

Table 5: Health impacts of substances used in the Metal Finishing Industry

Substance	Potential Impacts
Cyanide Compounds	Health Rating = 3 (Severe - Poison) * The main cyanide compounds used in the metal finishing industry include copper-, potassium-, silver-, hydrogen- and zinc-cyanide. Common symptoms of cyanide poisoning are rapid, deep breathing and shortness of breath, followed by convulsions and loss of consciousness. In cases of acute cyanide poisoning, death is extremely rapid. Exposure to small amounts of cyanide compounds over long periods of time is reported to cause loss of appetite, headache, weakness, nausea, dizziness, and symptoms of irritation of the upper respiratory tract and eyes. Cyanide compounds are practically insoluble in water or dilute acid. Most cyanide compounds are toxic of aquatic at relatively low concentrations species and can bio-accumulate. Chronic Aquatic Toxicity Limits vary for the different compounds - potassium (.72 ppm) and hydrogen (2ppb).There is no evidence to suggest the compounds are carcinogenic.
Zinc	Health Rating = 3 (Severe)* Inhalation of zinc oxide is common in occupational exposures and can produce serious injury to the respiratory system upon direct contact. Inhalation of zinc chloride can result in coughing, chest pain, and respiratory tract irritation. Death can result from acute high dose inhalation of zinc chloride smoke. Significant zinc contamination of soil is only seen in the vicinity of industrial point sources. Zinc is a relatively stable soft metal, though burns in air. The two factors that influence Zn toxicity are water hardness and pH. Acute toxic effects may include the death of animals, birds, or fish, and death or low growth rate in plants. Zinc and its salts have high acute toxicity to aquatic life. Chronic toxic effects may include shortened life-span, reproductive problems, lower fertility, and changes in appearance or behaviour. Zinc and its salts have high chronic toxicity to aquatic life. Zinc and its salts are highly persistent in water, with half-lives greater than 200 days. Zinc bio-accumulates and the concentration of zinc found in fish tissues is typically considerably higher than the average concentration of zinc in the water from which the fish was taken.
Nickel	Health Rating = 3 (Severe - Cancer Causing)*

Table 5: Health impacts of substances used in the Metal Finishing Industry

Substance	Potential Impacts
	Dust may cause headache, coughing, dizziness or difficult breathing. Prolonged exposure may cause dermatitis. Ingestion may cause nausea, vomiting, headaches, dizziness, gastrointestinal irritation. Nickel and its compounds are highly persistent in water, with half-lives greater than 200 days. Nickel is one of the most common metals occurring in surface waters. It occurs naturally in surface waters from the weathering of rocks. Acute toxic effects may include the death of animals, birds, or fish, and death or low growth rate in plants. Water hardness affects nickel toxicity to aquatic organisms - the softer the water, the higher the toxicity. Nickel and its compounds have high acute toxicity to aquatic life. Chronic toxic effects may include shortened lifespan, reproductive problems, lower fertility, and changes in appearance or behaviour. Nickel and its compounds have high chronic toxicity to aquatic life.
Copper	Health Rating = 3 (Severe) * Dust may cause sneezing and coughing and may irritate skin or eyes. Prolonged exposure may cause dermatitis. Ingestion may cause nausea, vomiting, headaches, dizziness, gastrointestinal irritation. Chronic toxic effects may include shortened lifespan, reproductive problems, lower fertility, and changes in appearance or behaviour. Copper is highly persistent in water, with a half-life greater than 200 days and does bio-accumulate. Concentrations found in fish tissues tend to be considerably higher than the average concentration of copper in the water from which the fish was taken.

Table 5: Health impacts of substances used in the Metal Finishing Industry

Substance	Potential Impacts
Hydrochloric Acid	Health Rating = 3 (Severe - Poison) * Inhalation of vapours may cause coughing and difficult breathing, pulmonary edema, circulatory system collapse, damage to upper respiratory system, collapse. Liquid may cause severe burns to skin and eyes. Ingestion is harmful and may be fatal; may cause severe burning of mouth and stomach and may cause nausea and vomiting. Releases of hydrochloric acid to soil or water will be neutralised to a certain extent by the buffering capacities of both systems. Spills to waterways of high concentrations may adversely affect aquatic life. Acute toxic effects may include the death of animals, birds, or fish, and death or low growth rate in plants. It has slight acute toxicity to aquatic life. Chronic toxic effects may include shortened life-span, reproductive problems, lower fertility, and changes in appearance or behaviour. It has slight chronic toxicity to aquatic life. Hydrochloric acid does not tend to bio-accumulate.
Hydrofluoric Acid	Health Rating = 4 (Extreme - Poison) * Vapours may be irritating to skin, eyes, nose and throat. Inhalation of vapours may cause severe irritation or burns of the respiratory system, pulmonary edema, or lung inflammation. Liquid and vapour cause severe burns which may not be immediately painful or visible. Substance is readily absorbed through skin, penetrating skin to attack underlying tissues and bone. Ingestion may cause severe burns to mouth, throat, and stomach. It may have adverse effect on kidney function and may be fatal. Chronic effects of exposure may include hypocalcemia, bone and joint changes.
Sulfuric Acid	Health Rating = 3 (Severe - Poison) * Inhalation of vapours may cause severe irritation of the respiratory system. Liquid may cause severe burns to skin and eyes. Ingestion is harmful and may be fatal. Ingestion may cause nausea and vomiting; may cause severe burns to mouth, throat, and stomach; and may have adverse effect on kidney function and may be fatal. Chronic overexposure may result in lung damage. Environmental effects are similar to those of hydrochloric acid.

Table 5: Health impacts of substances used in the Metal Finishing Industry

Substance	Potential Impacts
Sodium Hydroxide	Health Rating = 3 (Severe - Poison) * Excessive inhalation of dust is irritating and may be severely damaging to respiratory passages and/or lungs. Contact with skin or eyes may cause severe irritation or burns. Ingestion is harmful; may be fatal or cause severe burning of mouth and stomach or cause nausea and vomiting. Acute toxic effects may include the death of animals, birds, or fish, and death or low growth rate in plants. Sodium Hydroxide has high acute toxicity to aquatic life. Chronic toxic effects may include shortened life span, reproductive problems, lower fertility, and changes in appearance or behaviour.

* Baker SAF-T-DATA(TM) Health Rating Scheme

Sources: Environmental Health Center, Howard Hughes Medical Institute and the National Academy of Sciences, University of Utah Department of Chemistry, MSDS, ICI Chemical Fact Sheet, OPPT Chemical Fact Sheets, USEPA Sector Notebooks, Hazardous Substances Data Bank (HSDB), University of Virginia Office of Recycling and Environmental Information.

Prager J (ed.) Dangerous Property of Industrial Materials Report

2.5 Is Waste Inevitable?

Advances in wastewater treatment and the ever-increasing costs of waste disposal have lead to the development of near "zero-discharge" processes. In developing processes to attain zero discharge, the production process, rinse steps and chemicals are no longer chosen for their technical or economic performance alone but with regard to their capacity for recycling. (Hong Kong Productivity Council)

It should be noted that the term "zero discharge" is an ideal goal. Although significant gains can be made to eliminate or decrease volumes of wastewater, material mass balances still dictate that process residuals such as sludges will require management and possibly off-site disposal. (USEPA, 1997).

For Queensland, the development of near zero discharge may be uneconomic for most operators at this time, even if the technical know-how were available. However, the concept will become increasingly attractive as full cost recovery for water and waste disposal are introduced and as technologies for reuse and recycling become more widely available and economically attractive.

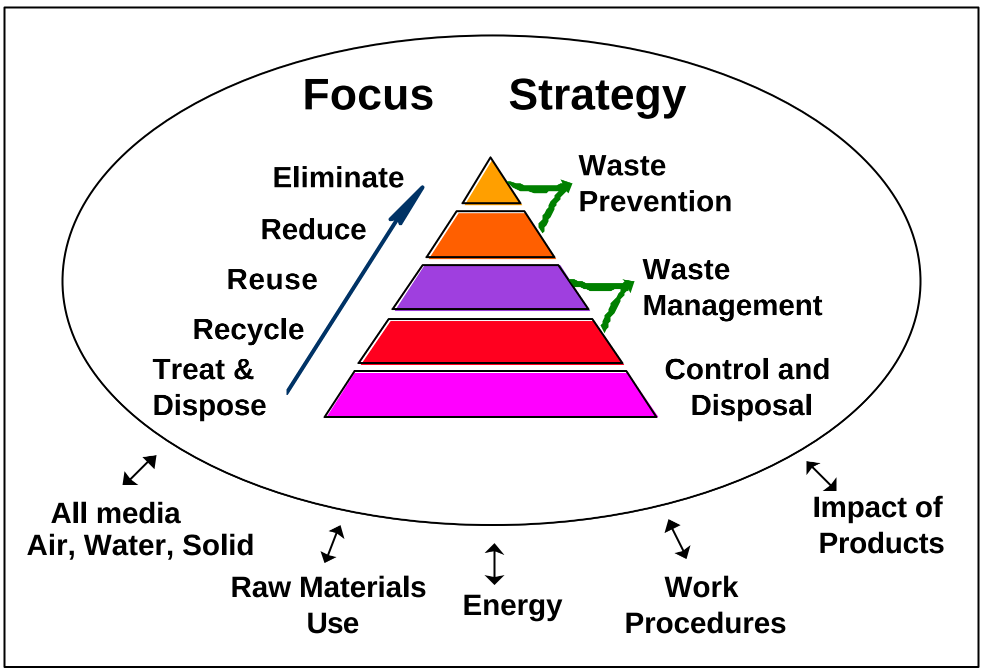
3. What is Cleaner Production & What are Its Benefits?

Cleaner Production focuses on eliminating waste and inefficiency at their source, rather than finding 'end-of-pipe' solutions once the wastes have been generated. It involves rethinking conventional methods to achieve 'smarter' production processes and products to achieve sustainable production.

In adopting the Cleaner Production approach, try to consider how wastes can be avoided in the first place rather than focusing on how to manage or treat them once they have been generated.

Waste avoidance and reduction should be considered as the first options. Once all avoidance and reduction options have been eliminated, then options for on-site reuse and recycling can be considered. Only as a last resort should treatment and disposal options be considered. This approach is depicted in the Cleaner Production Hierarchy shown in Figure 2.

Figure 2: The Cleaner Production Hierarchy



Cleaner Production has been the major environmental initiative for industries in the 1990's. Thousands of manufacturing companies, including the metal finishing industry, in both developed and developing countries, have taken up Cleaner Production approaches to manufacturing.

In the United States, where perhaps the most significant Cleaner Production efforts have been made, it has been reported that environmental performance has a significant effect on the competitive dynamics within the industry (WRITAR). Firms that are able to keep up with compliance demands and accommodate increased costs of operation can be expected to reap some benefits from increased out sourcing activity and transferred business from defunct shops.

The term "Cleaner Production" may not mean much to individual businesses in Queensland, but there are many Australian businesses that have profited from Cleaner Production (case studies are provided in Part 3).

3.1 Saving money

Cleaner Production can save money; money which would have otherwise been spent on wasted resources, waste treatment, disposal and compliance costs.

Cleaner Production strategies typically cost less than treatment and disposal (so called 'end-of-pipe') technologies. Complying with the emission limits established by government through on-site treatment can be a significant cost; may require specialist knowledge and attention, and generally provide no profit for the organisation.

Many strategies, such as general housekeeping and process improvements can be implemented at low cost and can have immediate benefits, up to 30% in some cases. Substantial process modifications or technology changes will require capital investment, however numerous case studies demonstrate that pay-back periods can be as little as months to 2 years.

3.2 Preventing pollution

Pollution prevention by reducing energy, water and resource consumption and minimising waste is at the core of Cleaner Production. With the emphasis on reducing waste at the source rather than controlling pollution after it has been generated with 'end-of-the-pipe' solutions, many pollution problems can be eliminated.

3.3 Complying with environmental legislation

Working toward Cleaner Production will greatly assist in complying with stricter environmental legislation, bringing the benefits of reduced liability, reduced regulation, reduced monitoring costs, potentially reduced licensing charges and better control over your business.

Environmental regulations and standards are becoming tighter and more comprehensive and this trend is expected to continue in the future. In addition to licensing requirements under Queensland's Environmental Protection Act, 1994, the Environmental Protection (Waste Management) Policy (currently in draft form) includes the requirement for nominated industries to implement a Cleaner Production plan.

4. Related Environmental Legislation

Under Queensland's Environmental Protection Act (EP Act), a person carrying out an activity that could cause harm to the environment has a General Environmental Duty to conduct that activity so that harm does not occur. The EP Act includes provisions for licensing of activities and enforcement.

The EP Act is supported by a number of Environmental Protection Policies (EPP). An EPP for Waste Management is currently being prepared, and will embrace the waste management hierarchy, which forms the basis of Cleaner Production. The proposed Policy includes the provision that under certain circumstances a business may be required to prepare a Cleaner Production Plan. Table 6 contains the type of information that must be included in Cleaner Production Plans.

Table 6: Contents of a Cleaner Production Plan

A Cleaner Production Plan must contain details of:	A Cleaner Production Plan may need to address other issues such as:
• Current waste management practices; • Material, energy and resource inputs; • Material, waste and energy outputs; • Impacts of the production process on environmental values; • Opportunities and actions to be taken to avoid and reduce waste (including toxicity, energy and water); • Opportunities and actions to be taken to recycle wastes; • Recommendations of any life cycle assessment conducted; • Targets and goals; • Program of action and timeframes; • Any certified or approved quality assurance or environmental management system or standard; • Monitoring and reporting program.	• input substitution—replacing an input with a non-hazardous or less hazardous substance; and/or • product reformulation—substituting an alternative end product which is non-hazardous or less hazardous upon use, release or disposal; and/or • production process modification—upgrading or replacing existing production process equipment and methods with other equipment and methods, and/or • improved operation and maintenance of production process equipment and methods—modifying or adding to existing equipment or methods; and/or • closed-loop recycling—recycling or extended use of substances which become an integral part of the production process.

5. Process Descriptions

5.1 Electroplating

Electroplating is a electrolytic process where one metal is surface coated with another by electrodeposition. Electroplating activities involve applying predominantly inorganic coatings onto surfaces to provide corrosion resistance, hardness, wear resistance, anti-frictional characteristics, electrical or thermal conductivity, or decoration. The most commonly electroplated metals and alloys include brass (copper-zinc), cadmium, chromium, copper, gold, nickel, silver, tin, and zinc. (OECA, 1995). A basic representation of the electroplating process is depicted in Figure 3.

The first step in the process is to strip contaminants (oils, greases, soils etc.) from the metal surface. Aluminum and steel, two of the most common base metals, go through two different types of stripping processes. Steel can be dipped in hot caustic soda while aluminum surfaces must be cleaned with either acid or epoxy strippers since caustic is very corrosive to aluminum.

Depending on the piece of work, some buffing or preliminary polishing may be necessary. The base metal is normally dipped in a pickling solution as a final cleaning step. There are a variety of acid dips that can be used:

- Single Acid: 50% nitric acid at room temperature
- Double Acid: 15% sulfuric acid for 2 minutes at 82°C, a rinse, and then dipped in a 50% Nitric acid solution
- Mixed Acid: 75% nitric acid with 25% hydrofluoric acid

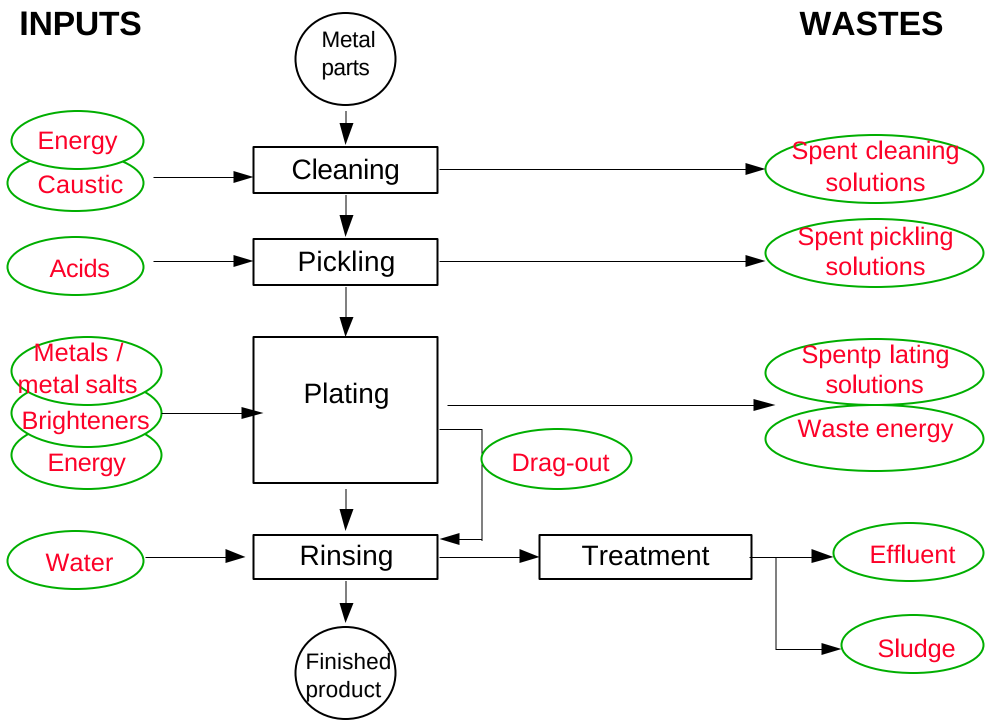
Steel may also be placed in a reverse current electro-cleaning tank to remove oxygen and any remaining oil, grease or dirt.

The base metal can be initially plated with a thin film of copper (copper strike), which serves as a good corrosion inhibitor and provides a better surface for the subsequent nickel layer.

The piece is then dipped in an electrolytic bath containing nickel sulphate solution and nickel anodes, with the piece to be plated acting as the cathode. Nickel provides the "jacket" that gives most of the corrosion protection and accounts for most of the finish and brightness. The thickness of the plating depends on the strength of the current and the time that the piece is immersed in the bath.

After rinsing with water, the piece is then placed in an chromic acid bath to be plated with chrome. The energy efficiency of chrome deposition from a chromic acid solution is poor, and therefore chrome plating is energy intensive.

Figure 3: Process for electroplating showing inputs and wastes



5.2 Galvanising

The galvanising process is the non-electrolytic coating of prepared steel surfaces with zinc. Galvanizing provides the highest quality corrosion protection for steel of all major coating techniques. In the galvanising process the metal is alloyed to the substrate. Therefore, the zinc coat will not peel off like a paint offering a permanent protection for the substrate.

The first step is hot caustic degreasing to remove surface contaminants. Then the parts are placed in a pickling bath (sulfuric or hydrochloric acid) to remove mill scale, rust and other surface contaminants. The parts are rinsed to remove any remaining pickling solution.

The part can then be immersed in a preflux 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 for up to two hours before galvanising.

The prepared items are then immersed in molten zinc, maintained at about 450^{o}C, producing a uniform coating of zinc and zinc-iron alloy layers.

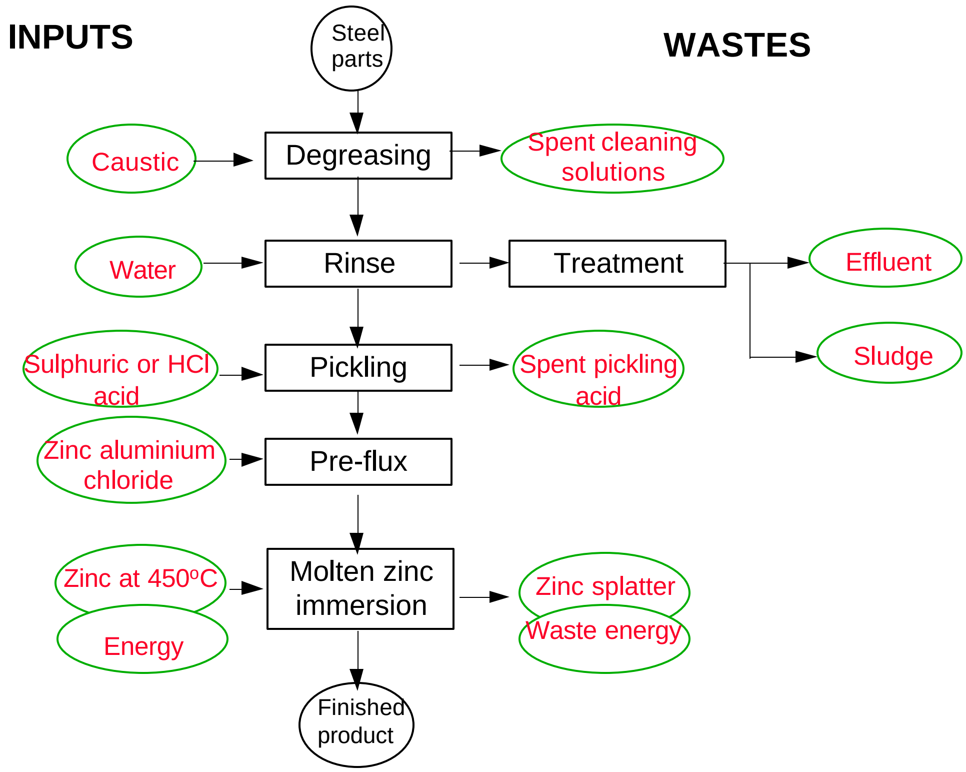
Alternative processes involve a combined flux / galvanising bath which has a layer of molten zinc ammonium chloride floating on top of the molten zinc, and electrolytic galvanising is also used widely.

This galvanising process is typically only suitable for large, simple structures. Small holes of ornate surfaces tend to get filled with zinc slag. In-line centrifuge galvanising processes spin off excess zinc, enabling the quality of smaller parts to be significantly enhanced.

As well as zinc splatter, a major waste product from the zinc bath is zinc oxide which forms rapidly on the surface of the bath. This oxide layer must be skimmed off before items are withdrawn from the bath to avoid staining and ash deposits. This can be a problem for items that must be removed slowly as this oxide layer tends to re-form and stick to the surface of the work.

Without proper safety precautions, galvanising can present risks to operations. As parts are dipped into the 450^{o}C bath the zinc tends to react violently creating significant amounts of 'zinc splatter'. The air in any cavities heats up extremely rapidly and can create massive pressure. Without proper vent holes the product can be blown apart. Also zinc can temporally fill the ends of tubes and as the pressure builds the material can be 'shot like a cannon'. Without proper guards the process can lose significant amounts of zinc and be dangerous to operators. If operators have to evacuate the process area during dipping this can have a major impact on productivity.

Figure 4: Process for galvanising showing inputs and wastes



5.3 Anodising

Anodising is an electrolytic process which converts aluminium surfaces to an insoluble oxide coating. Like electroplating, anodising is an electrolytic process, except that the item being treated is the anode rather than the cathode in the electrolytic bath. The anodic process creates a thick protective oxide layer on the item.

Aluminum is a reactive metal which naturally oxidises in air. This oxide layer protects the metal from further oxidation. The layer is unstable and easily scraped off leading to further oxidation. Unlike natural oxidation, anodising forms a particularly structured and dense oxide layer which resists abrasion and thus protects the underlying metal. The layer is colorless but pigment can be added at a specific stage in the process to permanently color the surface.

Anodising is most suitable for aluminium because the resulting aluminium oxide (Al_2O_3) layer is durable and shares many similar physical properties to elemental aluminium. Anodised coatings on aluminium provide corrosion protection, a decorative matt finish and a base for painting and other coating processes.

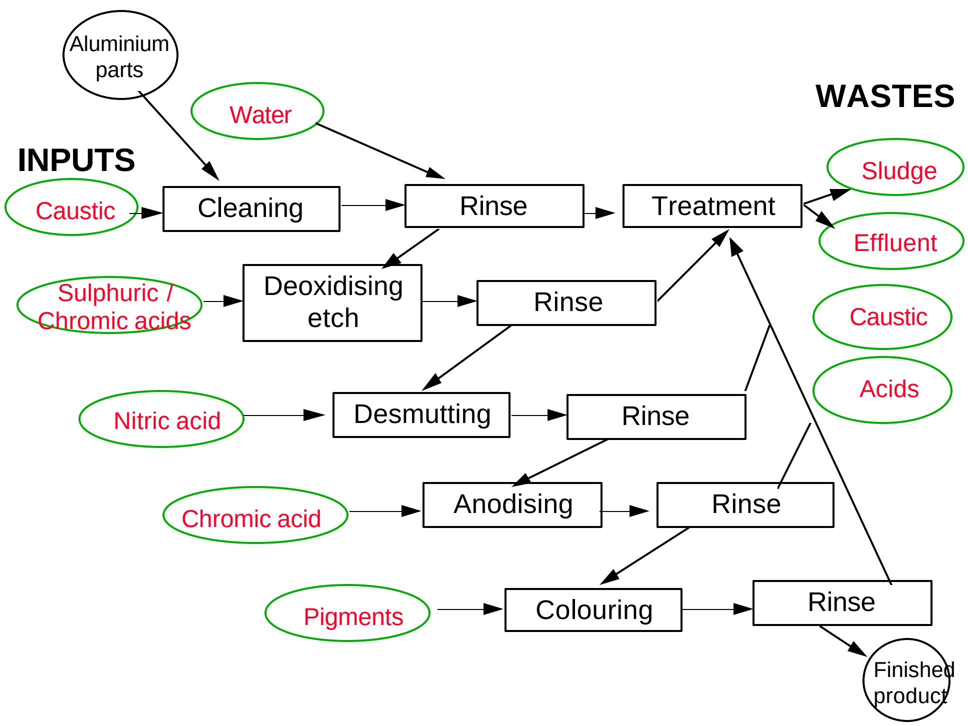
The first stage of the anodising process is the removal of oils and greases, typically with a non-etching, alkaline soak cleaner. The item is then immersed in a deoxidising etch solution containing 16% H_2SO_4 and 3% CrO_3 at 70-80°C for 2 - 5 minutes. This removes any oxide film, and permits the anodising process to occur uniformly.

The next step in the process is desmutting, where the item is immersed in a 50% nitric acid solution for 5 to 30 seconds at room temperature to remove etch smut or any siliceous material from the aluminium surface.

The actual anodising step is performed in an electrolyte solution containing 3-10% chromic acid at approximately 35 °C. Sulphuric acid and boric-sulphuric acid solutions can also be used. A low voltage (5 V) is applied at first to minimise current surge and the possibility of burning parts. The voltage is then raised gradually during the next 5 minutes to 40 Volts and held constant for 30 minutes.

After the anodising step, the oxide layer is sealed in a chromic acid solution at a pH of 5. Sealing may also be performed in a 5% sodium or potassium dichromate solution.

Figure 5: Process for anodising showing inputs and wastes



5.4 Powder coating

Powder coating involves the application of a dry resin to coat items. There are two common categories of resins, thermoplastic resins and thermoset films. Thermoplastic resins are those that form a coating but do not undergo a change in molecular structure (i.e. polyethylene, polypropylene, nylon, polyvinylchloride, and thermoplastic polyester). Thermoset films crosslink to form a permanent film that withstands heat and cannot be remelted (i.e. epoxies, hybrids, urethane polyesters, acrylics, triglycidyl isocyanurate (TGIC) polyesters) (EnviroSense, 1994).

Materials suitable for powder coatings include steel, aluminum, galvanized steel, magnesium, aluminum, zinc and brass castings. Powder coatings are used commercially for a wide range of small- to medium-sized metal parts, including lighting fixtures, equipment cabinets, outdoor furniture, shelving, and window fixtures (EnviroSense, 1994).

The coat is formed by spraying an electrostatically charged powder to the surface of the item, which is then heated, thereby melting the powder. Powder coatings are usually applied in a single coat.

Powder coating is increasing in popularity as a coating technology largely because is of the low emissions in comparison to other technologies. This is being driven by the increasing cost and time associated with compliance to environmental regulations. The major advantage of powder coatings is that it avoids the need for Volatile Organic Compounds. Therefore, expensive VOC destruction equipment such as incinerators or carbon absorbers is not required (EnviroSense, 1994).

The transfer efficiency of powder systems is significantly higher than solvent-borne or waterborne spraying. Any powder that does not adhere to an item can be collected and reused (EnviroSense, 1994). Compared to wet spraying techniques, electrostatic spraying achieves greater coverage of the substrate because the powder tends to "wrap" around corners and coat surfaces that are not "line-of-sight" with the spray gun.

Before powder is applied, the surface must be thoroughly cleaned, dried and enhanced. Enhancement is achieved with an acid wash or rinse. Typical pretreatment methods include sophisticated solvent cleaning systems, abrasive blasting or cleaning, and aqueous chemical cleaning. Pre-cleaning of the surface is typically more critical in powder coating processes than electroplating as there is no cleansing as part of coating process.

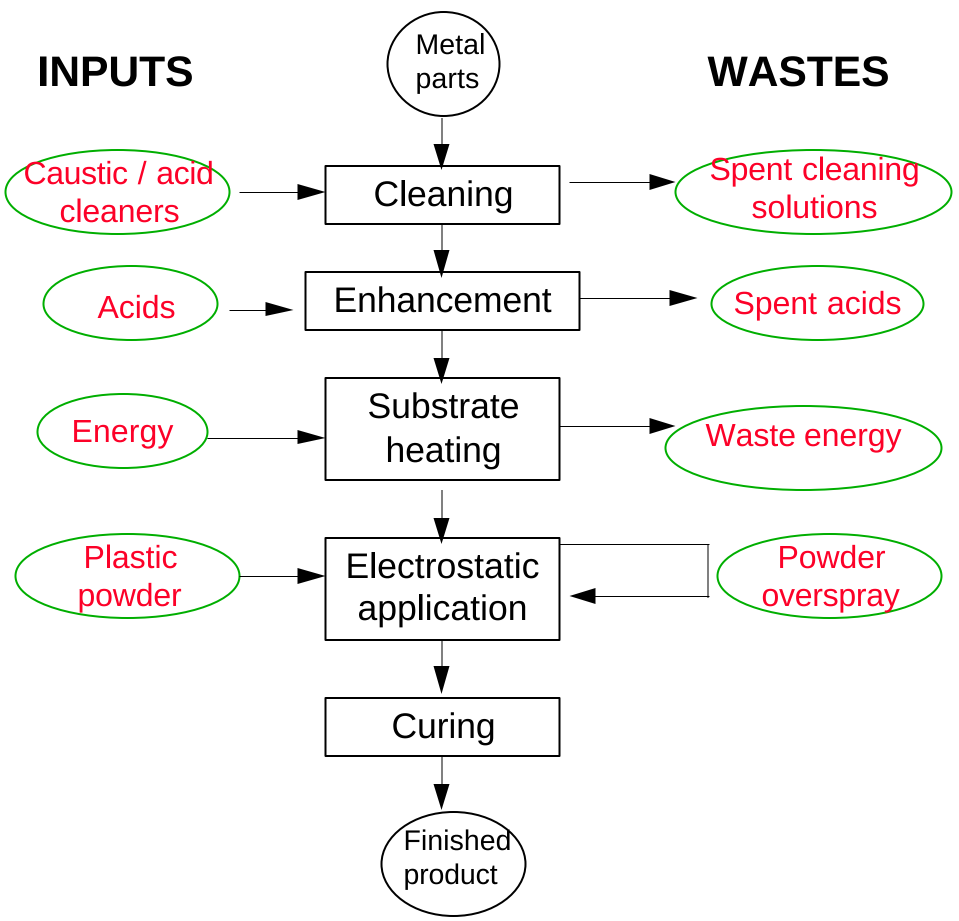
Many different thermoplastic resins are available for powder coatings, such as polyethylene, polypropylene, nylon, PVC and thermoplastic polyester. Thermoplastic resins are used principally as functional and protective coatings, rather than as an alternative to solvent-borne paints.

Thermoset resins can be ground into very fine powders and applied in thin film coatings, therefore producing a surface coating that is comparable to liquid coatings. There are five basic families of thermoset resins; epoxies, hybrids, urethane polyesters, acrylics, and triglycidyl isocyanurate (TGIC) polyesters.

Powder coating materials are typically more expensive than conventional coating materials on a volume basis. In many cases, however, the cost of producing a finished coating is lower, thereby offsetting the higher cost of the powder, particularly where thick coats are required (EnviroSense, 1994).

The major limitations of the use of powder coating include the need to heat the substrate to high temperatures (260 ^{o}C) to melt the powder; its applicability to metallic substrates only; the sizes of parts that can be placed in baking ovens and the ability to match colors from one batch to another and with other popular coatings (EnviroSense, 1994).

Figure 6: Process for powder coating



6. What Does Waste Cost

The table below shows the annual costs associated with waste generation and disposal for an electroplating business in Brisbane. It has been provided as an indication of the scale of money spend on waste in the metal finishing industry. It is expected that these costs will vary from one business to the next depending on the type of processes used, the scale of the business and the type of treatment and disposal used.

Table 7: Examples of annual waste costs for an electroplating business in Brisbane

Waste Type	Volume	Material cost	Treatment	Dispos-al	Trans-port	TOTAL
Spent cleaning solutions	13,000 l	$2,275	-	$3,200	$600	**$6,075**
Spent pickling solutions	22,000 l	$3,850	-	$4,750	$2,500	**$11,100**
Drag out / tank *	1,800 l	$3,960	included with effluent costs			**$3,960 / tank***
Waste-water	15,600 Kl	$9,360 (water)	$23,400	$14,000	-	**$47,000**
Sludge	30 T	-	-	$13,500	$2,800	**$16,300**

* This is a theoretical value. Refer to the discussion that follows for more detail.

The treatment and disposal of wastewater represents the most significant of these costs, and is an area where substantial gains can be made. The aspect of the electroplating process that has the most significant contribution to the requirement to treat wastewaters is drag-out from plating solutions. It is worthwhile therefore to appreciate the costs associated with drag-out.

The amount of drag-out generated depends on many factors including the size and shape of the pieces being plated, the temperature, density and viscosity of the plating solution as well as the drain time. As an example Hagler Bailly report that approximately 8 litres/day can be lost in drag-out from each tank. This equates to approximately 150 litres/month or 1,800 litres/year for each tank. It has been calculated that the chemical cost of losing 1 litre of plating solution will be at least $2.20 (W. Clarke). Therefore the chemical costs of drag-out from each tank are valued at approximately $330/month or $3,960/year, and for the case described above, it is possible that up to $100,000 could be spent on chemicals to replace that lost from drag-out. This is a theoretical amount only and has been provided as an indication.

The costs of waste for your business may be different to the figures in this table. As part of your businesses' Cleaner Production strategy the first and most important step is to gain an understanding of how much is being spent on the generation, treatment and disposal of wastes. The Self Assessment Guide contained in this Manual will help you do this.