

Industrial Processes & The Environment

(Handbook No. 1)

Metal Finishing - Electroplating



DEPARTMENT OF ENVIRONMENT
MINISTRY OF SCIENCE, TECHNOLOGY AND THE ENVIRONMENT, MALAYSIA



R 363.7 IND



1000002526
Industrial processes & the environment : (handbook no. 1) metal
finishing-electroplating / Department of Environment.

Metal Finishing-

Electroplating

UNIVERSITY NO.	0000020159
ACQUISITION NO.	1000002526
DATE	29-7-2005

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This handbook has been made possible with the generous support from DANCED, the Danish Cooperation for Environment and Development.

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Printed June 1999

FOREWORD

The overall goal of the Department of Environment is to ensure sustainable development, and in particular sustainable industrial development. This is not possible without a concerted effort from all parties concerned. Industrial enterprises are engaged in various industrial activities that may pollute the environment unless such activities are operated in an environmentally sound manner. In this connection, there need to be close consultation between the two parties so that the dual objectives of pollution control and of sustainable industrial development are achieved. Both parties must share their knowledge and engage in constructive dialogue on how to achieve compliance with the environmental regulations and standards.

Presently, the Department of Environment is embarking on an extensive training programme within the organization with respect to enforcement work. As an intergral part of this effort, DOE is also promoting an information-friendly approach with the individual enterprises. This stems from the realisation that policing should not be the only means to enforce the EQA, but should go hand in hand with a process of dialogue with the industries to bring about compliance.

The present Handbook has therefore been prepared with the dual purpose of supplementing the technical knowledge of DOE officers engaged in the inspection of industries, and providing some information on cleaner technology that may be of use to the individual enterprises.

Through this effort, it is hoped that the factory inspection visits can be carried out more effectively as well as with due consideration to helping the enterprises to comply with the regulations and standards.

The Handbook has been discussed extensively with industry representatives to ensure that the technical information and suggestions presented in the Handbook are both current and realistic. The implementation of recommendations for cleaner technology are expected to produce substantial savings for the industry. I therefore hope that this Handbook will be studied and used by both DOE inspection officers and the industry, thereby ensuring compliance in a cost-effective manner.

This Handbook is the first in a series of handbooks on the Industry and Environment that will be published by the DOE. This task could not have been undertaken without the generous support of the Danish Cooperation for Environment and Development (DANCED).



Hjh. Rosnani Ibarahim
Director General of the Environment, Malaysia.

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GLOSSARY

The following are definitions of the common terms used in this Handbook.

Buffing	:	Cleaning of the raw material to be plated by mechanical means, e.g. abrasive blasting or grinding
Busbar	:	A metallic bar which serves as a junction for incoming and outgoing electrical cables
Counter-current rinsing	:	A process in which fresh water is used only for the last rinsing tank - wherein the overflow from the last rinse is used for the earlier rinses
Drag-out	:	Drag-out is the plating solution which clings to the work items being plated during the transfer of the work items from one tank to another
Osmosis	:	The process of the flow of water through a semi-permeable membrane wherein the membrane will permit the passage of the water but not the dissolved substances
ODS	:	Ozone Depleting Substances
Passivation	:	A process to make the active material inert
SMI	:	Small and medium-scale industry
TCA	:	1,1,1- Trichloroethane

1.0 ABOUT THIS HANDBOOK

1.1 DEVELOPMENT OF TOOLS FOR ENFORCEMENT

Enforcement of the Environmental Quality Act 1974 and its subsidiary regulations is a core responsibility of DOE. Hence, there is a continuous need to strengthen and improve the effectiveness of the enforcement activities executed by DOE.

On this background, a manual on practical enforcement has been developed and more handbooks such as this are currently being developed to assist the DOE inspection officers in their enforcement activities. At present the following sectors have been selected to be covered by such handbooks:

- *Metal finishing-electroplating*
- *Raw natural rubber industry*
- *Palm oil industry*

The industry-specific Handbooks shall be seen as a supplement to the DOE Practical Enforcement Manual. The Manual will provide general advice on how to prepare, perform and follow-up on-site inspections. The industry specific handbooks will provide more detailed technical information on the production processes, the commonly experienced environmental problems and viable technical solutions.

More specific enforcement activities, such as conducting various kinds of sampling and prosecution will be covered by separate manuals and guidelines.

Training courses and training materials have been developed, as a supplement to the manuals, handbooks and guidelines.

1.2 OBJECTIVES OF THE HANDBOOK

This Handbook is meant specifically for the DOE inspection officers as a source of basic information on electroplating and related environmental issues.

The objective of the Handbook is to assist the inspection officers to:

- *Enhance the knowledge of common industrial processes*
- *Conduct on-site inspections more effectively*
- *Give advice to the industry on preventive and remedial measures in order to ensure a better environmental performance*

However, the Handbook may also serve as a tool for improving the flow of information between DOE and the owners and operators within the electroplating industry. In this way, it aims to :

- *Increase the awareness on environmental issues and potential impacts*
- *Change the attitude towards better compliance and housekeeping*
- *Highlight the advantages and opportunities of cleaner production and technologies*

1.3 STRUCTURE OF THE HANDBOOK

The first chapters (chapter 2 and 3) of the handbook will provide general information on the electroplating industry and its production processes.

Then the potential environmental impacts and other environmental issues of relevance for this industry will be explained (chapter 4).

Subsequently (chapter 5), the formal environmental requirements to this industry in terms of the EQA and its regulations will be highlighted.

To assist the inspection officer in his advisory function, the following sections (chapter 6 and 7) of the Handbook will deal with conventional pollution control practices and cleaner production issues.

Finally, as the conclusion of the information provided by the Handbook, the last chapter (chapter 8) will give the inspection officer advice on what to look for specifically during the inspection visit to ensure more effective inspection and enforcement.



2.0 ELECTROPLATING INDUSTRY OVERVIEW

The industry overview covers the:

- *current situation*
- *industry issues*

2.1 CURRENT SITUATION

The metal finishing industry in Malaysia :

- *on record consists of 385 small-medium scale establishments scattered around the country based on DOE 1997 Annual Report*
- *normally uses end-of-pipe treatment*
- *has a low compliance rate of 69% with the Industrial Effluents Regulations but a satisfactory compliance rate of 93% with the Clean Air Regulations (DOE 1997 Annual Report)*

There are 4 categories of metal-finishing, namely :

- electroplating
- electroless plating
- anodising
- coating

As mentioned earlier, this document focuses only on the first category i.e. electroplating.

2.2 INDUSTRY ISSUES

The electroplating industry is unique in that it consists mainly of a scattered distribution of numerous backyard factories. Most are small and medium scale industries engaged in plating component parts with heavy metals for supply to multi-national corporations. The industry produces waste and wastewater which contain large amounts of heavy metals. It has historically been problematic due to inability to comply with environmental and waste disposal regulations in that :

- *many fail to install treatment systems*
- *those that do are often found to have malfunctioning systems or inadequate treatment facilities thereby contaminating the waterways and land with their waste discharges*

Issues in pollution control that the industry is presently facing and which are likely to continue to be of concern facing in the coming years are :

- *Financial and Technical Constraints to Pollution Control*
- *Increased Tariffs to Encourage Pollution Control*

2.2.1 Financial and Technical Constraints To Pollution Control

The SMIs have cited various constraints standing in the way of implementing effective pollution control. These include a combination of the following :

- *unsuitable location*
- *lack of capital*
- *high cost of land for pollution control facilities*
- *high cost of treatment equipment and recurrent operating cost of treatment*
- *poor pay back period (time taken to recover capital expenditure through expected cost-savings)*
- *difficulty to access financing due to lack of collateral*
- *space limitation for pollution control facilities*
- *lack of awareness of available technologies*
- *lack of access to available technology*
- *inadequate waste management skills*
- *low priority of action on environmental protection compared to business investment*
- *lack of awareness of environmental regulations*

From a different viewpoint, it would appear that there is also a tendency for SMIs to resist :

- *change to new technology*
- *relocation to new areas with central wastewater treatment facilities*

2.2.2 Increased Tariffs to Encourage Pollution Control

It is well known that there is :

- *a close correlation between water consumption and wastewater discharged, and*
- *an indirect link between electricity consumption and pollution levels*

At the moment, the availability of public utility resources (water and electricity) is taken for granted as the tariffs are relatively low as shown below (Table 1). Without governmental intervention, factories have no reason to view the utility costs as part and parcel of their pollution control expenditure.

Table 1: Malaysian Water And Electricity Tariffs (1998)

Water Tariffs	Charges in sen		
Industrial	120 sen / m ³		
Electricity Tariffs	Charges in sen		
Industrial – medium voltage (i.e. SMIs)	19 sen / kwh	Peak period	(9am - 9pm)
	11 sen / kwh	Off-peak period	(9pm - 9am)
Industrial – high voltage (i.e. Factories)	18 sen / kwh	Peak period	(9am - 9pm)
	10 sen / kwh	Off-peak period	(9pm - 9am)

Up to now, Malaysia's approach to pollution control has been based on the Command and Control Approach wherein a "common set of standards" is applied to industries for pollution control. In this command and control approach, fines and penalties are imposed and in severe cases plant operations are suspended. However, pollution levels have not been reduced over the years and water is progressively becoming a scarce resource.

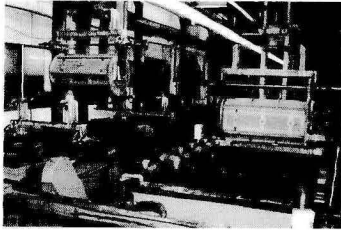
All these point to the possibility that the government may introduce increased tariffs to improve environmental quality, such as :

- *increased water and electricity tariffs (as is being done overseas in European countries for instance) to put pressure for better environmental performance by the industries*
- *higher effluent charges (known as environmental tax in overseas countries) to encourage better use of water*

As it is, for every manufacturing activity there is already a disposal cost attached. The increased tariffs, together with the existing waste disposal charges of Kualiti Alam, are expected to compel the electroplating industry in the long run to :

- *institute measures to decrease the volume of effluent*
- *treat wastewater and recycle it back to the plant*

In the final analysis, it is equally vital for industry to recognise and acknowledge that it is absolutely possible and important for pollution abatement and industrial expansion to co-exist side by side.



3.0 ELECTROPLATING PROCESS OVERVIEW

Electroplating is a process in which a thin coating of one metal (e.g. chromium) is electro-deposited from a plating solution onto the prepared surface of either :

- *a ferrous substrate material (e.g. bolts, nuts, screws, etc.), or*
- *a non-ferrous substrate material (e.g. plastic)*

The key process inputs and process outputs related to electroplating are as shown in Figure 1 :

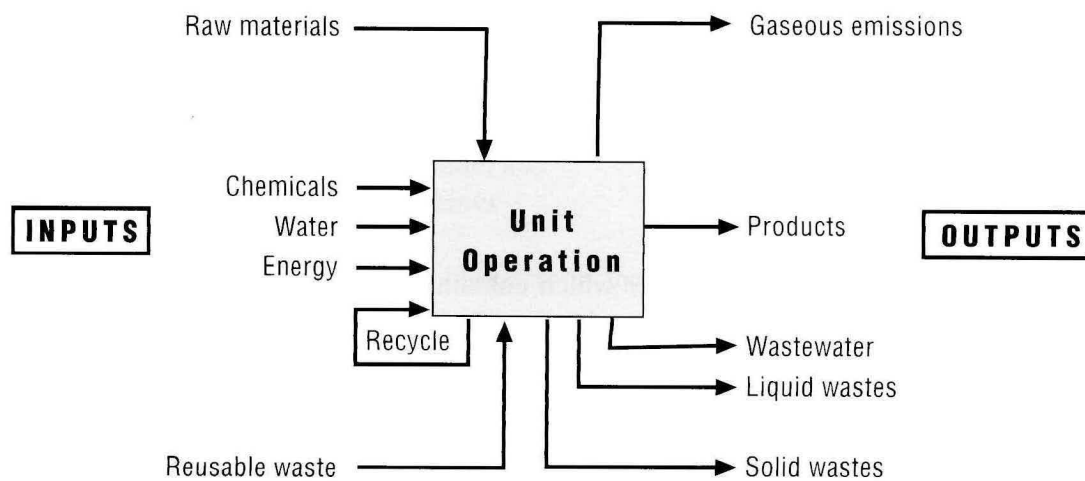


Figure 1 : Inputs and Outputs of an Electroplating Plant

3.1 PROCESS INPUTS

Raw Materials

A multitude of raw materials go into the electroplating process. These include :

- *items to be plated*
- *coating materials which are either :*
 - protective metals (e.g. nickel, chromium, copper, zinc or in combination), or
 - precious metals (e.g. gold, silver, platinum, palladium etc)

The others are materials used in the surface preparation and finishing activities which include :

- *cleansing chemicals (aqueous cleaners, acid and alkaline solvents), and*
- *metal salts (complexing agents in plating baths)*

Water

Water is used extensively in electroplating operations. It plays an active part in the preparation of chemical reagents for the plating baths, in cleaning and rinsing activities. The water comes mostly from the urban water mains, whereas the more progressive factories use de-ionised water by treating the urban water using their in-house water treatment plant.

Energy

Most factories do not produce their own power but obtain it from the national power supply network. Electricity is used for many of the automated operations related to the electroplating process, namely :

- *electro-chemical degreasing*
- *electro-deposition*
- *transferring of items to be rinsed/plated from one tank to another*
- *drying of finished plated items in ovens*
- *utility operations (pumps, air venting, etc.)*

In some plants, the hot processes use steam and thereby the consumption of energy in terms of heat has to be addressed separately.

3.2 PROCESS OUTPUTS

Electroplating produces waste streams in all three media : water, air and land. The key outputs in order of significance are :

Wastewater

The plating industry produces wastewater which contains large amounts of heavy metals. This comes mainly from

- *periodic dumping of highly contaminated spent process solutions containing high concentrations of residual process chemicals and metal constituents, if these are not regenerated and reused*
- *"drag-out" of chemicals (heavy metals) from one tank to another, from the rinsing operations. (Drag out are drips of chemical solution carried over when the items are transferred from one tank to another)*

Solid and Liquid Wastes

The introduction and subsequent disposal of fluids is a potential source of pollution once they outlive their usefulness. Typically, process solid waste streams result from excess substrate metal materials that are trimmed to prepare the items for plating or are metal component rejects and packaging materials. The liquid wastes are usually oil and grease, sludges from process tanks and spent bath solutions. Treatment of wastewater will also produce sludges. Dirty solvents will be produced by the degreasing process.

Air Emissions

Air emission from metal finishing consists mainly of aerosols and vapours. These come from the hot processes (i.e. solvent and plating bath and drying operations). Some dust is also produced during the buffing process.

3.3 ELECTROPLATING PROCESS

Within the electroplating category, there are a variety of specific electroplating processes. The more common of these are :

- *chromium plating*
- *copper plating*
- *nickel plating*
- *silver plating*
- *zinc plating*

Apart from using different coating substances and having different wastewater containing the associated coating substances, all these processes have many similarities. To be better acquainted with the various electroplating processes, it is best to look at the generic process first before getting to know the specific processes.

3.3.1 Generic Electroplating Process

The main features of the generic electroplating process are the :

- *electroplating system, and*
- *principal work steps*

a) Electroplating System

The electroplating system (see Figure 2 below) consists of :

- *a plating bath filled with water containing :*
 - a small amount of acid or alkali to improve its conductivity
 - metal salts
 - an anode (positive electrode)
 - a cathode (negative electrode) and
- *a series of cleansing/rinsing tanks*

The electroplating system essentially operates on the principle of passing an electric current through the water to cause the migration of :

- *positively charged particles (cations) towards the negative electrode (cathode), and*
- *negatively charged particles (anions) towards the positive electrode (anode)*

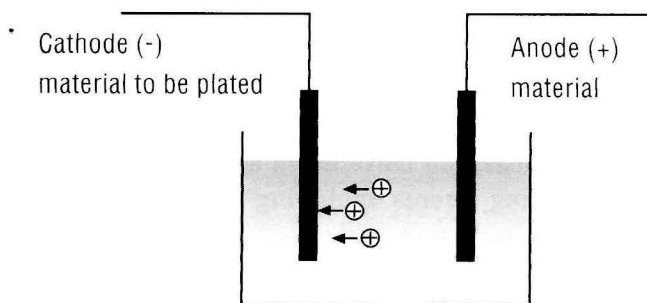


Figure 2 : Electroplating Bath Containing Metal Salts

The item to be coated is immersed in the bath solution as the cathode and the coating substance the anode. However, if an inert electrode is used as the anode, then the coating substance would be the metal salts in liquid form added to the solution. The metal salts subsequently dissociate into cations and anions which then deposit onto the items to be plated.

The process efficiency depends to some degree on the :

- *concentration of acid and alkali in the solution*
- *temperature and*
- *voltage applied across the electrodes*

b) Principal Work Steps

Electroplating operations may involve three (3) principal work steps. The principal work steps are :

- i) Surface Preparation / Pre-treatment; ii) Plating; and iii) Post-treatment

However, most electroplating operations are completed by the plating operation if the items do not require post-treatment. This is typical in Malaysia where there are 2 principal work steps.

However, for the sake of completeness, the typical work flow showing the three (3) principal work steps is presented in Figure 3. Of the principal steps in the electroplating process, the surface preparation/pre-treatment step is the main contributor to pollution.

i) Surface Preparation / Pre-treatment

The purpose is to prepare and clean the items for plating. The activities involved are as summarised below (Table 2).

Table 2 : Main Activities in Surface Preparation and Pre-Treatment

Main Activity	Stages	Operation	Involvement
Surface Preparation	1	Buffing	Smoothing or removal of surface deficiencies by scrapping
Pre-Treatment	2	Cleaning	Removal of oil, grease, dirt, scales from the surface of the items using solvents (often chlorinated hydrocarbons) & surface stripping agents (often alkaline and acid solutions)
	3	Rinsing	Removal of adherent solvent / alkali / acid using water flow

Surface preparation involves cleaning, degreasing and other steps to prepare the component or item for plating. Cleaning is usually accomplished in tanks using a variety of solvents (often chlorinated hydrocarbons), and surface stripping agents including strong alkaline and acid solutions.

The strong acids are mainly to remove oxides and other corrosion from the metal surface. The alkaline and acid dips are followed by rinsing which is performed in either flowing-water rinse tanks or in counterflow rinse tanks to conserve water.

Surface preparation may involve one or more of the following cleaning methods:

- *Vapour Degreasers* : The vapour of non-flammable organic solvents such as 1,1,1-trichloroethane (TCA) are used in closed system equipment to remove oil and grease adhering to the item surface.

Note : TCA should no longer be used under Malaysia's ODS phase out programme under the Montreal Protocol.

- *Di-phase Cleaning* : A two layer system of water soluble and water insoluble organic solvents is applied in the cleaning process by a similar method as vapour degreasing.
- *Alkaline Cleaning* : Alkaline cleaners commonly contain sodium hydroxide, sodium carbonate, sodium metasilicate, sodium phosphate, sodium tetraphosphate, sodium silicate, and wetting agents. Usually low concentrations occur in associated rinse waters. In some cases tanks may be periodically dumped and cleaned.

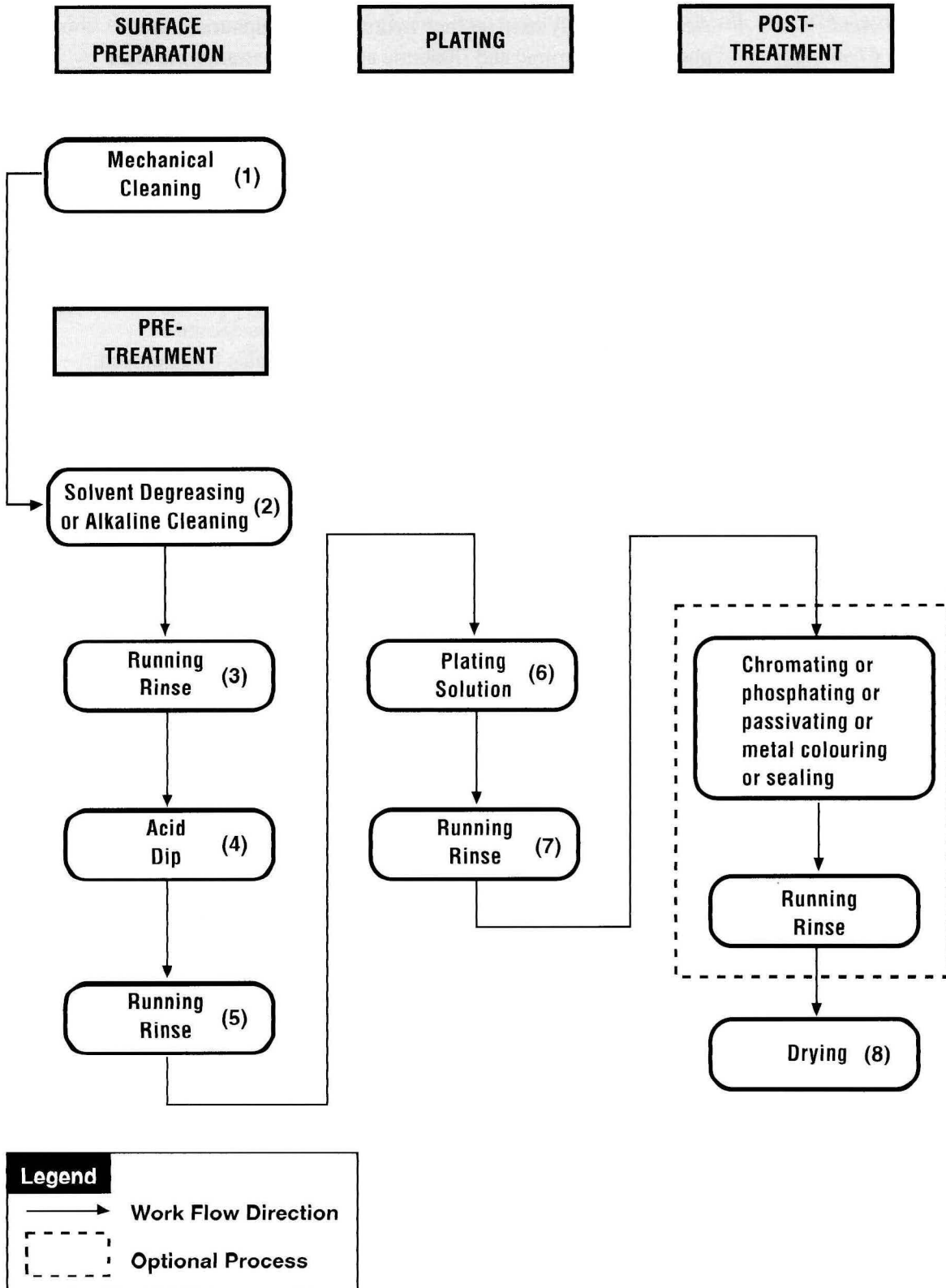


Figure 3 : Typical Work Flow In Electroplating Processes

Source: Industrial Wastewater Source Control: An inspection Guide By Nancy Riikonen and Clay Jones (Technomic Publishing Company, Inc.)

- *Acid Cleaning* : Acids commonly used include hydrochloric, sulphuric, nitric, phosphoric, chromic and fluoboric acid. Concentrations in rinse waters are often significant. Baths have a short life and are replaced or replenished frequently.
- *Emulsion Cleaning* : Common organic solvents are used in emulsions of various phase configurations.
- *Ultrasonic Cleaning* : A high cost, mechanical method using high frequency that does not produce waste.
- *Descaling* : A molten salt bath followed by water quenching and acid dipping is used for removal of difficult oxides as in the case of stainless steel and other corrosion-resistant materials. Specialised oxidising, reducing and electrolytic baths may also be employed.

ii) Plating

In the plating activity, the items to be plated are placed as the cathode in an electrolytic bath. A current is passed through wherein metal ions are plated onto the cathode. The ions in solution are replenished by :

- *the dissolution of metal from the anode (the plating substance) which consists of small pieces of the plating metal or*
- *adding the metal salts to the bath solution (when using an inert electrode). An example of this is chromium plating in which case the anode is usually made of an inert material like lead*

There are essentially three types of plating solutions: acid, alkaline solutions and metal salts which may contain complexing agents such as cyanides to keep the plating metal in solution.

Many plating bath solutions also contain metallic, organo-metallic and organic additives to induce grain refining, levelling of the plating surface and deposit brightening.

When plating is completed, the plated items are rinsed with water. After this, the items are dried in an oven.

The common plating baths and their constituents are shown in Table 3.

iii) POST-TREATMENT

Certain electroplating operations may end at the plating step if the item does not require post-treatment. However, the plating step may sometimes be followed by some post-treatment of the item to improve its physical appearance, corrosion resistance, or for decorative purposes.

These treatments include conversion coatings as well as many other types of coatings. Some of the more common post-treatment coating processes are chromating, phosphating, passivating, metal colouring and sealing.

This table shows the various types of plating baths and their normal chemical constituents.

TABLE 3 : TYPES OF PLATING BATHS USED

Category	Type of Bath	Constituent
Brass	Cyanide brass bath	$\text{Cu}(\text{CN})_2$, NaCN , $\text{Zn}(\text{CN})_2$, Na_2CO_3
Bronze	Cyanide bronze bath	$\text{Cu}(\text{CN})_2$, NaCN , Na_2SnO_3 , NaOH
Cadmium	Cyanide cadmium bath	$\text{Cd}(\text{CN})_2$, NaCN , Na_2CO_3 , NaOH
Chromium	Chromic acid bath	H_2CrO_4 , H_2SO_4 , NaF
Copper	Cyanide copper bath	$\text{Cu}(\text{CN})_2$, NaCN , Na_2CO_3 , NaOH
	Copper pyrophosphate bath	$\text{Cu}_2\text{P}_2\text{O}_7$, NH_4OH , $\text{K}_4\text{P}_2\text{O}_7$
	Acid copper bath	CuSO_4 , H_2SO_4
	Electroless copper bath	CuSO_4 , NaOH , HCOH , EDTA
Gold	Gold cyanide bath	$\text{KAu}(\text{CN})_2$, KCN , KOH , K_2CO_3
	Neutral gold bath	$\text{KAu}(\text{CN})_2$, KCl , K_2HPO_3
	Acid gold bath	$\text{KAu}(\text{CN})_2$, KCl , Citric acid
	Flash gold bath	AuCl_3 , HCl
Nickel	Watts nickel bath	NiSO_4 , NiCl_2 , H_2SO_4 , H_3BO_3
	Nickel sulphamate bath	$\text{Ni}(\text{NH}_2\text{SO}_3)_2$, $\text{H}_2\text{NH}_2\text{SO}_3$
	Wood's nickel bath	NiCl_2 , HCl
	Electroless nickel	NiSO_4 , Acetic acid, sodium hypophosphate
Palladium	Palladium chloride bath	PdCl_2 , NH_4Cl , HCl
Palladium / Nickel	Palladium / nickel bath	$\text{Pd}(\text{NH}_3)_2(\text{NO}_2)_2$, nickel sulphamate, NH_4OH
Platinum	Alkaline platinum bath	H_2PtCl_6 , $(\text{NH}_4)_3\text{PO}_4$, NH_4OH
	Acid platinum bath	$\text{H}_2\text{Pt}(\text{NO}_2)_2\text{SO}_4$, H_2SO_4
Rhodium	Acid rhodium bath	Rhodium sulphate, H_2SO_4
Silver	Silver cyanide bath	$\text{KAg}(\text{CN})_2$, KCN , K_2CO_3
	Neutral silver bath	$\text{KAg}(\text{CN})_2$, Na_2HPO_4 , H_3PO_4
Tin / Lead (Solder)	Tin lead fluoroborate solder bath	$\text{Sn}(\text{BF}_4)_2$, $\text{Pb}(\text{BF}_4)_2$, HBF_4 , H_3BO_3 , HF
Tin	Alkaline tin bath	Na_2SnO_3 , NaOH
	Tin sulphate bath	SnSO_4 , H_2SO_4
	Tin fluoroborate bath	$\text{Sn}(\text{BF}_4)_2$, HBF_4 , H_3BO_3 , HF
Lead	Lead fluoroborate bath	$\text{Pb}(\text{BF}_4)_2$, HBF_4 , H_3BO_3 , HF
Tin / Nickel	Acid tin / nickel bath	SnCl_2 , NH_4HF_2 , NiCl_2
Zinc	Cyanide zinc bath	ZnCN , NaCN , NaOH , Na_2CO_3
	Alkaline zinc bath	ZnO , NaOH
	Zinc chloride bath	ZnCl_2 , KCl , NH_4Cl , H_3BO_3
Anodising	Sulphuric acid anodising bath	H_2SO_4
Phosphating	Phosphating bath	Zinc-calcium phosphate, Na_3PO_4
Chromating	Chromating bath	Na_2CO_3 + Na_2CrO_4

Source : Paper on Overall View of Treatment of Electroplating Waste and the Situation in Hong Kong by Chiu, Tsang and Lee

Post-treatment operations are also normally followed by rinsing steps as in the case of the plating operations. The rinsing wastewaters may typically contain the following pollutants :

- Chromium, trivalent and hexavalent
- Nickel
- Zinc, and
- Cyanide

3.3.2 Specific Electroplating Process

The relevant elements of the specific electroplating process are :

- the specific flow
- the input materials
- the types of wastes

These are as summarised in the tabulation below (Table 4).

Table 4 : Elements of Specific Electroplating Process

Specific Flow	Cr Plating	See Figure 4A
	Cu Plating	See Figure 4B
	Ni Plating	See Figure 4C
	Ag Plating	See Figure 4D
	Zn Plating	See Figure 4E
Input Materials • Degreasing agents • Cleaning solutions	Cr Plating	See Figure 4A
	Cu Plating	See Figure 4B
	Ni Plating	See Figure 4C
	Ag Plating	See Figure 4D
	Zn Plating	See Figure 4E
• Plating Bath (From Table 1)	Cr Plating	• Chromic acid bath - Hydrogen chromate, sulphuric acid and sodium fluoride
	Cu Plating	• Cyanide copper bath - Copper and sodium cyanide, caustic soda and sodium carbonate • Copper pyrophosphate bath - Copper and potassium pyrophosphates and ammonium solution. • Acid copper bath - Copper sulphate and sulphuric acid
	Ni Plating	• Watts nickel bath - Nickel sulphate and chloride, sulphuric acid and boric acid • Nickel sulphamate bath - Nickel sulphamate, Sulphamate acid • Wood's nickel bath - Nickel chloride and hydrochloric acid
	Ag Plating	• Silver cyanide bath - Silver and potassium cyanide and potassium carbonate • Neutral silver bath - Silver and potassium cyanide, phosphoric acid and sodium hypophosphate
	Zn Plating	• Cyanide zinc bath - Zinc and sodium cyanide, caustic soda and sodium carbonate • Alkaline zinc bath - Zinc oxide and caustic soda • Zinc chloride bath - Zinc, potassium and ammonium chlorides and boric acid
Types of Wastes	Cr Plating	See Figure 4A
	Cu Plating	See Figure 4B
	Ni Plating	See Figure 4C
	Ag Plating	See Figure 4D
	Zn Plating	See Figure 4E

Abbreviations used : Cr = Chromium Cu = Copper Ni = Nickel
Ag = Silver Zn = Zinc

3.4 OTHER METAL FINISHING OPERATIONS

Apart from the electroplating process, there are three (3) common metal-finishing operations that are ordinarily included in the “electroplating” industry category although they are not strictly considered as true electroplating. There are as follows:

- *electroless plating*
- *anodising*
- *coating*

3.4.1 ELECTROLESS PLATING

Electroless plating is almost always accompanied by another electroplating operation.

In the electroless plating process, the metallic ions of the plating metal undergo a chemical reduction reaction in an aqueous solution containing a reducing agent and a catalyst. The reduced metal is uniformly deposited on the item without the use of an external electric current as in the case of true electroplating.

The basic constituents in an electroless plating solution are:

- *A source of the plating metal, usually a metal salt*
- *A reducing agent to reduce the metal ion to its base state*
- *A chelating agent to hold the metal in solution (hydroxy acids, or amines or aminocarboxylic acids)*
- *Various buffers and other chemicals to maintain bath stability and increase bath life*

Electroless plating of a plastic item involves the following steps : acid or alkaline cleaning, mechanical roughing or acid etching (usually chromic acid), catalyst application (deposition of a thin layer of palladium in association with tin) and plating.

Electroless plating of a metal item involves the following steps : solvent cleaning, smoothening by mechanical honing followed by acid dipping and alkaline cleaning, catalyst application (usually a rapid deposition, or pre-plating with nickel or copper).

3.4.2 ANODISING

Anodising is a process involving the electrolytic oxidation of the metal surface to an insoluble oxide. The oxide layer serves as a protection against corrosion, decoration, or the basis for other coating processes.

Metals that are most commonly anodised are:

- *Aluminium*
- *Zinc*
- *Magnesium, and*
- *Titanium*

The metal surface is first soak-cleaned using an alkaline cleaner or a phosphoric acid solution; this also causes the metal surface to etch slightly and provide an active surface for anodising.

In aluminium anodising the metal is subsequently immersed in sulphuric and chromic solutions and rinsed.

Magnesium anodising solutions may contain a combination of fluoride, phosphate and chromic acid, or potassium hydroxide, aluminium hydroxide, and potassium fluoride.

Nickel acetate or other sealers, complexing agents and dyes are also used in the finishing operations.

3.4.3 COATING

In coating processes, protective or decorative coatings or films are applied to the metal surface. The processes include:

- *Chromating*
- *Phosphating*
- *Immersion Plating*
- *Colouring*

I) Chromating

Chromating or chromate conversion coating is more commonly applied to the following metals for protection, decoration or to improve subsequent paint adhesion where painting is involved :

- *Zinc*
- *Cadmium*
- *Aluminium*
- *Copper*
- *Bronze*
- *Silver*
- *Magnesium*
- *Brass*

This type of conversion coating is applied either by electrochemical action or chemical immersion.

Chromate conversion coatings are frequently applied to zinc and cadmium plated items immediately after electrodeposition.

In the chromating process, a surface layer of the metal is converted to a component of the film which is formed by reaction with an aqueous solution containing hexavalent chromium and other active organic and inorganic compounds.

Chromating is also referred to as alodising or alodyning due to the use of a proprietary coating solution with the trade name of Alodine.

II) Passivating

Passivating is a process of treatment of the metal with a strong oxidising agent to form an oxide coating on the metal surface. Nitric acid and/or sodium dichromates are among the oxidising agent commonly used.

Passivating can be accomplished by anodising or chromating.

III) Phosphating

Phosphating is a process of treatment of iron, steel, zinc-plated steel and other metals by immersion in a dilute solution of phosphoric acid or other reagents to form a conversion coating on the surface.

The process is similar to chromating except that the new surfaces are non-metallic and non-conductive.

IV) Immersion Plating

Immersion plating is a chemical treatment process in which a thin deposit of the plating metal is formed on the base metal by chemical displacement and replacement of a surface layer of the base metal.

The base metal to be plated is always electrochemically more active than the plating metal (higher in the electrochemical series) and therefore displaces it from solution and causes it to be deposited onto the base metal surface.

Immersion plating is commonly performed in the following combinations:

- *Tin on brass, copper, steel or aluminium*
- *Copper on steel*
- *Gold on copper or brass*
- *Nickel on steel*

Preparation of the base metal surface involves an alkaline cleaning step and an acid pickling step. The acids commonly used for the pickling step are sulphuric, hydrochloric, or phosphoric.

V) Metal Colouring

Metal colouring involves the application of colour to the base metal surface by immersing the base metal item in dilute aqueous solutions that can induce colour formation. The types of solutions used include:

- *Ammonium molybdate (black on zinc and aluminium)*
- *Black oxide process (with dichromate)*
- *Ammonium polysulphide (gray or silver)*
- *Copper carbonate and ammonia (black on brass)*
- *Black oxide process (black on steel, zinc, and cadmium)*
- *Ferric chloride/potassium ferricyanide (blue on aluminium)*
- *Potassium dichromate/nitric acid (brown on cadmium)*
- *Potassium chlorate/nickel sulphate (brown on copper)*

VI) Sealing Operations

The surface sealing step is applied essentially to treated metal surfaces that are porous and therefore vulnerable to degradation.

Examples of sealing solutions and compounds are:

- *Distilled or de-ionised water applied at a temperature of about 100° C*
- *Dichromates, and*
- *Nickel / cobalt acetate*

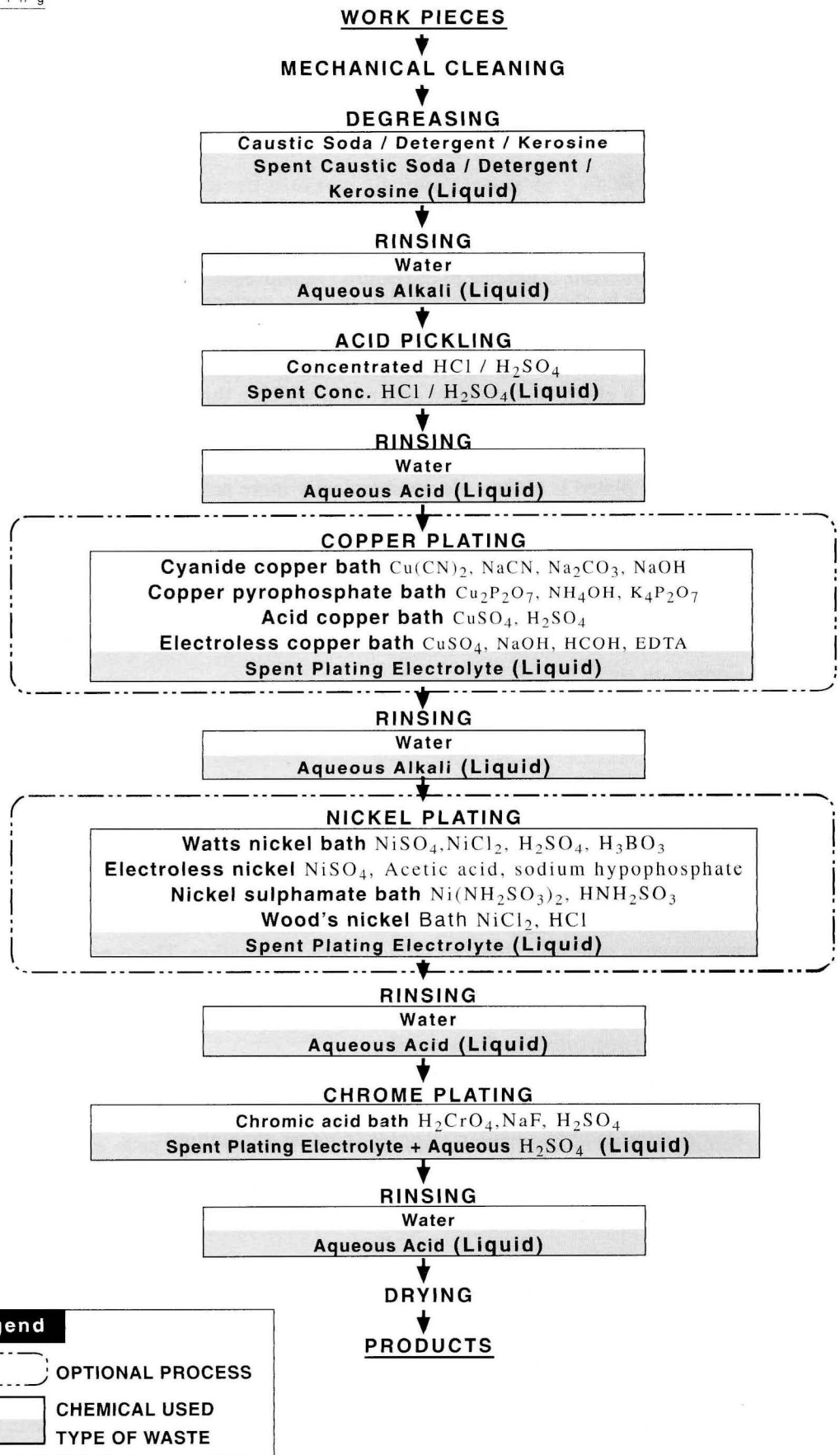


Figure 4A : Specific Electroplating Process - Chrome Plating

Source : Adapted from Flowchart R.033 in Flowcharts of Industrial Processes (Toxic and Hazardous Waste Generation) 1988 by Development of Regulations and Guidelines Unit, Development and Planning Section Department of Environment Malaysia

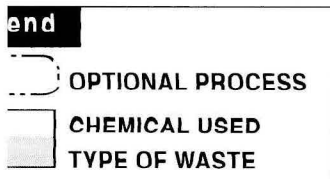
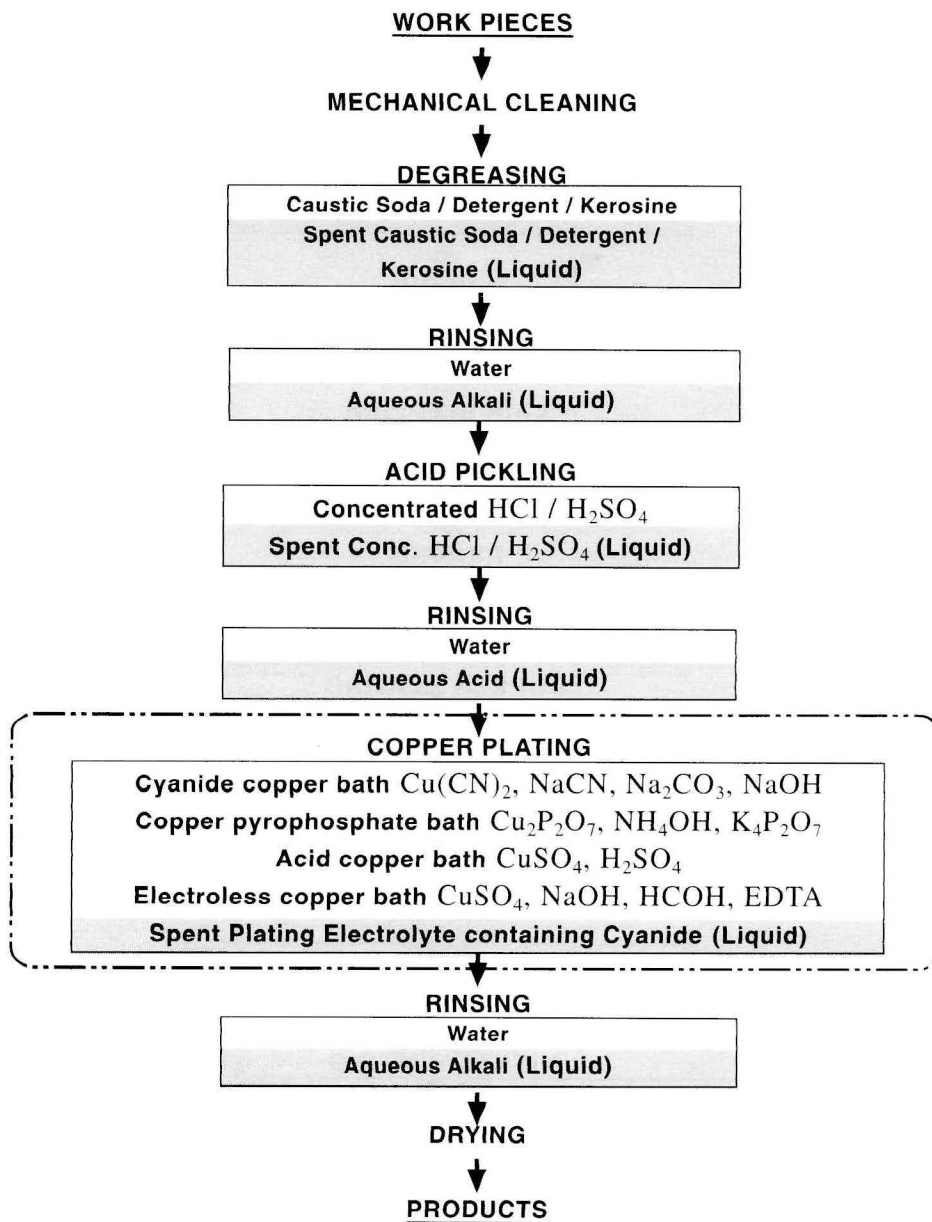


Figure 4B : Specific Electroplating Process - Copper Plating

: Adapted from Flowchart R.038 in Flowcharts of Industrial Processes (Toxic and Hazardous Waste Generation) 1988 by Development of Regulations and Guidelines Unit, Development and Planning Section Department of Environment Malaysia

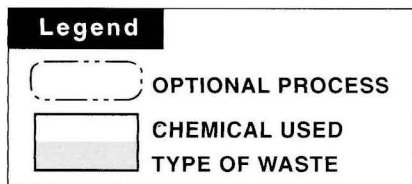
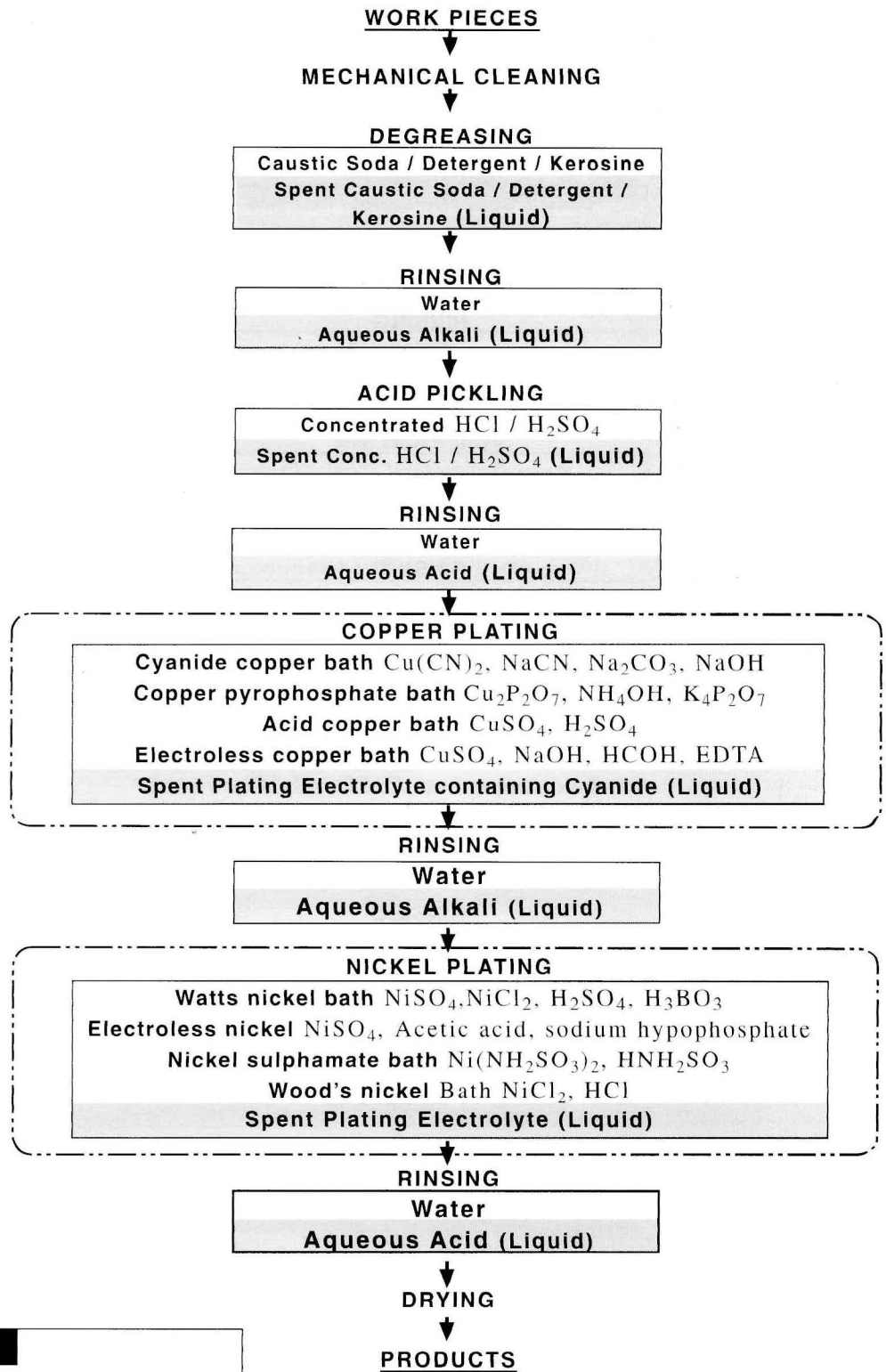


Figure 4C : Specific Electroplating Process - Nickel Plating

Source : Adapted from Flowchart R.038 in Flowcharts of Industrial Processes (Toxic and Hazardous Waste Generation) 1988 by Development of Regulations and Guidelines Unit, Development and Planning Section Department of Environment Malaysia

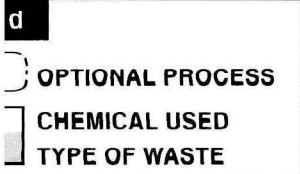
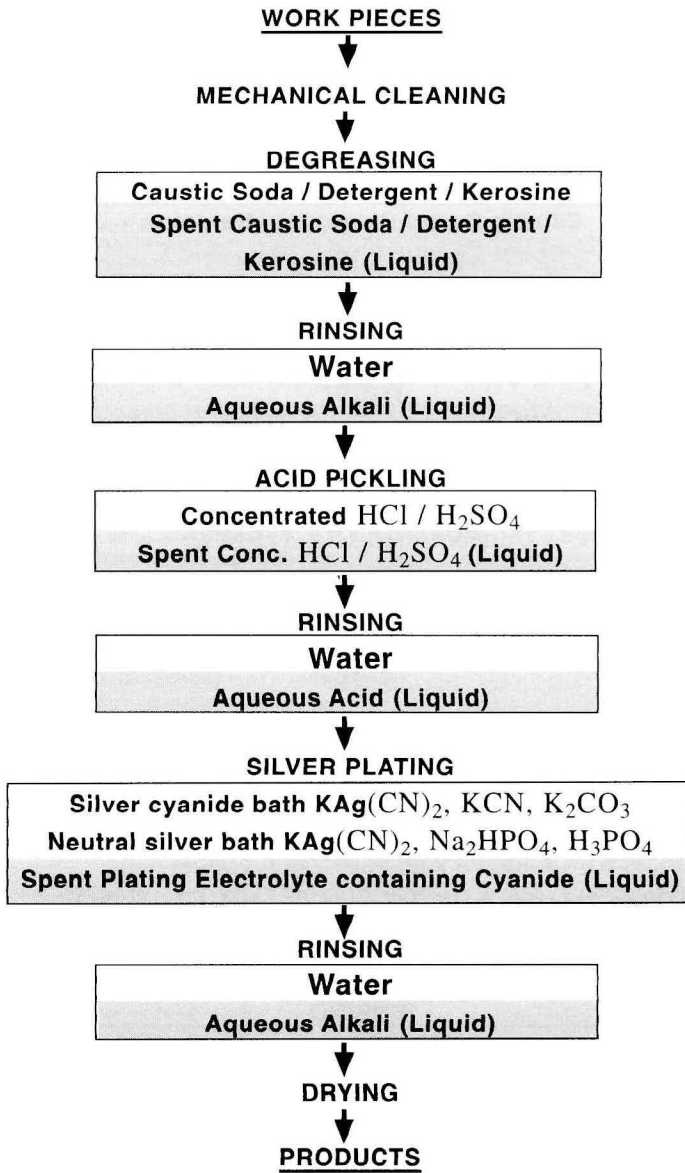


Figure 4D : Specific Electroplating Process - Silver Plating

Adapted from Flowchart R.037 in *Flowcharts of Industrial Processes (Toxic and Hazardous Waste Generation)* 1988 by Development of Regulations and Guidelines Unit, Development and Planning Section, Department of Environment Malaysia

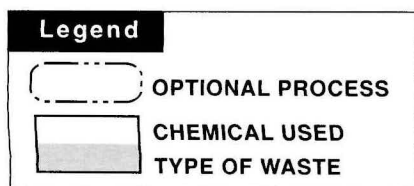
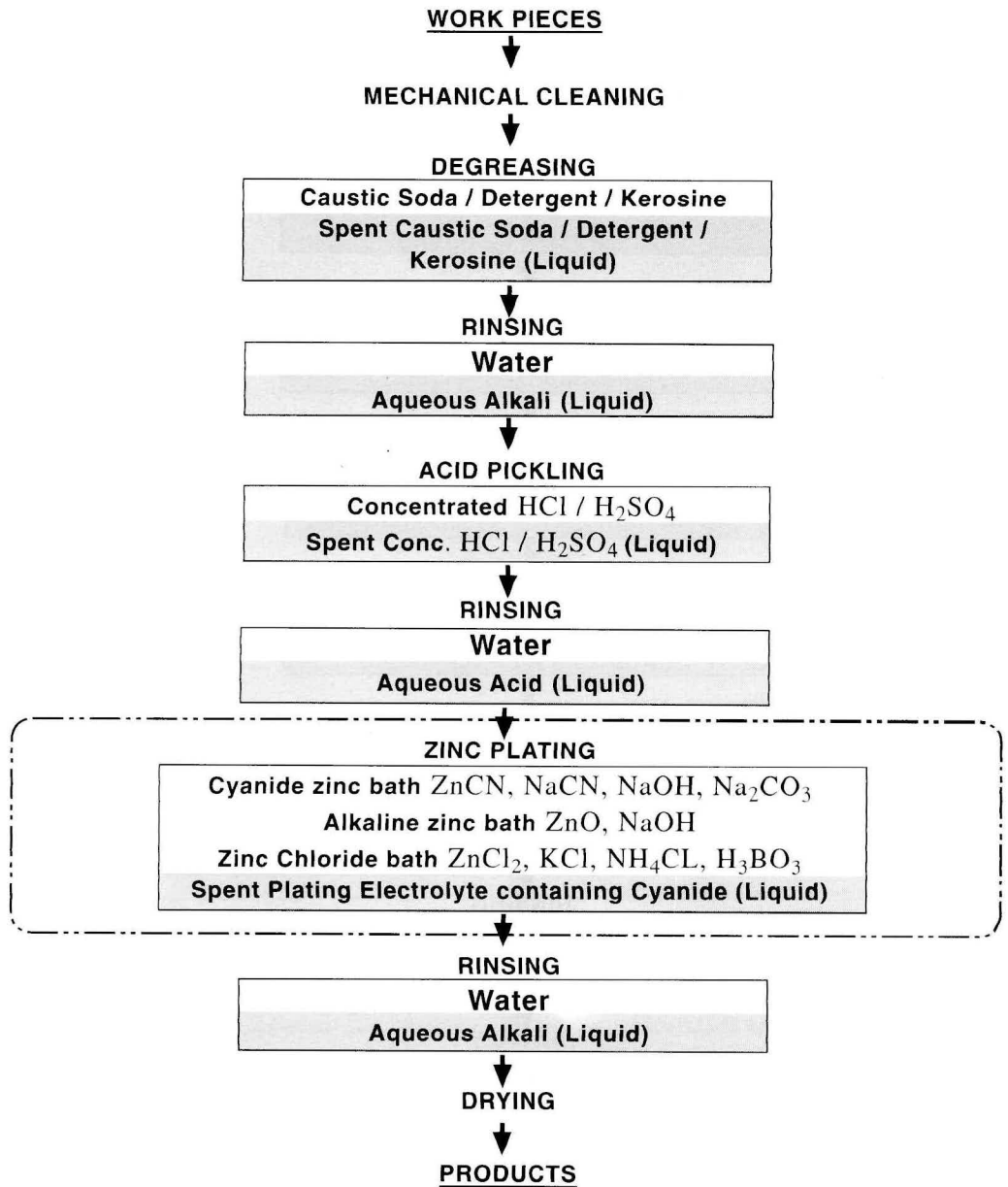
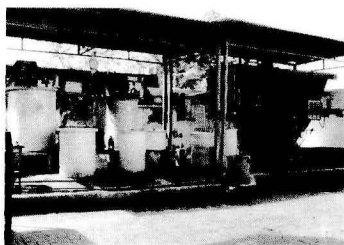


Figure 4E : Specific Electroplating Process - Zinc Plating

Source : Adapted from Flowchart R.038 in Flowcharts of Industrial Processes (Toxic and Hazardous Waste Generation) 1988 by Development of Regulations and Guidelines Unit, Development and Planning Section Department of Environment Malaysia



4.0 ENVIRONMENTAL ISSUES

The environmental issues are in the areas of :

- *environmental aspects / impacts and*
- *sources and characteristics of wastes*

4.1 ENVIRONMENTAL ASPECTS / IMPACTS

The usual environmental aspects / impacts caused by electroplating plants that have not introduced cleaner production technologies or processes are as summarised in Table 5 :

Table 5 : Summary of Environmental Aspects / Impacts from Electroplating Plants

Surface Preparation / Pre-treatment activity	Problem Area	Environmental Aspects / Impacts
Pre-cleaning	<ul style="list-style-type: none"> • Material input <ul style="list-style-type: none"> - chemical stocking - work items to be cleaned • Energy consumption 	<ul style="list-style-type: none"> - Chemical spillages to floor due to improper storage and handling - Generation of metal scraps and powder during buffing - Air pollution (dust etc)
Degreasing of work items	<ul style="list-style-type: none"> • Material input <ul style="list-style-type: none"> - solvents, alkalis and acids • Process wastewater • Hot process bath 	<ul style="list-style-type: none"> - Source of floor contamination : <ul style="list-style-type: none"> ▪ tank and pipework leaks ▪ spillages - Spent degreasing solution - Wastewater and sludge containing heavy metals - Air emission (e.g. NaOH) - Losses of heat
Rinsing of work items	<ul style="list-style-type: none"> • Water consumption • Wastewater generation 	<ul style="list-style-type: none"> - Heavy use of fresh water - Tank and pipework leaks - Wastewater pollution
Plating Activity	Problem Area	Environmental Aspects / Impacts
Plating of work items	<ul style="list-style-type: none"> • Material input <ul style="list-style-type: none"> - bath solutions • Hot process bath • Water consumption • Wastewater generation 	<ul style="list-style-type: none"> - Poor product quality due to non-optimisation of chemical concentration - Aerosol emission from hot processes above 60° C - Heat loss - Heavy use of fresh water - Tank and pipework leaks - Metal sludge generation may be caused by insufficient plating time - Spent plating solution
Rinsing of work items	<ul style="list-style-type: none"> • Water consumption • Wastewater generation 	<ul style="list-style-type: none"> - Drag-out of chemicals - Wastewater pollution - Tank and pipework leaks - Sludge generation

4.2 SOURCES AND CHARACTERISTICS OF WASTES

In general, the sources and characteristics of wastes from electroplating are a function of the types of plating, rinsing methods and plating practices. The most common waste/wastewater streams/environmental impacts generated by the electroplating industry (in order of pollution-causing significance) are :

- *wastewater*
- *scheduled wastes*
- *air emission*
- *noise*

A listing of the typical electroplating activities and the characteristics of the wastes impacts generated are presented in Table 6.

4.2.1 Wastewater

Any or all of the substances used in electroplating, including degreasers, acid solutions, alkaline cleaners, solvents, toxic metal solutions and cyanide can be found in the wastewaters either via rinsing of the item or due to spillage or dumping of the process baths.

The major sources of generation of wastewater come from :

- *chemical drag-out*
- *rinse water effluent*
- *spent process solutions*
- *leaks of process solutions (from storage tank leaks, pipework leaks)*
- *accidental spills*

I) Drag-out

Drag-out is plating solution which clings onto the item being processed and contaminates the rinse water during the subsequent rinsing operation.

The extent of drag-out contamination depends on:

- *Type of design of rack or barrel carrying the item*
- *Shape of item, and*
- *Dripping time of item over the process tank*

II) Rinse Water

Large quantities of rinse water are used to:

- *Clean the processed item of drag-out, and*
- *Protect the next process bath from drag-out contamination.*

Water rinsing after each processing step to prevent chemical drag-out from one processing step into the next results in the use of large quantities of rinse water amounting to nearly 90% of the total water requirements for plating operations. Rinse waters that follow the plating steps typically contain between 15 and 100 mg/l of the plating metal.

Table 6 : Electroplating Activities And Characteristics Of Wastes Generated

STEP	ACTIVITIES	SPENT BATH SOLUTIONS AND WASTEWATERS						AIR EMISSIONS	SOLID WASTES	SCHEDULED WASTES
		CHROMIUM	OTHER METALS	CYANIDE	OILS	SOLVENTS				
Surface Preparation (Physical process)	Buffing / Polishing	X	X		X			X	X	
	Electrocleaning		X	X	X			X	X	X
Pre-treatment (Chemical process)	Solvent cleaning				X	X		X	X	X
	Alkaline cleaning		X	X	X	X		X	X	X
	Acid cleaning	X	X					X	X	X
Electro-deposition (Electro-chemical process)	Electroplating	X	X	X				X	X	X
	Electroless plating		X					X		X
	Electropolishing	X	X					X		X
	Anodising	X	X					X		X
Post-treatment	Chromating	X	X							X
	Phosphating	X	X		X			X	X	X
	Passivating	X	X					X		X

Source : Pollution Prevention in Electroplating Industries by Frank Altmayer, Scientific Control Laboratories, Inc.
Published in Industrial Pollution Prevention Handbook by Harry M. Freeman (McGraw-Hill, Inc.)

III) Spent Process Solutions

Among the spent process solutions that may be discarded by electroplaters are:

- *Spent cleaners*
- *Spent acids and*
- *Spent bright dips*

These chemicals do not normally contain metals, but their spent solutions can contain several thousand milligrams per litres of heavy metals and cyanide due to:

- *Drag-out from previous process operations, and*
- *Leaching of the work pieces into the process chemical solution.*

Plating solutions and other process chemicals with such high metal concentrations are seldom discarded, but subjected to in-situ decontamination and reuse.

IV) Leaks and Accidental Spills

These are occasionally responsible for causing higher contamination levels of effluent.

V) Other sources of wastewater

Other sources of wastewater may include :

- backwash from plating bath filter systems
- floor washings

VI) Quantities of Wastewaters

The quantities of wastewater generated are highly variable and also depends on the factory size as shown in Table 7:

Table 7 : Expected Discharge Volume Relative To Factory Size

Factory Size	Discharge Volume
Small (< 20 workers)	3 - 5 m ³ / day
Medium (< 50 workers)	10 - 40 m ³ / day
Large (> 50 workers)	50 - 80 m ³ / day

Source : Overall View of Treatment of Electroplating Waste and the Situation in Hong Kong by Chiu, Tsang and Lee

In Malaysia most metal finishing factories have difficulty complying with the wastewater limits in respect of :

- *chemical oxygen demand (COD)*
- *suspended solids (SS)*
- *oil and grease (O&G)*
- *heavy metals*

4.2.2 Scheduled Wastes

The scheduled wastes would be :

- *degreasers*
- *spent alkali*
- *spent acid*
- *fluxes*
- *sludges*
- *spent plating bath*

Sludges may be generated from the following sources :

- *bottom of exhausted plating baths*
- *precipitation and/or sedimentation units of wastewater treatment plants*

These sludges contain high levels of heavy metals. They are often stored at the premises under unsatisfactory conditions before disposal.

4.3 Air Emission

The air pollution potential of electroplating operations is a function of :

- *Type and rate of gas emissions or release of gas bubbles from the plating solutions, and*
- *Temperature of the plating baths.*

The severity of air pollution ranges from insignificant to one of a nuisance nature or of occupational concern. The following are characteristic of air emissions observed in plating operations :

- *Mist formation over plating tanks, especially in the case of hot plating baths and concentrated acid/alkali baths due to release of gases with entrained fine droplets of process solutions.*
- *Elevated levels of volatile organic compounds (VOCs), and in some cases volatile metal compounds (which may contain chromates), due to solvent vapours from hot plating baths.*
- *Up to 30% of solvents and degreasing agents released as VOCs when baths are not regenerated.*
- *Emission of VOCs containing toxic organics such as chlorinated hydrocarbons (e.g. trichloroethylene and trichloroethane).*

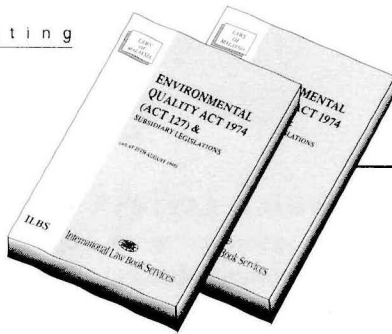
A more serious concern is mixing of cyanide and acidic wastewaters which can lead to the generation of lethal hydrogen cyanide gas which must be avoided at all costs.

The air emissions from open tanks can lead to external emissions when the respective tanks are equipped with local exhaust ventilation systems that discharge to the atmosphere.

4.4 Noise

Sources of noise emission in electroplating operations include :

- *machining operations and mechanical processes*
- *conveyors*
- *ventilation outlets*
- *dryers*
- *generators, if any*



5.0 REGULATORY FRAMEWORK

The main legislative instrument to prevent, abate and control pollution and to enhance the environment is the Environmental Quality Act 1974. The Act is administered by the Director General of the DOE.

5.1 ENVIRONMENTAL QUALITY ACT 1974

Briefly, the Environmental Quality Act 1974 :

- came into force on 15 April 1975
- was amended 3 times to make it progressively more effective - in 1985, 1996 and most recently in 1998
- has 20 subsidiary legislations comprising of 11 Regulations, 8 Orders and 1 Rule (as at 1st November 1996) to restrict the discharge of wastes into the environment above acceptable quantified limits.

The 1996 amendment was specially significant in that, among others, it :

- *increased the penalty charges for offences*
- *empowered the DOE to inspect an offending site without a warrant*
- *authorised the DOE to request for an environmental audit, if found necessary*

The major changes in the recent 1998 amendment were the :

- *introduction of guidelines for activities exempted from open burning prohibition*
- *stipulation that the Attorney General has the sole right to prosecute (Notwithstanding this, DOE can prosecute an alleged offender after getting the approval of the Deputy Public Prosecutor)*
- *increase in penalty for open burning offences from RM 100,000 to RM 500,000*

5.2 ENVIRONMENTAL REQUIREMENTS RELEVANT TO THE ELECTROPLATING INDUSTRY

The Environmental Quality Act 1974 requires the electroplating industry to :

- *obtain the following prior approvals from the DOE Director under Regulation 4 of the Environmental Quality (Sewage and Industrial Effluents) 1979 :*
 - Site suitability evaluation
 - Written permission to construct
- *comply with the following legislations upon subsequent operation :*
 - Environmental Quality (Clean Air) Regulations 1978 (for the control of air emissions)
 - Environmental Quality (Sewage and Industrial Effluents) Regulations 1979 (for the control of municipal and industrial wastewater pollution)
 - Environmental Quality (Scheduled Wastes) Regulations 1989 (for the control of toxic and hazardous wastes)

In brief, **Environmental Quality (Clean Air) Regulations 1978** stipulate standards for emission of air pollutants including acid gases and toxic particulates.

The **Environmental Quality (Sewage and Industrial Effluents) Regulations 1979** control the discharge of wastewater from domestic, industrial premises and centralised electroplating parks. These regulations stipulate standards for effluent discharge into inland water bodies and public sewers.

The **Environmental Quality (Scheduled Wastes) Regulations 1989** control the disposal of 107 categories of toxic and hazardous wastes.

Besides the above environmental requirements, electroplaters are encouraged to adhere to the **Guidelines For Siting and Zoning of Industries** which, among others, controls the noise level at the factory boundary fence.

5.3 STANDARDS AND LIMITS RELEVANT TO ELECTROPLATING

Relevant standards and limits applicable to the electroplating industry are given in the following annexes :

- *Air Emission Standards* - See Annex A
- *Effluent Standards A and B* - See Annex B
- *Scheduled Waste Requirements* - See Annex C
- *Noise Requirements* - See Annex D

5.4. NON-COMPLIANCES, PROSECUTION AND PENALTIES

The following sections in respect of the various regulations are chargeable offences when a non-compliance is evident :

Table 8 : Chargeable offences under the EQA 1974

Regulation	Chargeable Section	Particulars
Clean Air	EQA Section 22(1)	Restriction on pollution of the atmosphere
Sewage & Industrial Effluents	EQA Section 25(1)	Restriction on pollution of inland waters
Scheduled Wastes	EQA Section 24(2B) EQA Section 34B(1)	Restriction on pollution of the soil Prohibition against placing, deposit, etc, of scheduled wastes
Noise	EQA Section 23(1)	Restriction on noise pollution

With regard to prosecution in respect of the above relevant Standards, the current EQA Section 22(3), Section 23(2), Section 24(3) and Section 25(3) each individually states that an offender shall be liable to :

- *a maximum fine of RM 100,000, or*
- *a maximum jail term of 5 years, or*
- *both fine and jail term, and*
- *further maximum fine of RM 1,000 a day for every day that the offence is continued after a notice by the Director General of DOE to cease the offence*

As for compounding of offences, EQA Section 45 states that an offender can be compounded a sum of money not exceeding RM 2,000. Specifically, the following offences may be compounded :

Table 9 : Compoundable offences under the EQA 1974

Regulation	Regulation No.	Particulars
Clean Air	No. 4	Written approval to install industrial facilities
	No. 11	Conditions of open burning
	No. 26	Emission of metals and metallic compounds
	No. 27	Emissions of gaseous substances
	No. 34	Carry over of liquid droplets
Sewage and Industrial Effluents	Not compoundable	Not applicable
Scheduled Wastes	No. 3	Notification of generation of scheduled wastes
	No. 4	Disposal of scheduled wastes
	No. 7	Movement of scheduled wastes
	No. 8	Storage of scheduled wastes
	No. 9	Upkeep of inventory of scheduled wastes
	No. 10	Information by waste generator, contractor and occupier of prescribed premises
	No. 11	Scheduled wastes transported outside waste generator's premises to be accompanied by information
No. 12	Spill or accidental discharge	
Noise Requirements	Not compoundable	Not applicable

5.5 EXPECTED REGULATORY CHANGES

Recognising the electroplating industry to be a major source of heavy metals contamination in wastewater streams, DOE intends to :

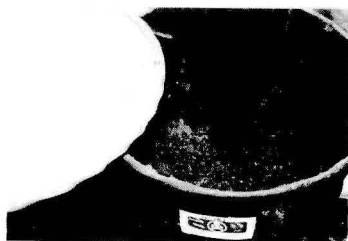
- include metal finishing as a prescribed activity wherein factories will need to obtain a licence from the DOE to operate
- set separate stricter standards for the industrial sector (as done for effluent discharge from rubber and palm oil mills)
- review / re-categorise the existing list of scheduled wastes
- limit the maximum storage period of toxic wastes in the factories to 180 days
- relocate the electroplating factories to industrial parks with centralised waste water treatment facilities

Furthermore, the following have been proposed by the private sector which has the support of the Government :

- *an Eco-Industrial Park with a common Wastewater Treatment Plant to treat electroplating wastes at Pulau Indah, Klang in the near future*
- *a regional electroplating park to cater for 2-3 adjacent states in Malaysia in the not too distant future*

5.6 HEALTH AND SAFETY ASPECTS

This handbook does not cover the occupational safety and health requirements of the Department of Safety and Health. It should be stressed that integration of OH & S (Occupational Health and Safety) in to cleaner production solution is very important in order not to increase health and safety exposure to the workers while solving impacts on the external environment.



6.0 CONVENTIONAL POLLUTION CONTROL PRACTICE

The conventional pollution control measures commonly practised are herewith summarised under :

- *surface preparation / pre-treatment activity*
- *plating activity*
- *wastewater treatment*

6.1 POLLUTION CONTROL PRACTICES IN SURFACE PREPARATION / PRE-TREATMENT

This table shows measures related to the surface preparation / pre-treatment activities.

Table 10 : Conventional Practices in Surface Preparation / Pre-Treatment

Surface Preparation / Pre-treatment activities	S : Source and O : Outlet	Practices	Weaknesses
a) Consumption of Materials	S : Degreaser baths O : See wastewater under Item (c) of Table 11	- Chemical top-up or total chemical change based on ad hoc manual chemical analyses or visual inspection	- Slow response to chemical top-up or total chemical change leading to non-optimisation of chemical concentration and consumption
b) Air pollution	S : Hot baths and concentrated baths O : Vents / stacks	- Local exhaust vents - Closed system of conveyor lines and installation of hoods - Wet chemical scrubber - Increase height of outlet	- Scrubber requires water and increases amount of wastewater - Insufficient increase of vent/stack outlet height to disperse pollution - Little maintenance
c) Water consumption and process wastewater	S : Rinsing process and degreaser baths O : Discharge to recipient or drainage	- One or two rinsing tanks with separate high water inflow - Cascade rinsing and collection tanks - Wastewater treatment consists of conventional separation techniques	- No assessment of overall water balance resulting in insufficient optimisation of water
d) Solid waste	S : Used degreaser baths, used chemicals, chemical containers and sludge from wastewater treatment O : Disposal	- See solid waste under item (d) of Table 11	- See solid waste under item (d) of Table 11
e) Ambient noise	S : Handling of metal parts and transport thereof as well as generators, if any O : Outdoor operations	- Move operations indoors - Limit the transport to and from the plant to business operation hours - Encapsulations of outdoor generators	- Might increase the indoor noise exposure - The business is based on 3-shift operation and so transport is required before and after normal business hours
f) Energy consumption	S : Electro-chemical degreasing, hot baths conveyance system O : For electricity : Indirect - by emission to the air from power plant. For heat : See air pollution above	- Cleaning of contact points - Insulation of hot tanks and pipes	- The procedures of cleaning and maintaining insulation are not implemented sufficiently

6.2 POLLUTION CONTROL PRACTICES IN PLATING

This table shows the measures related to the plating activities.

Table 11 : Conventional Practices in Plating

Plating Activities	S : Source and O : Outlet	Practices	Weaknesses
a) Consumption of materials	S : Plating baths and Wastewater treatment O : Wastewater discharge and solid waste	- Automatic or manual adjustment of chemical dosing - Storage of chemicals	- Tends to be overdosed - No overall assessment of consumption of chemicals and water - Poor storage of chemicals directly on the floor or on the ground leads to contamination of soil and groundwater and
b) Air pollution	S : Hot baths and concentrated baths O : Vents/stacks	- See air pollution under item (b) of Table 10	- See air pollution under Item (b) of Table 10
c) Water consumption and process waste water	S : Rinsing process and plating baths O : Discharge to recipient or drainage	- Cascade rinsing and collection tanks - Once through flow of clean water of individual rinsing tank - Conventional wastewater treatment by precipitation	- May result in unnecessary high consumption of water and chemicals - May result in unnecessary generation of waste
d) Solid waste	S : Used plating baths, used chemical containers and sludge from wastewater treatment O : Disposal	- Disposal of waste on the premise - Disposal of waste at landfill	- Disposal of waste on the premise results in contamination of soil - Disposal of waste at landfill have significant costs for the company and the capacity of the landfill is limited
e) Ambient noise	S : Operation of generators O : Outdoor operations	- Enclosure of outdoor generators	- None in particular
f) Energy consumption	S : Electroplating and hot baths O : For electricity : Indirect - by emission to the air from power plant (supplier) For heat : See air pollution above	- Cleaning of contact points and busbars - Insulation of racks - Insulation of hot tanks and pipes	- The procedures of cleaning and maintaining insulation are not implemented sufficiently

For visualisation of some of the above applications, see illustrations in Figures 5 and 6 in accompanying pages.

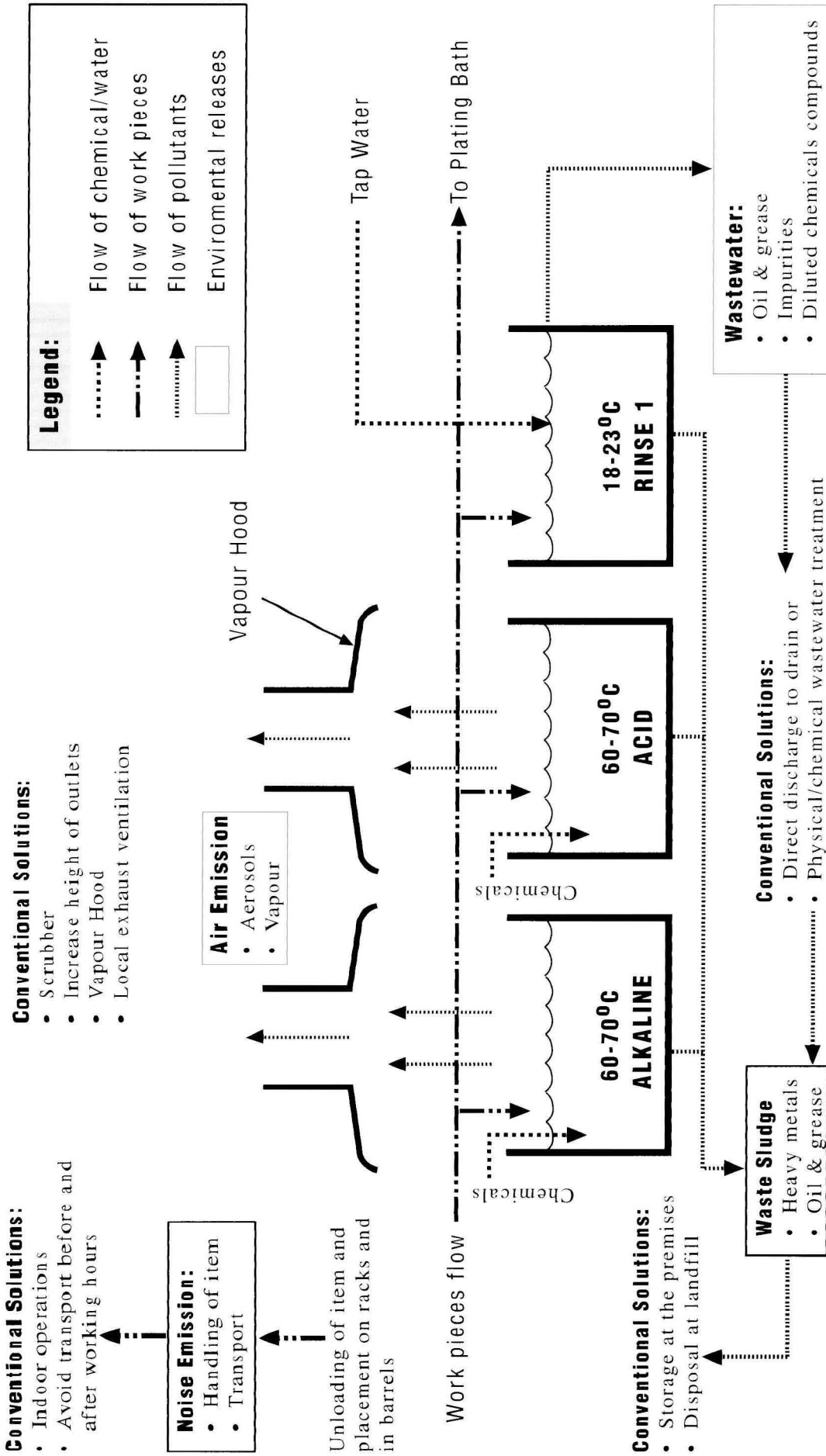


Figure 5: Electroplating Pre-treatment Operation - Conventional Practices Electroplating Work Step 1

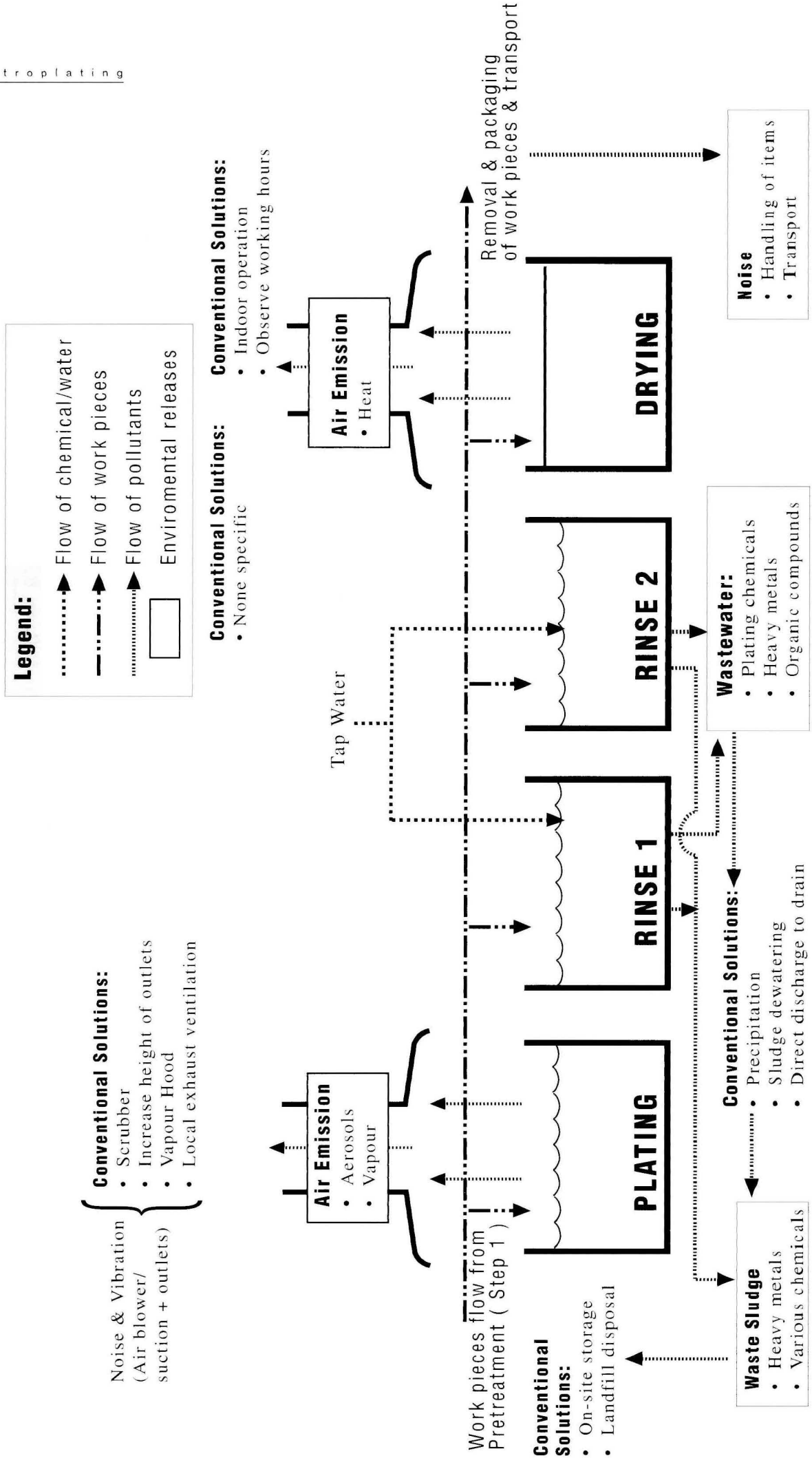


Figure 6: Plating Operation - Conventional Practices

Electroplating Work Step 2

6.3 WASTES TREATMENT

Wastes generated by the electroplating process can be treated either on-site or off-site.

a) On-site Treatment

As mentioned earlier, the major pollutants of concern are wastewaters and sludges - mainly from rinse water effluent and spent process baths which contain heavy metals. Being hazardous wastes, these have to be treated and disposed off in an environmentally sound manner.

Electroplating operations typically treat the wastewater by removing or destroying each single pollutant in a wastewater treatment system. The treatment technologies include:

- *pH adjustment / neutralisation* - for acid and alkali
- *Coagulation / flocculation / precipitation* - for metals
- *Sedimentation / filtration / floatation* - for suspended solids

The figure below shows the above treatment diagrammatically

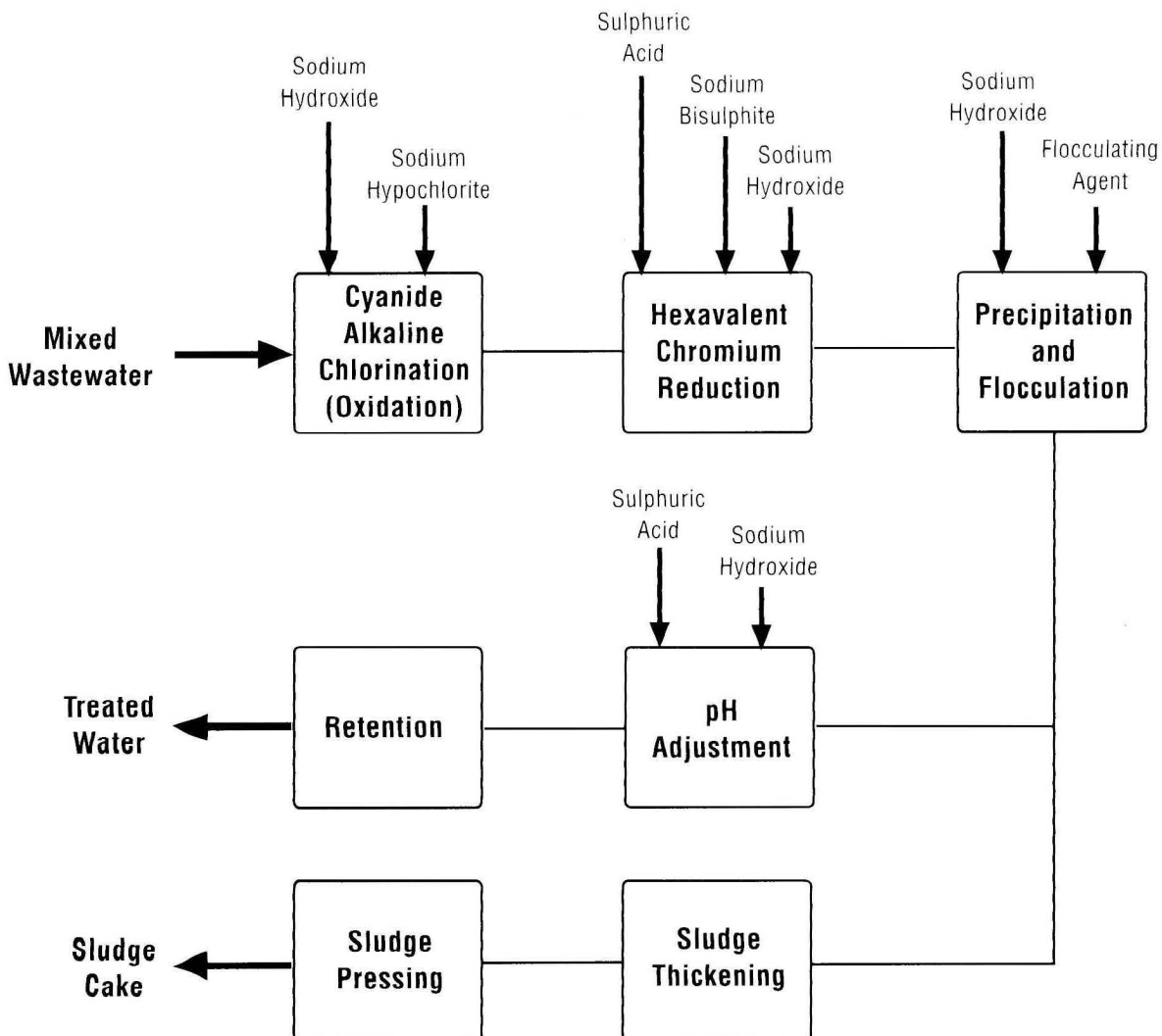


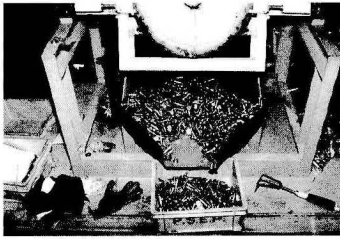
Figure 7 : A Conventional Wastewater Treatment Plant

Comparatively, air emission is a minor pollutant. It is mainly metal ion-bearing vapour being released from hot plating baths due to the elevated temperature operation. The air emission is usually controlled using a wet chemical scrubber. The treatment in turn generates further waste that must be treated, disposed or recycled.

b) Off-site Treatment

For off-site treatment/disposal of the scheduled wastes, the electroplating industry has the option to make use of the following service providers (private facilities) :

- *Kualiti Alam Scheduled Waste Treatment and Disposal Facility at Bukit Nanas in Port Dickson, Negeri Sembilan*
- *Common Wastewater Treatment Plant at Electroplating Park at Bukit Kemuning in Shah Alam, Selangor - for tenants at the Park*
- *Recovery Facilities (DOE State-specific Reference List)*
- *Recycling Facilities (DOE State-specific Reference List)*



7.0 CLEANER PRODUCTION APPROACH

Cleaner production (CP) is defined by UNEP as - “the continuous application of an integrated, preventive environmental strategy to process, products and services to improve eco-efficiency and reduces risks to humans and the environment”.

7.1 CLEANER PRODUCTION RATIONALE

The main rationale of cleaner production is that :

- *all wastes are to be considered as unused raw materials. However a complete zero-waste discharge may not be attainable*
- *cleaner production can be applied in the three key areas*
 - good housekeeping practices involving habits and attitudes
 - technical modification involving modifications on existing machinery
 - process modification involving substitution of chemicals and alternative processes
- *cleaner production can be applied at different levels of sophistication :*
 - immediate application : applying low-tech measures
 - intermediate application : applying medium-tech measures
 - advanced application : applying high tech measures
- *cleaner production measure(s) can be applied progressively i.e. singly or in combination as some measures require :*
 - no investment but need more frequent cleaning and better supervision with maintenance
 - investment in the form of additional equipment

7.2 CLEANER PRODUCTION BENEFITS

Cleaner production will result in :

- *reduction in resource consumption in :*
 - water
 - chemicals
 - heat and electricity
- *better bottom line by way of :*
 - reduced production costs
 - improved product quality
 - credibility and competitiveness
- *reduced amount of :*
 - wastewater containing chemicals
 - sludge waste
 - air emission

The following other benefits can be expected :

- *Minimised daily impact on the surrounding environment*
- *Minimised risk of pollution in event of accidents*
- *Minimised chemical exposure of employees*
- *Improved personnel morale due to healthier and safer work environment*
- *Less production downtime*
- *Reduced scrap production caused by improper choice of materials, insufficient programming facilities, bad maintenance of equipment or bad configuration of the processes*

7.3 CLEANER PRODUCTION MEASURES

The cleaner production measures available for surface preparation/pre-treatment and plating activities respectively are summarised below. These involve :

- *Good housekeeping* (▲)
- *Improved material handling* (🍏)
- *In-plant changes/process recycling* (★)

Table 12 : Cleaner Production Measures in Surface Preparation and Pre-Treatment

Surface Preparation / Pre-treatment	Location Fig 3	Measures	Benefit
Ensure proper storage of chemical drums (▲)	Up-Stream of (1)	Have paved and sheltered storage with drums stacked not more than 3 tiers and to allow free movement of the fork lift. Drums should be clearly labeled.	<ul style="list-style-type: none"> • Minimise risk of : <ul style="list-style-type: none"> - chemical contamination of floor - spillage onto floor
Purify raw materials (🍏)	(1)	Impose on suppliers to pre-clean their raw materials at own factory before sending for electroplating	<ul style="list-style-type: none"> • Reduce pollution as well as consumption of chemicals and energy (heat and electricity)
Spray rinsing in small pulses (★)	(3), (5) and (7)	Install water pipe with spray nozzles over the rinsing tanks wherein work items are sprayed during hoisting	<ul style="list-style-type: none"> • Reduce consumption of water • Reduce chemical drag-out
Adopt multiple counter-flow rinsing (★)	(3), (5) and (7)	Use, for instance, air-lift pumps for backfilling to previous rinsing tank with : <ul style="list-style-type: none"> - inlet pipe at top position - outlet pipe at bottom position 	<ul style="list-style-type: none"> • Reduce drag-out of chemicals • Minimise use of fresh water • Less cross contamination between tanks
Replace worn-out tanks and leaky pipes (▲)	(2) to (7)	Use tanks which are resistant to corrosion eg. fibreglass or stainless steel	<ul style="list-style-type: none"> • Prevent chemical leakage • Reduce water consumption • Increase life span of tanks
Pre-cleaning of raw material items for plating (▲)	Up-Stream of (1)	Use a centrifuge to remove all dirt prior to degreasing or to impose cleanliness requirement onto the client (medium tech)	<ul style="list-style-type: none"> • Reduce lengthy pre-treatment • Reduce electricity consumption in surface preparation
Removal of accumulated oil and grease in degreaser tank (★)	(2)	Use centrifuge (medium tech)	<ul style="list-style-type: none"> • Reduce infiltration of impurities (undesirable salts and organics including oil and grease) • Prolong life span of degreaser tank
Ultra-filtration for inlet water to alkaline degreaser tank (★)	(2)	Use ultra-filter (high tech)	<ul style="list-style-type: none"> • Reduce infiltration of impurities (undesirable salts and organics including oil and grease)
Ultrasonic degreasing (★)	(2)	Use ultrasonic degreaser (high tech)	<ul style="list-style-type: none"> • Reduce infiltration of impurities (undesirable salts and organics including oil and grease)

Table 13 : Cleaner Production Measures in Plating

Plating	Location In Fig 3	Measures	Benefit
Insulate hot process tanks and piping (▲)	(2), (4), (6) & (8)	Use insulation material	<ul style="list-style-type: none"> • Reduce heat losses
Introduce drip guard between adjacent tanks (▲)	(2) to (7)	Use inverted V-shaped deflectors to return chemical drag-out back to the relevant tanks	<ul style="list-style-type: none"> • Avoid spillage onto the floor • Recovery of chemical drips back into relevant tanks
Rotate plating barrels at top position (★)	(6)	Use auto controller to effect the rotation	<ul style="list-style-type: none"> • Shake off chemical drag-out
Use plastic balls in hot process tanks (▲)	(2) & (6)	Place sufficient plastic balls to cover the whole water surface area	<ul style="list-style-type: none"> • Reduce chemical evaporation loss • Minimise heat loss • Prevent mist formation
Clean contact points and busbars (▲)	(6)	Manually clean by use of steel brush	<ul style="list-style-type: none"> • Ensure good electrical connections • Keep busbars free from "chemical cake" and unwanted coatings • Reduce electricity consumption • Improve plating quality
Maintain rack insulation (▲)	(6)	Coat all parts, except the electrical contact points, with chemical resistant polymer. The coating shall be non-porous and without cracks	<ul style="list-style-type: none"> • Avoid unnecessary : <ul style="list-style-type: none"> - consumption of plating metal - plating of the racks - usage of electricity for surplus plating
Automation to maintain optimum water flow and chemical dosage (★)	(6)	<ul style="list-style-type: none"> - Introduce on-line flow meter in water intake pipe - Introduce on-line conductivity meter in plating tank (medium tech) 	<ul style="list-style-type: none"> • Avoid chemical depletion or chemical over-dosage. Also water savings from correct adjustment of: <ul style="list-style-type: none"> - water flow into last rinse tank - plating chemical replenishment
Reverse osmosis to treat last rinse water for inlet water (★)	(7)	RO is not recommended for use in systems where : <ul style="list-style-type: none"> - pH is 12-14 or pH is 0-2 - organics in influent water > 5 g/l (high tech) 	<ul style="list-style-type: none"> • Reduce infiltration of impurities (undesirable salts and organics) into rinsing tanks
Reduce voluminous quantity of counter-flow rinse water in Zinc plating (★)	(6)	Place evaporator next to the plating bath. The inlet pipe and backfilling pipe is installed in the process tank (high tech)	<ul style="list-style-type: none"> • Reduce consumption of zinc
Recover heavy metals from used rinsing water for reuse in baths of nickel, chrome, tin and copper plating (★)	(7)	Use electrolytic cell or ion exchanger and evaporation unit, if required (high tech)	<ul style="list-style-type: none"> • Minimise use of raw materials • Reduce amount of sludge • Reduce concentrations of heavy metals in wastewater • Recover heavy metals for re-use or secondary raw materials to be sold off

For visualisation of some of the above applications, see illustration in Figures 8, 9 and 10.

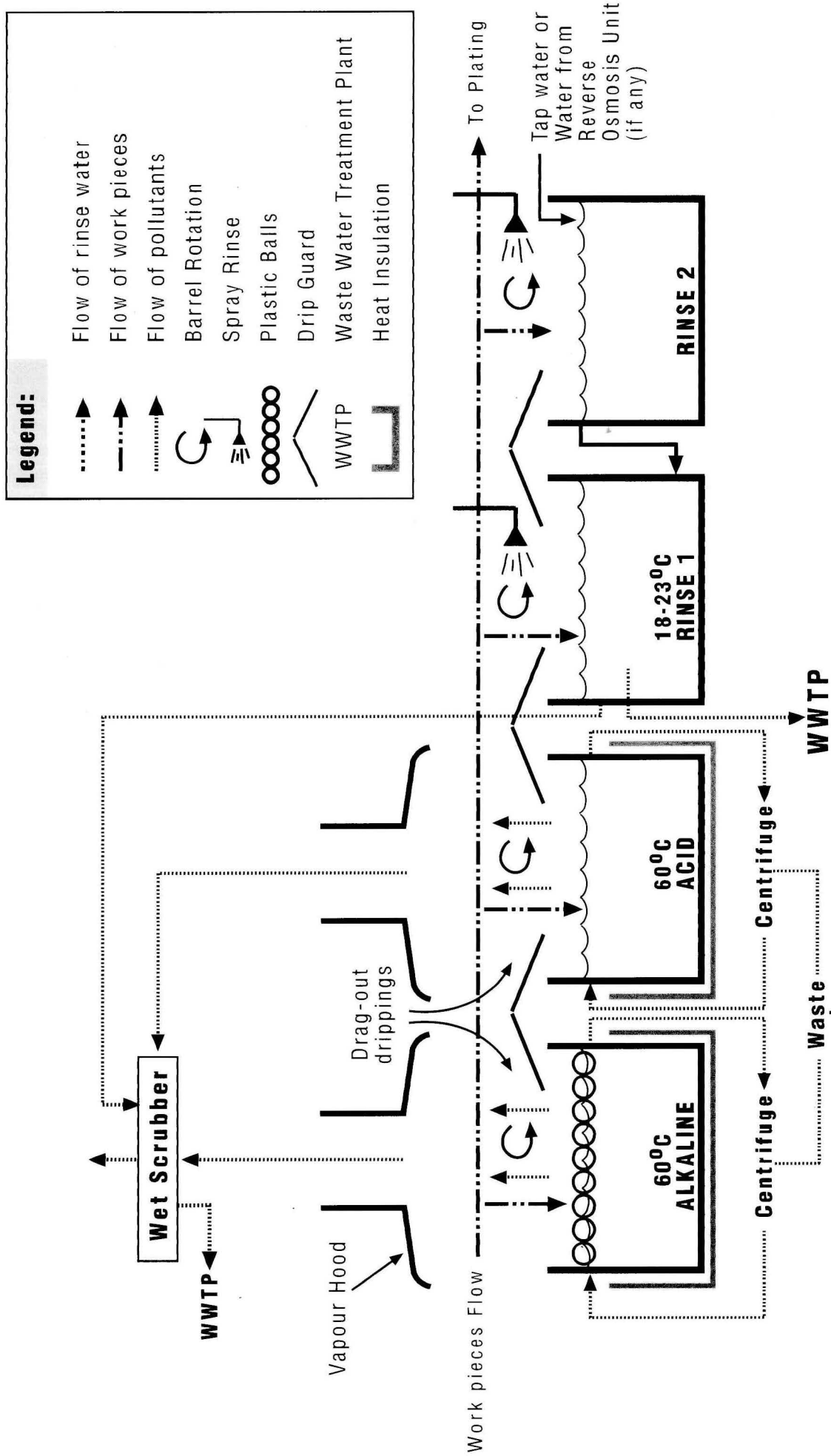


Figure 8 : Pre-treatment Operation - Cleaner Production Electroplating Work Step 1

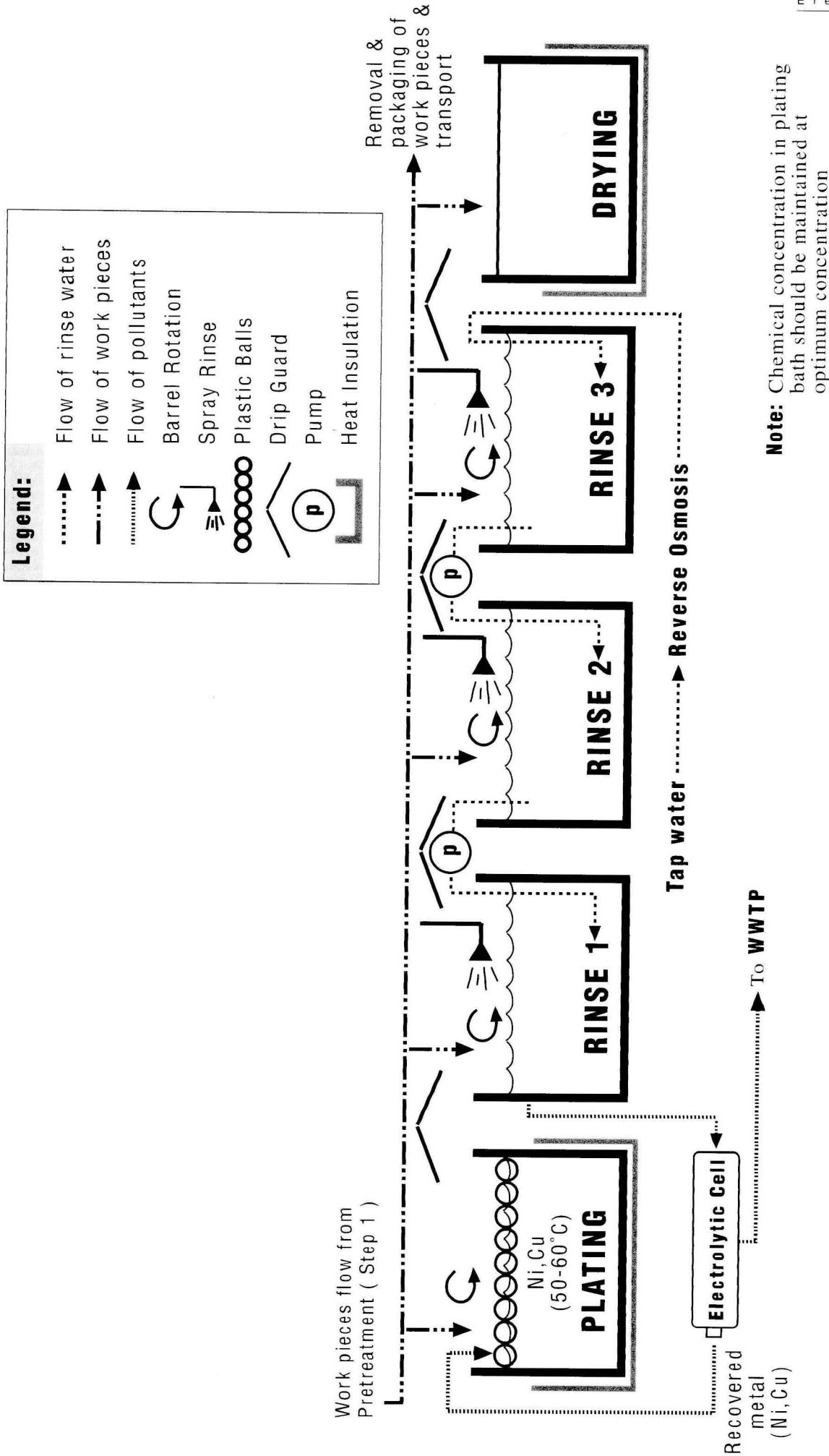
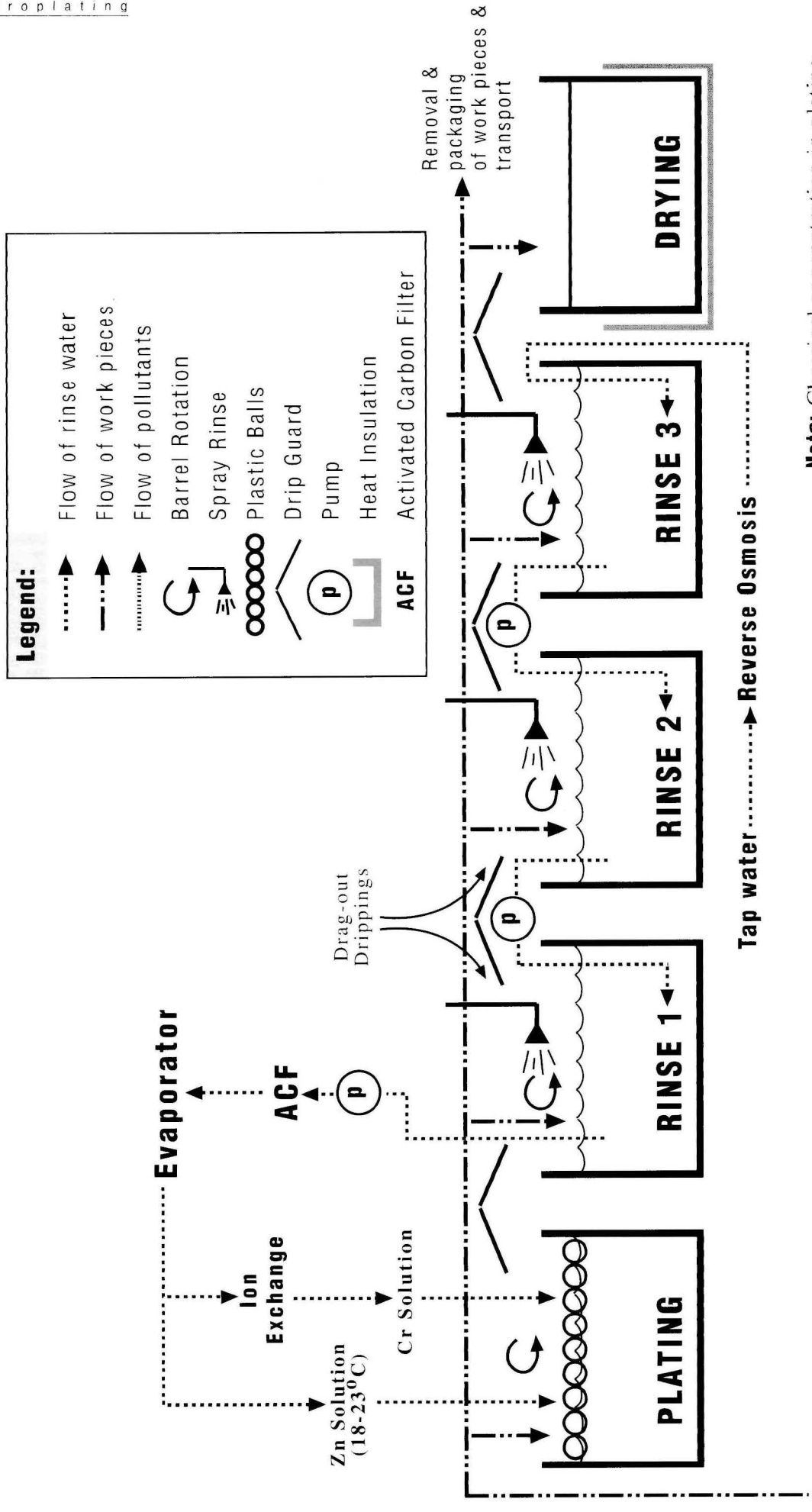


Figure 9 : Plating Operation - Cleaner Production for Nickel & Copper Plating Electroplating Work Step 2



Note: Chemical concentration in plating bath should be maintained at optimum concentration

Figure 10 : Plating Operation - Cleaner Production for Zinc & Chromium Plating Electroplating Work Step 2

7.4 POTENTIAL INITIATIVES AND COST ESTIMATES

Table 14 below gives an idea of the different cost ranges relating to the various initiatives.

Table 14 : Potential Initiatives and Cost Estimates

Applicability	Initiatives / Actions	Estimated Cost Range in RM
Low-tech measures	<ul style="list-style-type: none"> • Cleaning and maintenance <ul style="list-style-type: none"> - cleaning of raw materials by suppliers - replace worn-out tanks and leaky pipes - clean contact points and busbars - maintain rack insulation 	Negligible
	<ul style="list-style-type: none"> • Drip guard (polypropylene plastic material) between tanks 	Negligible
	<ul style="list-style-type: none"> • Replace leaky tanks and repair leaky pipes 	Negligible
	<ul style="list-style-type: none"> • Sheltered storage for chemical drums with containment bund but without drainage 	Negligible
	<ul style="list-style-type: none"> • Placement of plastic balls in hot process tanks 	Negligible
	<ul style="list-style-type: none"> • Insulation of hot process tanks and piping 	Negligible
Medium-tech measures	<ul style="list-style-type: none"> • Water flow meter and conductivity meter * 	800 - 5,000
	<ul style="list-style-type: none"> • Multiple counter-flow rinsing 	4,000 - 20,000
	<ul style="list-style-type: none"> • Barrel rotation * (at top position) 	6,000 - 12,000
	<ul style="list-style-type: none"> • Spray rinsing * 	4,000 - 20,000
	<ul style="list-style-type: none"> • Centrifuge (pre-treatment) 	40,000 - 60,000
High-tech measures	<ul style="list-style-type: none"> • Reverse osmosis 	50,000 - 250,000
	<ul style="list-style-type: none"> • Ultra filtration / Ultrasonic (pre-treatment) 	60,000 - 100,000
	<ul style="list-style-type: none"> • Back filling to plating baths <ul style="list-style-type: none"> - Evaporator bath and activated carbon filter - Electrolytic cell 	8,000 - 25,000 20,000 - 50,000

* Includes construction and installation of electrical contacts for operation mechanisms

Source : Mr. Claus Primdal Sørensen, 1998, Carl Bro International (Denmark)

Note : In view of the availability of different designs and systems, the details of costs can vary. The industry is encouraged to acquire the latest cost information from the equipment supplier if any cleaner production initiative in the above is taken up.

7.5 ADDRESSING FACTORY CONSTRAINTS

As indicated earlier, factories are perceived to face a number of constraints in wanting to practise pollution control. In view of the cleaner production measures mentioned above, it would appear that many of the factory constraints may be caused by lack of knowledge of relevant cleaner production measures. In fact, the constraints may be misperceptions or assumptions which may be overcome by the following arguments :

Table 15 : Addressing Factory Constraints

Factory Constraints	Counter Arguments
<ul style="list-style-type: none"> No profit in pollution control 	<ul style="list-style-type: none"> Profit margins can be expected to increase due to reduced costs on consumption of water and chemicals and fee for disposal of hazardous wastes Market potential may be enhanced due to improved product quality (being experienced by some local electroplaters already)
<ul style="list-style-type: none"> Space limitation to install the waste water treatment plant 	<ul style="list-style-type: none"> Main parts of CP measures are to be installed at the process lines and therefore require little extra space e.g. counter-flow rinsing In general, improved cleaning and maintenance procedures do not require dedicated separate space
<ul style="list-style-type: none"> High cost of land and factory space for the treatment equipment 	<ul style="list-style-type: none"> Medium tech measures require limited space e.g. ion exchanger to produce de-ionised water High tech measures may require some space e.g. reverse osmosis unit or ultra-filtration
<ul style="list-style-type: none"> High treatment equipment cost and recurrent operating cost of treatment 	<ul style="list-style-type: none"> The cost can be justified by the cost savings from reduced production costs
<ul style="list-style-type: none"> Poor pay-back period 	<ul style="list-style-type: none"> Prices of water and electricity can be expected to increase in the future and thereby the pay-back time may be more attractive – normally can be brought down to below 2 years
<ul style="list-style-type: none"> Difficulty to access financing 	<ul style="list-style-type: none"> Cleaner production can be packaged as process / productivity improvement projects Banks responding to the government's prompting are giving end financing up to 90%. Many incentive schemes are available to SMIs
<ul style="list-style-type: none"> Lack of access to technology 	<ul style="list-style-type: none"> Information guidelines are available from DOE, SIRIM, private consultants, industry magazine, internet and component suppliers
<ul style="list-style-type: none"> Inadequate waste management skills 	<ul style="list-style-type: none"> Available from SIRIM and CP consultants Some CP measures do not require specific waste management skills but only proper maintenance and modifications of process lines in order to implement good process operational practices

7.6 SELF- REGULATION

Environmental protection is the co-responsibility of each and everyone. In practical terms, it is an obligation on the part of the factory to self-regulate. Being voluntary, this self-regulation requires commitment and effort. With the arrival of more stringent international standards such as the ISO 14001 being imposed by foreign buyers on export-bound products, it is the aspiration of DOE that all factories self-regulate - the sooner the better.

7.6.1 Objective

The immediate objectives of self-regulation are to :

- *stimulate factories to accept the responsibility for carrying out changes on their own rather than react to public complaints or a crisis*
- *raise the level of environmental awareness among all factory employees*
- *improve environmental practices to minimise wastes and pollution*
- *monitor environmental performance*
- *demonstrate compliance with regulations (which is the minimum requirement)*

It should be clearly understood that complying with the regulatory limits is not the ultimate objective. The ideal is to reduce as much pollution load through minimisation of water consumption, energy consumption and waste generation using the best available affordable means.

7.6.2 Requirements

Self-regulation focuses on environmental performance which requires the industry to :

- *reduce, recover and recycle wastes*
- *develop a programme to monitor the various processes*
- *recognise problems leading to non-compliance*
- *design and implement action plan(s) in event of non-compliance or to ensure compliance*

7.6.3 Monitoring

In monitoring, the larger enterprises are expected to be in the better position to monitor more than the small and medium-scale enterprises. The following monitoring programme (Table 16) may be proposed :

Table 16 : Recommended Monitoring Programme

Environmental Monitoring	Parameter To Monitor	Small Medium Enterprises	Large Enterprises
Input	• Water consumption	Daily	Daily
	• Energy consumption	Monthly	Daily
	• Chemical usage	Daily	Daily
Operational Performance	• Water inlet flow rate	Hourly	Hourly
	• Chemical concentration in plating bath	Every two hours	Every two hours
	• Rotation of plating barrels	Daily	Daily
	• Insulation of racks	Weekly	Weekly
Output	• Wastewater generation	Monthly	Daily
	• Sludge generation	Monthly	Daily
	• Production volume	Daily	Daily
Wastewater Quality	• Chemical oxygen demand (COD)	} Monthly testing and quarterly reporting	Daily*
	• Suspended solids (SS)		Daily*
	• Oil and grease (O&G)		Daily*
	• Heavy metals		Daily*
Air Quality	• Gases & vapours** (from baths / extraction outlet)	} Monthly testing and quarterly reporting	Weekly
	• Metallic dust (at buffing area)		Weekly

* Larger enterprises should adopt the continuous monitoring system

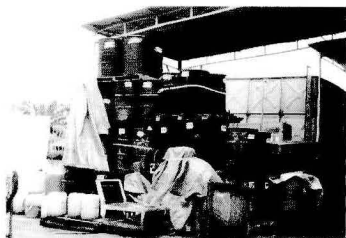
** As per Regulation 26 of EQ (Clean Air) Regulations 1978

7.6.4 Environmental Performance Indicators

It is essential in self-regulation to appraise the degree of programme effectiveness. The effectiveness of the self-regulation program is evaluated by performance indicators. Indicators basically provide the bigger picture of the current situation and also give an insight into the performance trend. These key indicators include :

Table 17 : Environmental Performance Indicators

Area	Key Performance Indicators
1. Regulation Compliance	<ul style="list-style-type: none"> • Compliance with requirements of EQA and regulations • Violation recorded by DOE
2. Operational Performance	<ul style="list-style-type: none"> • Implementation of corrective actions • Area of surface plated (m²) • Amount of monthly waste generation • Chemical, water and energy consumption
3. Due Diligence	<ul style="list-style-type: none"> • Environmental Management System/Enviro. Management Plan • ISO 14001 accreditation
4. Public Complaints	<ul style="list-style-type: none"> • Number of public complaints • Number of repeated complaints • Response time during / after receipt of complaint
5. Environmental Award, e.g. Prime Minister's Hibiscus Award	<ul style="list-style-type: none"> • Outstanding environmental performance / achievement



8.0 INSPECTION FOCUS

The carrying out of an inspection basically consists of three related activities. It involves the planning of an inspection visit, the performance of the inspection and the conclusion of the inspection.

A DOE manual on practical enforcement, dealing with the general procedure for preparation, implementation and follow-up of inspection visits, has been developed separately to assist the DOE inspection officers in their enforcement activities.

This Section on Inspection Focus is industry-specific and serves as a supplement to the above DOE Practical Enforcement Manual. The purpose is to provide:

- *guidance or the essential background information that should be obtained before the inspection*
- *the inspection checklist for (a) good housekeeping and cleaner production opportunities and (b) regulation compliance respectively*
- *the recording worksheets to be used for (a) and (b)*
- *guidance on the potential areas of environmental improvement for discussion at the closing meeting with the factory management*

The following are important points to consider when inspecting an electroplating factory.

Main Issues

In the electroplating industry, the spillage of chemicals is often a problem. These are caused by:

- *a certain amount of "drag-out" of chemicals occurring due to adherence to the workpiece as they are removed from the alkali/acid cleansing tanks, plating baths and rinsing tanks;*
- *accidental spillages or leakages of chemical solutions from baths and tanks;*

An additional issue is the disposal of spent solution from baths and tanks. These chemical solutions are dangerous because of their content of heavy metals. Spillages and leakages of these chemical solutions, not only result in run-offs to stormwater drains and eventual pollution of watercourses, but also economic losses due to wastage.

Of the 4 potential pollution sources - wastewater, scheduled wastes, air emissions and noise. It is usually the case that:

- *the two most important pollution sources are wastewater and scheduled wastes;*
- *air emissions are usually minor; while*
- *noise emission is also usually not significant.*

Inspection Objectives

The objectives of inspection are :

- *to check on the condition of housekeeping and potential for implementation of cleaner production;*
- *to check on the status of regulatory compliance;*
- *to enable advice to be given on environmental performance improvements and cleaner production*

Inspection Steps

With the above in mind, the main steps associated with a factory inspection include:

- (a) Pre-inspection planning and background information-gathering
- (b) Factory inspection
- (c) Closing meeting with factory management
- (d) Reporting and follow-up

a) PRE-INSPECTION BACKGROUND INFORMATION

The inspector would need to know, among other things, at least :-

- **factory background details:**

- operating hours (number of shifts, number of working days)
- number of staff
- age of factory

(The above information serves to indicate the size of the factory and the degree of receptiveness to environmental improvement)

- **production processes:**

- raw materials and chemicals used
- finished products
- process flow chart(s)
- piping / drainage layout(s)

(The above information will help the inspector to know the wastes to expect)

- **electroplating inputs**

- chemical consumption (and costs)
- water consumption (and costs)
- electricity consumption (and costs)

(The above information gives an idea of the production costs. Any proposed additional cost expenditure to improve environmental performance will have to be compared against these baseline costs)

- **electroplating outputs**

- production throughput (plated products)

(The above information can lead the inspector to ask for the expansion plans of the factory, if any)

- wastewater generation (from degreasing, acid/alkali cleaning, plating bath, rinsings)
 - waste type according to the categories of waste listed in the first schedule of EQ (Scheduled Wastes) Regulations 1989
 - quantity
 - treatment
 - discharge location

(The above information gives an idea of the management of the wastewater during the inspection)

- scheduled waste generation (sludge, fluxes etc)
 - scheduled category according to DOE scheduled waste code
 - treatment
 - disposal location
 - quantities
 - storage
 - waste disposal costs

(The above information gives an idea of the management of the scheduled wastes during the inspection)

- air emission
 - type of substance emitted
 - control system
 - final emission location

(This information indicates whether there is management of air emissions or not)

b) FACTORY INSPECTION

It is noteworthy that the inspection area of an average electroplating factory is usually not large - about the size of one to two link houses. However, the factory space can be quite congested with plant equipment, tanks, baths etc. As such, inspection accessibility can be difficult at times.

The factory inspection helps to :

- *verify data*
- *resolve uncertainties / inconsistencies, and*
- *identify missing or inaccurate data or obtain additional information*

To systematically cover the entire factory, a good approach is to conduct the inspection according to the production flow and include the two supporting activities, namely :

- *the raw materials reception and despatch activity, and*
- *the waste treatment, handling, labelling, storage and disposal activity*

This approach is beneficial in that it does not miss out any functional areas, processes and activities which may generate environmental impacts. In this regard, it would be beneficial if the inspection is timed to coincide with certain particular factory operations, such as :

- *factory start-up*
- *chemical addition to the plating baths*
- *solution dumping of the baths and/or tanks*
- *collection of wastes by waste collector*

To carry out the site inspection, checklists would be needed for guidance while worksheets would also be required for recording the observations and /or findings. For this purpose, two checklists and two worksheets have been developed. These are the :

- *Checklist for Good Housekeeping and Cleaner Production Opportunities*
- *Checklist for Regulatory Compliance*
- *Recording Worksheet for Good Housekeeping and Cleaner Production Opportunities*
- *Recording Worksheet for Regulatory Compliance*

i) Inspection Checklist on Good Housekeeping and Cleaner Production

The sample inspection checklist such as the one shown in Table 18 can be conveniently used to know what to look for in the context of good housekeeping and cleaner production opportunities.

**Table 18 : Inspection Checklist
for Good Housekeeping and Cleaner Production Opportunities**

Production Flow Sequence	Model Situation	Inspection Focus
1. Bulk material reception and despatch	<ul style="list-style-type: none"> • <i>clean and tidy area</i> 	<u>Look-out for</u> <ul style="list-style-type: none"> - litter - careless container storage <u>Cleaner Production Opportunities</u> <ul style="list-style-type: none"> - clear labelling of containers - free movement for forklift
2. Storage of raw materials <ul style="list-style-type: none"> - liquid materials - solid materials 	<ul style="list-style-type: none"> • <i>clean and tidy area</i> • <i>leak-proof containers</i> • <i>separation of containers with incompatible chemicals</i> • <i>spillage containment / bunding</i> • <i>recovery measures</i> • <i>proper storage and handling</i> • <i>drums placed on pallets</i> • <i>free movement for forklift</i> 	<u>Look-out for</u> <ul style="list-style-type: none"> - odours, fumes - damaged or uncovered containers - spillages - undersized bunding - leakage of chemicals <u>Cleaner Production Opportunities</u> <ul style="list-style-type: none"> - sheltered storage - concrete floor sloping to a sump - drums clearly labelled - proper ventilation
3. Mechanical cleaning of raw materials	<ul style="list-style-type: none"> • <i>clean and tidy area</i> • <i>localised air emission</i> 	<u>Look-out for</u> <ul style="list-style-type: none"> - ventilation - dust particles and fumes - metal scraps and debris - spillage of oils and lubricants - noise <u>Cleaner Production Opportunities</u> <ul style="list-style-type: none"> - suppliers to pre-clean their raw materials for plating - use centrifuge to pre-clean
4. Solvent degreasing or alkaline cleaning	<ul style="list-style-type: none"> • <i>label to indicate name and chemical contents of tank</i> • <i>vapour emission control & reduction</i> • <i>waste management and disposal of spent solutions and sludges</i> • <i>regular monitoring of alkaline concentration</i> 	<u>Look-out for</u> <ul style="list-style-type: none"> - spillage - leaks (tanks, pipes etc) - factory monitoring data - heat source <u>Cleaner Production Opportunities</u> <ul style="list-style-type: none"> - use corrosion-resistant tank - use vapour hood - use plastic balls - use spray rinsing - install drip guard - insulate tank - ultra-filtration for inlet water - ultrasonic degreasing - maintain alkaline concentration - energy reduction

Production Flow Sequence	Model Situation	Inspection Focus
5. Degreasing/alkaline clean rinsing	<ul style="list-style-type: none"> • <i>label to indicate name and chemical contents of tank</i> • <i>wastewater reduction and treatment</i> • <i>proper dumping of spent solution</i> 	<p><u>Look-out for</u></p> <ul style="list-style-type: none"> - spillage - leaks (tanks, pipes etc) - drag-out from cleaning tank <p><u>Cleaner Production Opportunities</u></p> <ul style="list-style-type: none"> - use corrosion-resistant tank - use spray rinsing - use counter-flow rinsing - use drip guard - use conductivity meter to indicate cleanliness of rinse water - use ion-exchanger or reverse osmosis to improve process water quality
6. Acid cleaning	<ul style="list-style-type: none"> • <i>label to indicate name and chemical contents of tank</i> • <i>vapour emission control & reduction</i> • <i>waste management and disposal of spent solutions and sludges</i> • <i>regular monitoring of acid concentration</i> 	<p><u>Look-out for</u></p> <ul style="list-style-type: none"> - spillage - leaks (tanks, pipes etc) - drag-out from rinsing tank - factory monitoring data <p><u>Cleaner Production Opportunities</u></p> <ul style="list-style-type: none"> - use corrosion-resistant tank - insulate tank - use drip guard - maintain acid concentration
7. Acid clean rinsing	<ul style="list-style-type: none"> • <i>label to indicate name and chemical contents of tank</i> • <i>wastewater reduction and treatment</i> • <i>proper dumping of spent solution</i> 	<p><u>Look-out for</u></p> <ul style="list-style-type: none"> - spillage - leaks (tanks, pipes etc) - drag-out from acid tank <p><u>Cleaner Production Opportunities</u></p> <ul style="list-style-type: none"> - use corrosion-resistant tank - use spray rinsing - use counter-flow rinsing - use drip guard - use conductivity meter to indicate cleanliness of rinse water
8. Plating	<ul style="list-style-type: none"> • <i>label to indicate name and chemical contents of tank</i> • <i>optimised addition of chemicals</i> • <i>regular monitoring of chemical concentration</i> • <i>proper vapour control system</i> • <i>regular maintenance of vapour control system</i> • <i>waste management and disposal of spent solutions and sludges</i> • <i>regular monitoring of chemical concentration</i> 	<p><u>Look-out for</u></p> <ul style="list-style-type: none"> - spillage - leaks (tanks, pipes etc) - widespread vapour within factory - outlet of air scrubbing system - factory monitoring data <p><u>Cleaner Production Opportunities</u></p> <ul style="list-style-type: none"> - use corrosion-resistant tank - insulate tank - use plastic balls - automation to optimise chemical concentration - rotate plating barrels at top position - use drip guard - clean contact points and busbars - maintain rack insulation - use evaporator to reduce voluminous quantity of counter-flow rinse water

Production Flow Sequence	Model Situation	Inspection Focus
9. Plating rinse	<ul style="list-style-type: none"> • <i>label to indicate name and chemical contents of tank</i> • <i>wastewater reduction and treatment</i> • <i>proper dumping of spent solution</i> 	<p><u>Look-out for</u></p> <ul style="list-style-type: none"> - spillage - leaks (tanks, pipes etc) - drag-out from plating bath <p><u>Cleaner Production Opportunities</u></p> <ul style="list-style-type: none"> - use corrosion-resistant tank - use spray rinsing - use counter-flow rinsing - use drip guard - use reverse osmosis to treat last rinse water for use as inlet water - use electrolytic cell or ion exchanger to recover heavy metals from used rinsing water for reuse in process baths - use conductivity meter to indicate cleanliness of rinse water
10. Drying	<ul style="list-style-type: none"> • <i>label to indicate name of process unit</i> • <i>obstruction free</i> 	<p><u>Look-out for</u></p> <ul style="list-style-type: none"> - rinse water drips - heaters <p><u>Cleaner Production Opportunities</u></p> <ul style="list-style-type: none"> - tank insulation - energy usage reduction
11. Wastewater treatment	<ul style="list-style-type: none"> • <i>proper operation of wastewater treatment plant</i> • <i>proper disposal of sludge</i> 	<p><u>Look-out for</u></p> <ul style="list-style-type: none"> - odours - other cover-up measures - unknown discharge or run-off under boundary fence - factory monitoring data <p><u>Cleaner Production Opportunities</u></p> <ul style="list-style-type: none"> - use spent acid to neutralise an alkaline waste stream or vice versa - waste segregation to facilitate salvage, treatment and disposal
12. Temporary storage of waste materials	<ul style="list-style-type: none"> • <i>Sign with wording "hazardous waste area" at entrance of storage area</i> • <i>clean and tidy area</i> • <i>floor is sloped to drain spills / leaks</i> • <i>consignment note system in place</i> • <i>proper inventory list</i> • <i>proper labelling</i> • <i>stacking of containers not more than 3 tiers</i> 	<p><u>Look-out for</u></p> <ul style="list-style-type: none"> - hazardous wastes inventory - containers unlabelled, corroded, bulging or leaking - remote areas or building for forgotten drums of hazardous materials (used / recycled drums) - waste collection activity by waste collector <p><u>Cleaner Production Opportunities</u></p> <ul style="list-style-type: none"> - containers to be on pallets - proper stacking of containers - waste segregation to facilitate salvage, treatment and disposal

The format on the next page is a sample recording worksheet for the gathering and registering of the above information.

**Table 19 : Recording Worksheet
In Relation To Good Housekeeping And Cleaner Production**

INSPECTION OF (Name of Factory)

Inspection Date :

Inspection Time :

Legend : Evidence

- Photos
 Samples
 Factory records

Findings

- S = Satisfactory
U = Unsatisfactory
F = Further Investigation

Waste Treatment

- R** = Recycling
r = Recovery
NT = No Treatment
T = With Treatment

Waste Destination

- ID** = Internal Disposal
ED = External Disposal

(Tick where applicable)

(Circle Where Applicable)

Inspection Area	Findings	Observations	Evidence Taken	Ref. No
Bulk material reception/despatch	S / U / F		<input type="checkbox"/> Photos <input type="checkbox"/> Samples <input type="checkbox"/> Factory records	
Chemical storage	S / U / F		<input type="checkbox"/> Photos <input type="checkbox"/> Samples <input type="checkbox"/> Factory records	
Mechanical cleaning	S / U / F		<input type="checkbox"/> Photos <input type="checkbox"/> Samples <input type="checkbox"/> Factory records	
Degreasing and rinsing	S / U / F		<input type="checkbox"/> Photos <input type="checkbox"/> Samples <input type="checkbox"/> Factory records	
Acid cleaning and rinsing	S / U / F		<input type="checkbox"/> Photos <input type="checkbox"/> Samples <input type="checkbox"/> Factory records	
Plating and rinsing	S / U / F		<input type="checkbox"/> Photos <input type="checkbox"/> Samples <input type="checkbox"/> Factory records	
Waste treatment	S / U / F	<ul style="list-style-type: none"> • Wastewater : R / r / NT / T • Solid wastes : R / r / NT / T • Air emission : R / r / NT / T 	<input type="checkbox"/> Photos <input type="checkbox"/> Samples <input type="checkbox"/> Factory records	
Waste storage	S / U / F	<ul style="list-style-type: none"> • Wastewater : • Solid wastes : 	<input type="checkbox"/> Photos <input type="checkbox"/> Samples <input type="checkbox"/> Factory records	
Waste destination	S / U / F	<ul style="list-style-type: none"> • Liquid waste : ID / ED • Solid wastes : ID / ED • Name of Waste Transporter : 	<input type="checkbox"/> Photos <input type="checkbox"/> Samples <input type="checkbox"/> Factory records	
Data Verification	Findings	Observations	Evidence	Ref.No
Electroplating input	S / U / F	<ul style="list-style-type: none"> • Chemical consumption : • Water consumption : • Electricity consumption : 		
Electroplating output	S / U / F	<ul style="list-style-type: none"> • Production volume : • Wastewater generation : • Solid waste generation : • Air emission generated : 		

Lead Inspector : Name

Designation

Date

ii) Inspection Checklist for Regulatory Compliance

Below is the inspection checklist on compliance with regulations.

Table 20 : Inspection Checklist for Regulatory Compliance

Final Discharge Status	Regulatory Requirement	Inspection Focus
Effluent discharge	<ul style="list-style-type: none"> • Compliance with regulatory limits 	<ul style="list-style-type: none"> - presence of monitoring and analysis - sampling locations and frequency - results of factory monitoring - public complaints
Solid wastes (sludge, flux wastes, degreasers, spent acid and alkali)	<ul style="list-style-type: none"> • Compliance with : <ul style="list-style-type: none"> - notification of generation - inventory of wastes - consignment note system 	<ul style="list-style-type: none"> - inventory of wastes - name of waste collector - period of on-site storage - public complaints
Air emission	<ul style="list-style-type: none"> • Compliance with air regulations 	<ul style="list-style-type: none"> - factory records - public complaints
Noise	<ul style="list-style-type: none"> • Compliance with noise level at boundary fence 	<ul style="list-style-type: none"> - factory records - public complaints

The format below is a sample recording worksheet for the gathering and registering of the above information.

Table 21 : Recording Worksheet For Regulatory Compliance

INSPECTION OF (Name of Factory)

Inspection Date :

Inspection Time :

Findings

(Circle where applicable)

NC= Non-Compliance

A = Acceptable

F = Further Investigation

Final Discharge Status	Inspection Focus	Evidence*	Findings
Effluent discharge	<ul style="list-style-type: none"> • Effluent by-pass • Effluent dilution • Discharge point • Discharge quality 	<input type="checkbox"/> Factory records <input type="checkbox"/> Samples taken <input type="checkbox"/> Photos	NC / A / F
Common parameter	<ul style="list-style-type: none"> • pH • Biochemical oxygen demand • Chemical oxygen demand • Suspended solids • Oil and grease 		
Specific parameter	<ul style="list-style-type: none"> • Copper, nickel, chromium, cyanide (for chrome plating) • Copper, cyanide (for copper plating) • Copper, nickel, cyanide (for nickel plating) • Silver, cyanide (for silver plating) • Zinc, cyanide (for zinc plating) 		
Solid wastes (sludge, flux wastes, degreasers, spent acid and alkali)	<ul style="list-style-type: none"> • Notification of generation • Inventory of wastes • Consignment note system 	<input type="checkbox"/> Factory records <input type="checkbox"/> Photos	NC / A / F
Air emission	<ul style="list-style-type: none"> • Visual fumes from air scrubbing system 	<input type="checkbox"/> Factory records <input type="checkbox"/> Photos	NC / A / F
Noise	<ul style="list-style-type: none"> • Factory noise meter 	<input type="checkbox"/> Factory records	NC / A / F

* Reference number should be recorded.

Lead Inspector : Name

Designation

Date

c) CLOSING MEETING WITH FACTORY MANAGEMENT

The main purposes of the closing meeting are to :

- *sum up the observations and findings*
- *ensure a common understanding on the findings so that misunderstandings are avoided*
- *enhance the awareness of the factory*
- *issue compounds if necessary*
- *announce any other formal follow-up by DOE as response to non-compliances*
- *arrange for a follow-up visit if necessary*
- *obtain a formal receipt confirming evidence and other material collected and the findings and conclusions of the inspection visit*

The general procedures relating to the above can be found in the corresponding section of the Practical Enforcement Manual.

Besides the above, the other purposes of the meeting are to :

- *discuss informally possible improvements of the environmental performance of the factory and*
- *to clarify and confirm any agreements made*

In the advice-giving role, the advice to give on improving environmental performance are summarised on the next page in **Figure 9** - Opportunities For Cleaner Production (condensed from **Tables 12, 13 and 14**).

d) REPORTING AND FOLLOW-UP

The main purposes of the reporting and follow-up are to ensure that :

- *all information and data collected are registered, filed and used appropriately*
- *further action is taken to ensure correct and sufficient enforcement response with the aim to enhance compliance*
- *the factory becomes aware of and understands the requirements for their environmental performance*
- *DOE's general commitment to enforcement of the EQA is demonstrated*

The general procedures relating to the above can be found in the corresponding section of the Practical Enforcement Manual.

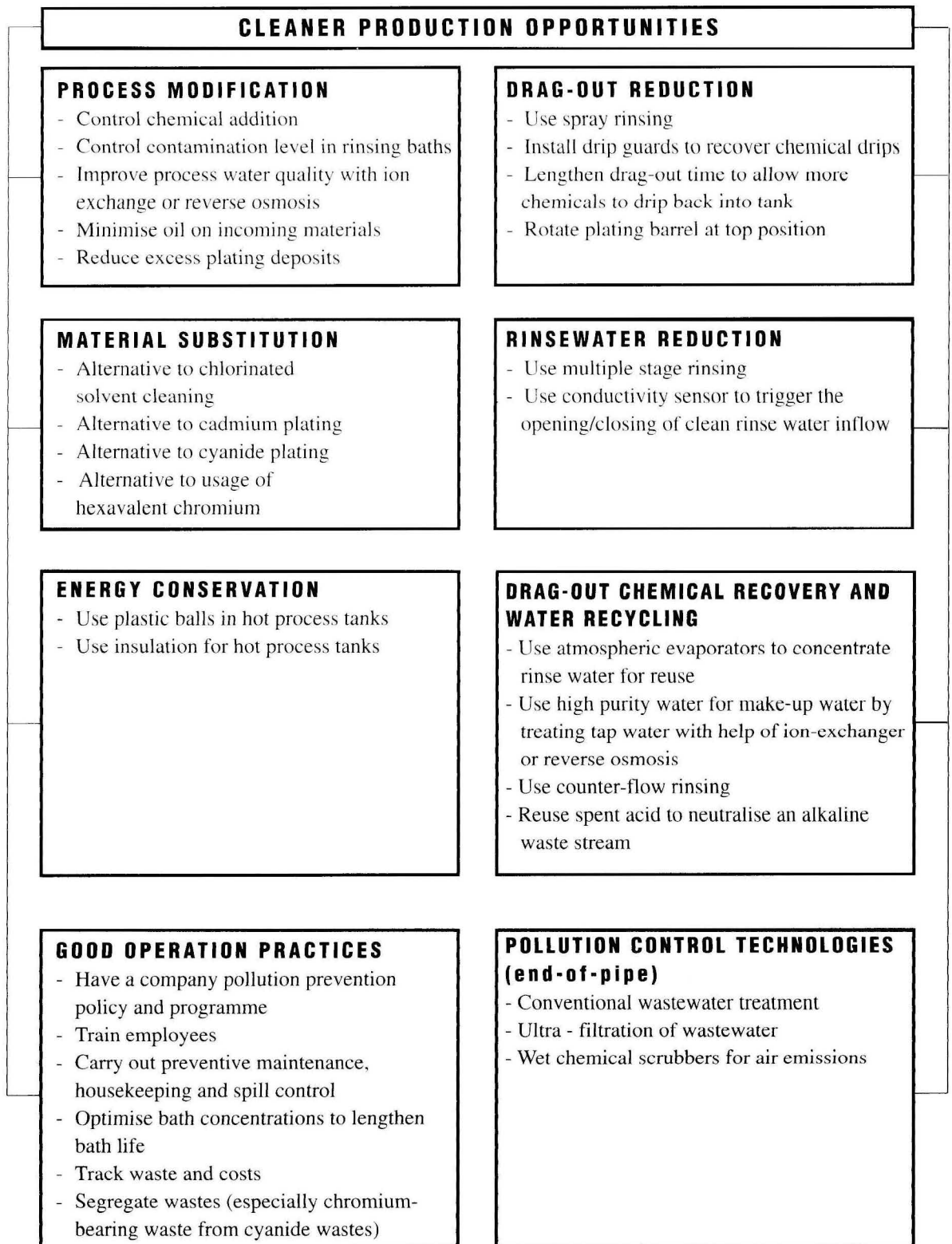


Figure 11 : Opportunities For Cleaner Production

ANNEX A : AIR EMISSION STANDARDS APPLICABLE TO METAL FINISHING

	Parameter	Emission Sources	Standard
1.	Dust	Any source	0.4 gm / Nm ³
2.	Metal and Metallic Compound		
	2.1 Mercury	Metal Finishing Industry	0.010 gm / Nm ³
	2.2 Cadmium	Metal Finishing Industry	0.015 gm / Nm ³
	2.3 Lead	Metal Finishing Industry	0.025 gm / Nm ³
	2.4 Antimony	Metal Finishing Industry	0.025 gm / Nm ³
	2.5 Arsenic	Metal Finishing Industry	0.025 gm / Nm ³
	2.6 Zinc	Metal Finishing Industry	0.100 gm / Nm ³
	2.7 Copper	Metal Finishing Industry	0.100 gm / Nm ³
3.	Gases		
	a) Acid gases	Sulphuric acid manufacturing	3.5 gm of SO ₃ eq / Nm ³ and no persistent mist
	b) Sulphuric acid mist or SO ₃ or both	Any sources other than (a)	0.2 gm of SO ₃ eq / Nm ³ and no persistent mist
	c) Chlorine gas	Any source	0.2 gm of HCl eq / Nm ³
	d) HCl	Any source	0.4 gm of HCl eq / Nm ³
	e) Fluorine, hydrofluoric acid, inorganic fluorine compound	Aluminium manufacturing from Alumina	0.20 gm of HF acid eq / Nm ³
	f) Fluorine, hydrofluoric acid, inorganic fluorine compound	Any source other than (e)	0.10 gm of HF acid eq / Nm ³
	g) Hydrogen sulphide	Any source	5 ppm (Volume %)
	h) NO _x	Nitric acid manufacturing	1.7 gm SO ₃ eq / Nm ³ and substantial colourless
	i) NO _x	Any source other than (h)	2.0 gm SO ₃ eq / Nm ³

Note:

* eq = equivalent

Source : *Environmental Quality (Clean Air) Regulations 1978*

ANNEX B : PARAMETER LIMITS OF EFFLUENT OF STANDARDS A AND B

Parameter	Unit	Standard	
		A*	B
i) Temperature	°C	40	40
ii) pH Value	-	6.0 – 9.0	5.5 – 9.0
iii) BOD ₅ at 20°C	mg / l	20	50
iv) COD	mg / l	50	100
v) Suspended Solids	mg / l	50	100
vi) Mercury	mg / l	0.005	0.05
vii) Cadmium	mg / l	0.01	0.02
viii) Chromium, Hexavalent	mg / l	0.05	0.05
ix) Arsenic	mg / l	0.05	0.10
x) Cyanide	mg / l	0.05	0.10
xi) Lead	mg / l	0.10	0.5
xii) Chromium, Trivalent	mg / l	0.20	1.0
xiii) Copper	mg / l	0.20	1.0
xiv) Manganese	mg / l	0.20	1.0
xv) Nickel	mg / l	0.20	1.0
xvi) Tin	mg / l	0.20	1.0
xvii) Zinc	mg / l	1.0	1.0
xviii) Boron	mg / l	1.0	4.0
xix) Iron (Fe)	mg / l	1.0	5.0
xx) Phenol	mg / l	0.001	1.0
xxi) Free Chlorine	mg / l	1.0	2.0
xxii) Sulphide	mg / l	0.50	0.50
xxiii) Oil and Grease	mg / l	Not Detectable	10.0

Note:

- * This standard applies to the industrial and development projects which are located within catchment areas (areas upstream of surface or above sub-surface water supply intakes, for the purpose of human consumption including drinking)

Source : Environmental Quality (Sewage and Industrial Effluents) Regulations 1979

ANNEX C : SCHEDULED WASTE REQUIREMENTS

	Requirement	Regulation No. / Order
1.	<ul style="list-style-type: none"> 107 categories of wastes have been classified as scheduled wastes 	EQ (Scheduled Wastes) Regulations Section 2, First Schedule
	<ul style="list-style-type: none"> Wastes generators should ensure their wastes are classified under schedule waste 	EQ (Scheduled Wastes) Regulations Section 2, First Schedule
	<ul style="list-style-type: none"> New generators of scheduled wastes are required to notify the DOE within one month from the date of generation of wastes 	EQ (Scheduled Wastes) Regulations Section 3, Second Schedule
2.	<ul style="list-style-type: none"> Scheduled wastes can be stored, recovered and treated within the premises of the waste generators 	EQ (Scheduled Wastes) Regulations Section 5
	<ul style="list-style-type: none"> Such activities do not require licensing by the DOE 	
	<ul style="list-style-type: none"> However, land farming, incineration, disposal and off-site facilities for recovery, storage and treatment can only be carried out at prescribed premises licensed by the DOE 	EQ (Scheduled Wastes Treatment and Disposal Facilities) Order, Section 3
3.	<ul style="list-style-type: none"> Waste generators shall also keep an up-to-date inventory of scheduled wastes generated, treated and disposed off 	EQ (Scheduled Wastes) Regulations Section 9, Fifth Schedule
	<ul style="list-style-type: none"> Proper labelling, containers and storage areas as well as prohibition of storage of incompatible waste are also required by law 	EQ (Scheduled Wastes) Regulations Section 8(2) and (3), Third Schedule
4.	<ul style="list-style-type: none"> In the case of transporting the waste from the waste generator to the treatment and disposal facilities, the transporting of waste shall conform to the consignment note system whereby the movement of waste is monitored until it reaches the approved destination 	EQ (Scheduled Wastes) Regulations Section 10, Sixth Schedule
	<ul style="list-style-type: none"> It is the responsibility of a waste generator to monitor and ensure that the waste transported from this factory reaches the approved destination 	EQ (Scheduled Wastes) Regulations Section 7
	<ul style="list-style-type: none"> The waste generator is responsible to inform the transport contractor regarding the nature of the waste and what actions to be taken during accidents to minimise damage to human life and the environment 	EQ (Scheduled Wastes) Regulations Section 11

Source : Environmental Quality (Scheduled Wastes) Regulations 1989

ANNEX D : NOISE GUIDELINES ALONG FACTORY PERIMETER FENCE

The noise at the factory boundary fence must not exceed the following levels :

Noise Target	Time
60 dBA during daytime	7 am - 10 pm
50 dBA during night-time	10 pm - 7 am

Source : DOE Guidelines on the Siting and Zoning of Industries 1976 (revised 1994)

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