Natsurv 2:

Water and Wastewater Management in the Metal Finishing Industry

(Edition 2)

HA Ally, W Kamish and T van der Spuy

WATER RESEARCH COMMISSION

TT 644/15

NATSURV 2: Water and Wastewater Management in the Metal Finishing Industry (Edition 2)

Report to the
Water Research Commission

by

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Stellenbosch University in association with the Metal Finishing Academy of South Africa

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Executive summary

The aim of this project is to undertake a survey of the South African Metal Finishing industry in order to obtain an overview of operations, specific water use, specific effluent volume and the extent to which best practice is being implemented. This was achieved through a review of the appropriate literature, holding workshops, interviewing companies and undertaking site visits.

A previous survey of this industrial sector was conducted in 1987 by Binnie and Partners Consulting Engineers. Since this time, the industry has undergone a number of significant changes such as new legislation, updated technology as well as the introduction of new processes and environmentally friendly chemicals. In addition, there is growing awareness of the need to optimise water use and reduce the production of waste, and this should be reflected in the specific water consumption and effluent production. It was therefore considered an opportune time to review the water and wastewater management practises of the industry and identify the changes that have been made since the 1987 survey.

The regional distribution of companies as well as the number of companies included in this industry survey is shown in **Table A**. In addition to the industry survey, a survey was also undertaken amongst the six biggest suppliers of equipment and chemicals to the metal finishing sector (supplier survey).

Table A – Regional distribution of companies of surveyed

	WC	Gauteng	KZN	Totals
Facilities	7	7	6	20
Production lines	24	40	20	84

Important findings from the surveys can be summarised as follows:

- The size of the industry varies between and 100 (SAMFA estimate) and 300 (supplier survey) factories.
- There is about an equal split between the amount of companies which are classified as jobshops and in-house establishments.
- 57% of the factories surveyed have certification and of these certificated factories 59% have ISO 9000 certification.
- The supplier and industry surveys suggest that single rinses still constitute between 50% and 75% of all the rinses in the industry, despite the fact that it is well known that dual and triple counterflow rinsing schemes result in significant water savings.
- Based on the data obtained from the supplier survey, it is evident that the uptake of cleaner production techniques is marginal with:

    - 63% of all zinc-plated solutions still being cyanide based
    - 70% of all post zinc plating passivation treatments still being Cr (VI) based
    - zero operating Cr (III) plants and
    - less than 1% of all the operating facilities having alkaline non-cyanide copper processes.

- 75% of the facilities are operating dragout tanks, but only 36% are recovering chemicals from the dragout tanks to the plating tanks.
- The implementation of best practise techniques is more likely to occur at in-house facilities and bigger companies.

A comparison of the Specific Water Index (SWI) results from both the previous study and the current survey are provided in the **Table B** below.

Table B – Comparison of SWIs obtained from 1987 and current survey

Time period	**Range of SWI (l/m^2)**	**Mean (l/m^2)**
Binnie 1987	30-1290	310
This study	4.23-399.57	95.02

The SWI results indicate that water in the sector is being used more efficiently. In fact, the international benchmark of 40 l/m^2 is improved on by several of the companies surveyed. Data collected on cleaner production (CP), however, indicates that the uptake of CP is very slow and this could be attributed to financial reasons and the current skill level of operators in the sector. For example, Cr (III) plating plants require more capital investment and the process requires a highly skilled technician to ensure that it operates as intended. The significant financial risk associated with the instability of the economy therefore does not justify the investment in expensive capital equipment nor the hiring highly skilled labour for operation of a Cr (III) plant.

The biggest barrier to the implementation of CP and best practise techniques now, as it was in the 1980s, is financial. Companies are not prepared to invest in CP in an uncertain economic environment, where this investment may not necessarily result in an increased revenue stream.

ACKNOWLEDGEMENTS

The research in this report emanates from a project that was undertaken for the Water Research Commission entitled:

NATSURV 2: Water and Wastewater Management in the Metal Finishing Industry (Ed 2)

The Reference Group is thanked for contributing their knowledge and insights to the project and the content of this guide.

The project team would like to extend their thanks to the following people:

- All the metal finishing companies who gave of their time to complete the survey and participate in the site visits and interviews

- The regulators who provided input into the development of the guide

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GLOSSARY

Anode	is an electrode through which an electric current flows into a polarised electric device
EPA	environmental protection agency
ISO	international standards organisation
METSEP	METals SEParation is the Johannesburg based company that recycles acids for industry. www.metsep.co.za
mg/m^3	milligrams per cubic metre (concentration)
Micron	1 millionth of a metre
MSDS	materials safety and data sheet
ppm	parts per million (concentration)
SABS	South African Bureau of Standards
SAMFA	South African Metal Finishing Association.
Tensides	is a substance which lowers the surface tension between two liquids and supports the formation of dispersions. They are also known as emulsifying agents
UNEP	United Nations Environment Program
zamak	is an alloy of zinc aluminium magnesium and copper and is used extensively in die casting industry – also commonly known in RSA as mazak

1. BACKGROUND

1.1 INTRODUCTION

The last National Survey relating to the management of resources in the Metal Finishing Industry was completed in October 1987, 25 years ago. Since then there has been concerted effort to develop coating systems that rely on more environmentally friendly chemicals along with scientific evaluation of process lines that has resulted in significant improvements to layout and handling methods.

Since the last NATSURV, a portion of the South African metal finishers have benefitted from financial and technical assistance from DANIDA (the Danish Foreign Aid agency) with the implementation of our own Resource Conservation program. This initiative, the CPMFI project [Cleaner Production in the Metal Finishing Industry] ran for a period of three and a half years, officially ending in 2004 and culminating in the establishment of SAMFA, the South African Metal Finishing Association.

Ultimately eighteen companies rebuilt their plants with partial subsidies from DANIDA totalling 1.2 million rand. Together they achieved combined savings of around 3.8 million rand in year one and on average recouped their investments through savings in an average period of 18 months. Scores of other companies made smaller but measurable improvements using their own resources.

To quantify the extent to which the metal finishing industry in South Africa has changed since the last NATSURV conducted in 1987, it was again necessary to collate up-to-date information such that meaningful conclusions could be drawn.

The major outcomes expected from this study are as follows:

- A review of current state of the metal finishing sector which would provide the platform for further initiatives aimed at positively transforming the sector.

- The development of a product that will allow more cost effective planning for the sector, resulting in better run factories with the potential to become more profitable.

- An assessment of the extent of compliance with ISO 14000 and Chemicals Management Action Plans (CMAP) to provide an indication of the protective measures currently provided to workers in this sector.

- To provide an indication of the varying degrees of training required for general worker safety awareness, the use of personal protective gear, correct operational procedures, improving the state of poor housekeeping and to rectify poor administration.

1.1.1 Industry overview

It is often necessary to use metals or metal alloys which have certain surface properties, e.g. resistance to corrosion, hardiness, high temperature tolerance, etc. Generally, no one metal will possess all the necessary properties. For example, steel has many good properties. It is inexpensive, abundant and a strong material that can easily be worked into all manner of shapes and forms. However, its major flaw is poor resistance to corrosion, causing it to rust severely in damp atmospheres. It needs to be coated with another material to provide corrosion resistance. The term metal finishing refers to a range of techniques that treat metal surfaces for its intended purpose. Metal Finishing enables the engineer to combine the good mechanical properties of one metal with the desirable surface properties of another. Electroplating, one of these processes thus offers the engineer a wide choice in combining various metals in determining a specific objective.

Currently, metal finishing operations take place in two broadly defined divisions:

1. **The jobbing shop sector (or commercial finishers)**: This sector includes businesses that offer metal finishing services to companies that elect not to install an in-house finishing capability to deal with their finishing requirements.

2. **In-house finishing operations**: It is possible that this sector has experienced growth since the last NATSURV, particularly amongst OEM (original equipment manufacturers) and second tier automotive component manufacturers (SAMFA, 2013). Some of the reasons for this growth are:

    - Inventory control is less complicated as parts are not transported to off-site locations;
    - The manufacturer is able to concentrate his resources on dealing with specific component configurations and finishes; and
    - The manufacturer is better able to manage finishing quality control, with no third party involvement

Even with a national survey, an estimate of the number of metal finishing installations in South Africa is difficult to quantify as a significant percentage of the work is performed in-house as an essential part of an overall manufacturing activity. The remainder of the metal finishing work is undertaken on a contract basis by specialist companies that include some large and dominant companies along with a greater number of smaller operators. Not all of the latter necessarily adhere to desirable industry standards, local and national legislation.

1.1.2 Industry Projection

The metal finishing sector does not form a major sector by itself, but it can be assumed that its growth can be directly related to events in the manufacturing sector in South Africa. This assumption is based on the fact that many of the in-house finishing operations exist because it offers a service to the manufacturing company to which it is attached. Smaller manufacturers who have not adopted in-house finishing or manufacturers who opt for outside contracting still make use of services provided by the jobbing shop sector. It is particularly difficult to gauge what percentage of the final product the metal finishing sector may claim, but trends and projections made for the manufacturing sector would be applicable to the metal finishing sector as well.

As the industry mirrors the manufacturing engineering industry and its market is a percentage of the overall industry, we have to be satisfied with the conclusion that a percentage of overall industry GDP can be allocated to this sector.

The size of the various sectors which constitute the South African economy is depicted in **Figure 1** which indicates that manufacturing contributed 15.2% to the GDP of South Africa which is a decrease of 3.8% since 1993. Between 1993 and 2010 the sector experienced growth of R 102 162 million (SEDA, 2012), but in spite of this growth its contribution to the GDP still decreased by 2%, implying that the contribution to the GDP of the metal sector is actually growing slightly slower than the other economic sectors. A detailed breakdown of the industries which constitute the South African GDP is shown in **Figure 2** which shows that metal related manufacturing constituted 3% of the manufacturing sector in 2010.

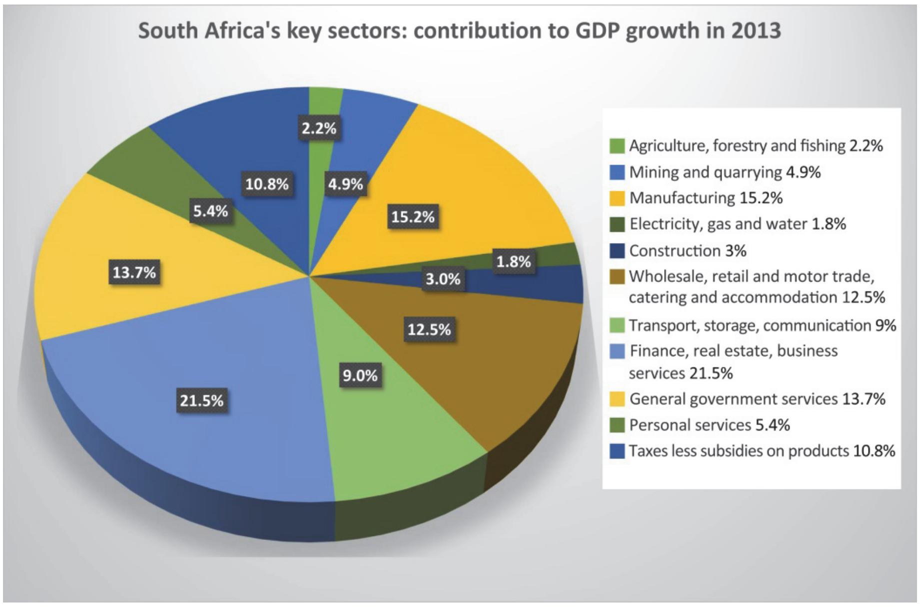

Figure 1 (StatsSA) **Sectoral contribution of various sectors to the South African Economy (2013)**

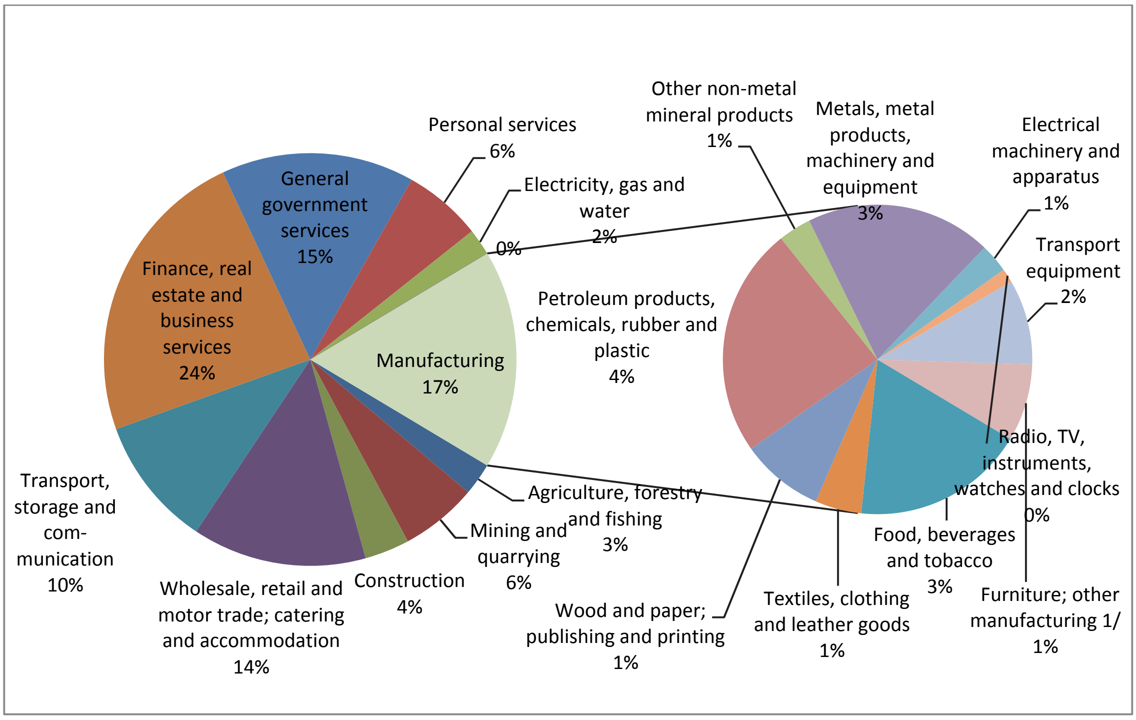

Figure 2 (StatsSA) **Detailed breakdown of sub-sectors constituting the manufacturing sector (2010)**

Based on the aforementioned it would seem that the sector is growing in absolute terms, but that the contribution to the GDP is not keeping pace with other sectors. Since manufacturing is such an important component of a country's economy, it is of national importance to stimulate growth in this sector in an effort to sustain the primary economy.

1.2 THE OVERALL OBJECTIVES OF THE PROJECT

The project objectives as formulated in the Agreement with the Water Research Commission were to:

1. Provide a general overview of the metal finishing industry in South Africa, its changes since 1980 and its projected change.
2. Evaluate and document the generic industry processes
3. Determine the water consumption and specific water intake
4. Determine the wastewater generation and typical pollutant loads
5. Determine local electricity, water and effluent prices and by-laws within which these industries function.
6. Critically evaluate the water (inclusive of wastewater) management processes adopted and provide recommendations
7. Evaluate the industry adoption of the following concepts: cleaner production, water pinch, energy pinch, life cycle assessments, water footprints, and ISO 14 000 to name a few.
8. Provide recommendations for best practice within the industry

The major findings obtained in meeting the abovementioned objectives are described in this report in the traditional format of previous NATSURV documents. Other information which could support this document, but cannot necessarily be included within the structure of the NATSURV document have been completed as supporting documents and will be discussed further in the ensuing sections.

1.3 DESCRIPTION OF THE RESEARCH PRODUCTS

In the original proposal one major research product and two supporting documents were envisaged for this Project:

- **NATSURV 2** : Water and Wastewater Management in the Metal Finishing Industry (Ed 2)
- An overview of the status quo of the metal finishing sector in South Africa
- An overview of source reduction methods which are or can be employed in the metal finishing sector.

The project yielded three deliverables in the form of reports:

- Ally, S.H., Kamish, W. and van der Spuy, A. (2015). *NATSURV 2: Water and Wastewater Management in the Metal Finishing Industry (Ed 2)*. WRC Report No. K5/2224, Water Research Commission, Pretoria. ***(This report)***

- Ally, S.H., Kamish, W. and van der Spuy, A. (2015). *Status Quo of the Metal Finishing Sector in South Africa*. WRC Report No. K5/2224, Water Research Commission, Pretoria.

- Ally, S.H., Kamish, W. and van der Spuy, A. (2015). *Source Reduction Measures Employed in the Metal Finishing Sector*. WRC Report No. K5/2224, Water Research Commission, Pretoria.

The major findings from the survey on industries in the metal finishing sector are described in this report. The updated NATSURV 2: *Water and Wastewater Management in the Metal Finishing*

Industry (Ed 2) can provide support to professionals in the plating industry, officials of the DWS as well as practitioners who supply support services in the field of cleaner production in the metal finishing sector.

The supporting documents provide a more detailed account of the status quo and the extent of implementation of cleaner production (CP) technologies in the metal finishing sector. Once again, the documents can be used by the sector as well as those providing support services to the sector as a point of departure for what is practically possible in term of CP implementation.

1.4 METHODOLOGY

To achieve the objectives of this project, a strong collaboration with the SAMFA was required. This collaboration allowed access to the SAMFA database of members and allowed the project team to attend the SAMFA Annual General Meetings (AGMs) in the various provinces where the project could be introduced and where project progress could be reported on. Although the collaboration with SAMFA made access to the sector easier, it in no way ensured full co-operation from the members.

The following processes were followed to obtain the information required information from the sector.

1. ***Creating awareness of the NATSURV project***: To create awareness of the project among the various factories which constitute the sector a workshop was held in each of the regional SAMFA centres. These meetings were held in the Cape Region: Thursday, June 13, 2013 in Bellville; KZN Region: Wednesday June 19, 2013 in Westville and the Gauteng Region: Thursday, July 4 2013, in Edenvale. In addition to the initiation workshops an article entitled "*How Big is the Metal Finishing Industry in South Africa?*" was also published in Issue 20 of the S.A. Metal Finisher, the official Journal of the SAMFA.

2. ***Status Quo of Metal Finishing in South Africa***: To obtain an indication of what the status quo in the metal finishing industry was, a desktop study reviewing the projects involving the metal finishing sector since 1987 was undertaken. The review specifically focussed on:

    a. Generic, general and specific process descriptions including pre and post treatment activities.
    b. Wastes generated during the metal finishing process and their typical treatment
    c. Changes in the metal finishing industry since the 1980s and projected future changes
    d. A description of the hot dip galvanizing process and industry changes which have occurred

3. ***Development of questionnaire for collation of information***: The format of the questionnaire developed in this study was based on the previously-expressed desire of SAMFA members for a self-assessment tool. The developed questionnaire was Excel-based and covered aspects such as water and energy consumption, chemicals usage and disposal as well as occupational health and safety issues. Since the spreadsheet was interactive it could provide red flags where deficiencies existed, based on the user input. To expedite large scale dissemination of the questionnaire it was first tested with a

pre-selected sample of members and then refined based on their feedback. The questionnaire thus underwent several iterations before it was distributed.

4. ***Introductory email and request to participate in survey***: Before the questionnaire was distributed an introductory email was sent to some SAMFA members who had either previously agreed to participate or whom the project team regarded as presenting a good chance of returning a completed questionnaire.

5. ***Dissemination of the questionnaire***: The questionnaire was disseminated electronically with a covering email. In certain cases problems were experienced with the electronic mail delivery system and a hardcopy of the survey was posted instead. In certain instances it was clear the project team would have to provide assistance with the completion of the questionnaire and in these cases assistance was provided telephonically or with a site visit.

6. ***Site visits to participating companies:*** Selected site visits were performed to assist participants with the completion of questionnaires and to obtain a first-hand impression of the industry. This approach worked most effectively when the participating company had already attempted to complete the questionnaire, because the completion of a totally incomplete questionnaire during a site visit inevitably resulted in the provision of data which proved to be erroneous during the quality assurance stage.

7. ***Follow-up emails and phone calls:*** Since the completion of a questionnaire did not form part of the companies' core business, several follow-up emails and phone calls were often required to obtain the requisite information. This step proved to be essential in gathering as much good quality data as possible.

8. **Quality assurance of data**: Once data was received it was reviewed for any gross errors. Typically the presence of gross errors was identified by querying water volume balances across the factory or by querying the input parameters on a mass balance. For example the operator claims that copper is being plated, but inventory data indicates that copper anodes are seldom or never replaced.

9. **Supplier survey**: To obtain an alternative snapshot of the metal finishing sector a "top down" survey was also undertaken with the 6 biggest suppliers to the metal finishing sector in South Africa. This information is considered to be much more inclusive (and reliable) than the snapshot obtained from the collation of information obtained from the individual companies, because most of the individual factories actually rely totally on the vendors from a technical operational perspective and as such the vendors would in majority of the cases know the technical and operational aspect better than the owners/operators of the factories.

10. ***Development of a Specific Water Index (SWI)*****:** Based on the information obtained from the data collection exercise it was possible to estimate an industry specific SWI for each process line that was surveyed and then to compare this with international standards. The fact that certain factories not only met, but exceeded these international standards implies that a relaxation in standard for "South African conditions" is probably not necessary and that many facilities are equal to their international counterparts.

1.5 LIMITATIONS OF THE STUDY

Attempting a survey on a national scale introduces several complexities and there is a potential risk of obtaining a skewed impression of the sector in any one of the items that were investigated. The sample size drawn from each of the provinces was limited due to time and budget and any conclusions drawn from the limited sample could be biased because of this. It should be noted that several of the factories that were given questionnaires and promised to submit them have used every stalling tactic in the book not to submit them while other operators who are respected and large players in the industry refused point blank to co-operate. In an attempt to correct for potential bias in the data collected from individual factories who did respond to the call, a secondary, simpler survey of the suppliers to the sector was undertaken to verify items related to the uptake of cleaner production (CP) in the industry.

The issue of compliance with municipal discharge by-laws in the preceding year was not verified with information from the local municipalities. Conclusions about non-compliance should therefore not be made without consulting with the local municipality.

Information regarding the Specific Water Index (SWI) could not be verified with any external data other than the data obtained from the factories. To this end, quality assurance was undertaken internally and erroneous data which could not be corrected after its identification was removed from the final report.

1.6 LAYOUT OF THE REPORT

The remainder of the report consists of the following chapters:

Chapter 2 presents a process overview of the metal finishing sector focusing of the major pre-treatment, surface treatment and post treatment processes.

Chapter 3 describes the legislative framework for the implementation of cleaner production in South Africa as well as other legislative requirements. This chapter also contains references to the by-laws in the various provinces.

In **Chapter 4**, a brief discussion water usage and wastewater is undertaken.

Chapter 5 presents the results from the survey and is followed by a description of resource conservation and cleaner production techniques available to the sector in **Chapter 6.**

Chapters 7 and 8 describe the current chemicals and products management as well cost of utilities.

Chapter 9 discusses the development of the Specific Water Index (SWI) for the sector and is followed by the discussion, conclusions and recommendations in Chapters 10, 11 and 12 respectively.

2. PROCESS OVERVIEW

2.1 INTRODUCTION

It is often necessary to use metals or metal alloys which have certain surface properties, e.g. resistance to corrosion, hardiness, high temperature tolerance, etc. Generally, no one metal will possess all the necessary properties. For example, steel has many good properties. It is inexpensive, abundant and a strong material that can easily be worked into all manner of shapes and forms. However, its major flaw is poor resistance to corrosion, causing it to rust severely in damp atmospheres. It needs to be coated with another material to provide corrosion resistance. The term metal finishing refers to a range of techniques that treat metal surfaces for its intended purpose. Metal Finishing enables the engineer to combine the good mechanical properties of one metal with the desirable surface properties of another. Electroplating thus offers the engineer a wide choice in combining various metals in determining a specific objective.

An estimate of the number of metal finishing installations in South Africa is difficult to quantify as a significant percentage of the work is performed in-house as an essential part of an overall manufacturing activity. The remainder of the metal finishing work is undertaken on a contract basis by specialist companies that include some large and dominant companies along with a greater number of smaller operators. Not all of the latter necessarily adhere to desirable industry standards, local and national legislation.

2.2 THE GENERIC PROCESS DESCRIPTION

The term metal finishing incorporates a wide variety of different activities and these are compartmentalised into three main operations and shown in Figure 3.

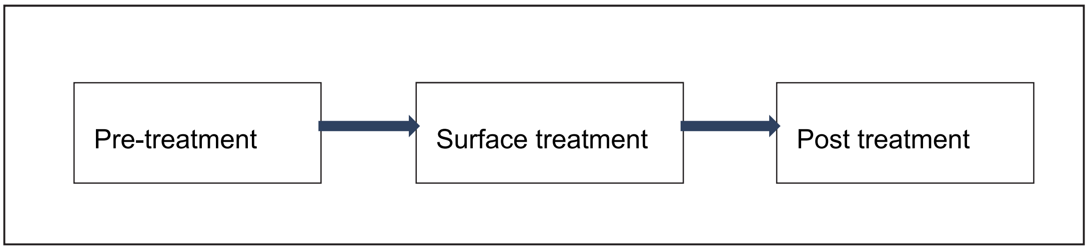

Figure 3 A generic process flow diagram for the metal finishing industry

1. The pre-treatment process – This procedure is essential and prepares the metal to be plated. It primarily involves the cleaning of the surface which ensures a good surface finish. This process could be of two types, (a) chemical surface treatment or (b) mechanical surface treatment of the object or both.
    a. Chemical surface treatment includes processes such as degreasing, pickling and phosphating
    b. Mechanical surface treatment includes descaling, brushing, scouring and polishing.
2. The surface treatment of the product is performed via anodising, electroplating, e-coating, chemical surface treatments, powder coating, or hot dip galvanizing.
3. The post treatment process usually involves passivation, lacquering, painting and/or rinsing of the workpiece.

Of these treatment processes mentioned above, only those which were found to use substantial quantities of water or generate substantial quantities of effluent have been studied. Some finishing operations, such as nitriding (and other similar processes) require very little water (Binnie, 1987) and were not covered in NATSURV 2. The electroplating, anodising and chemical surface treatment prior to powder coating have been found to be the most water-use-intensive of this group, and this guide deals exclusively with these three processes.

The annual water consumption by the metal finishing industry during 1987 was determined to be nearly 9 x 10^6 m^3, accounting for 0.7% of the total water intake of the industrial sector in South Africa with approximately 80% of this water being discharged as effluent (Binnie, 1987).

2.3 A GENERAL PROCESS DESCRIPTION OF ELECTROPLATING

Today there are many metal finishing techniques, including electroplating, anodising, hot dip galvanizing, powder coating and even painting. For the purposes of this study, each of the aforementioned techniques will be dealt with independently. Most of the information for this section was obtained from the SAMFA training manual,

Electroplating is the process of depositing a metallic coating onto a metal or other conducting surface in an electrolytic cell where the electrolyte is a solution of a dissolved metallic compound that provides ions. The component for plating is the cathode (negative) and a direct current is passed through the cell from an anode (positive) to the cathode.

The product to be plated is first thoroughly cleaned of grease and any other dirt by immersion in acid and alkaline cleaning solutions. It is then processed in a solution containing salts of the metal (the electrolyte) with which it is to be coated. Some common metals electro-deposited are:

- Zinc and zinc alloys for anticorrosion properties
- Chromium and nickel for decorative, corrosion, wear and temperature resistance
- Copper and gold for decorative and industrial properties
- Silver for decorative and electrical properties
- Tin for food containers and electrical contacts

Some of the properties imparted to articles by electroplated finishes include hardness, lubricity, solderability, conductivity, improved torque tension characteristics, enhanced appearance, reflectivity and anti-galling characteristics.

2.3.1 Pre-treatment processes, contaminants and their sources

Workpieces that are to be treated must be cleaned from dust, grease and, in the case of castings, moulding flash. There should also be no corrosion on the surface of the article so that a uniform application and permanent adhesion of the treated surface can be ensured. Many articles are oiled in transit or from a previous operation (such as pressing) to prevent corrosion. Pre-treatment steps therefore include the removal of greases, oil and oxides to provide chemically active surfaces for the subsequent treatment.

Mechanical pre-treatment

Mechanical pre-treatment processes consist of linishing (removal of roughness with sanders) and polishing, abrasive blasting and deburring and/or tumbling. Although mechanical pre-treatments may be viewed as a cleaner production initiative when compared to other process, this is not the case when an aqueous compound containing chemical additives is used.

Electrolytic and chemical polishing

Processes in electrolytic and chemical polishing include electropolishing, plasma-electrolytic polishing, electrolytic polishing and chemical polishing. These processes are applied to aluminium mainly, but stainless steel is often electropolished as well, e.g. for bathroom and kitchen racks and trays. The potential advantages of electrolytic and chemical polishing are:

- The ability to use a single production line because they are similar in operation to anodising and electroplating processes,
- the suitability for bulk treatment, so that labour costs are appreciably lower,
- the clean surface improves subsequent deposit adhesion and also provides a high corrosion resistance and,
- pre-treatment offers superior reflectivity and colour (SAMFA, 2011)

Solvent degreasing

Solvent degreasing is usually carried out by using chlorinated hydrocarbons, alcohols, terpenes, ketones, mineral spirits or hydrocarbons. The most common solvents are chlorinated hydrocarbons (CHCs). CHCs are used due to its high cleaning efficiency, universal applicability, quick drying and incombustibility, but its use is restricted by environmental and health legislation.

Metal stripping

Metals are stripped when it is necessary to process defectively electroplated components without losing the properties of the base material. The metal is then re-plated to the correct specifications. There can be increased waste production in sludge from treatment and used acids as well as wastewater generated.

Drag-out and rinsing

Drag-out is defined as the liquid which adheres to the workpiece surface after any process. As a result, rinsing is carried out as a common activity after nearly all process steps. Rinsing is necessary to prevent cross-contamination of process solutions and to ensure there is no deterioration of the workpiece and/or article surface by residual chemicals.

2.3.2 The specific surface treatments regimes and general wastes generated

The following specific surface treatments discussed can be inserted into a generic process flow diagram (PFD) – **Figure 4**. The PFD is not prescriptive and typically an establishment will have all the relevant components, depending on available space and operating budgets. The ensuing sections present descriptions of some of the popular surface treatment processes as well as the wastes generated. **For a more detailed description the reader is referred to the supporting report entitled: "*Status Quo of the Metal Finishing Sector in South Africa*. WRC Report No. K5/2224, Water Research Commission, Pretoria."**

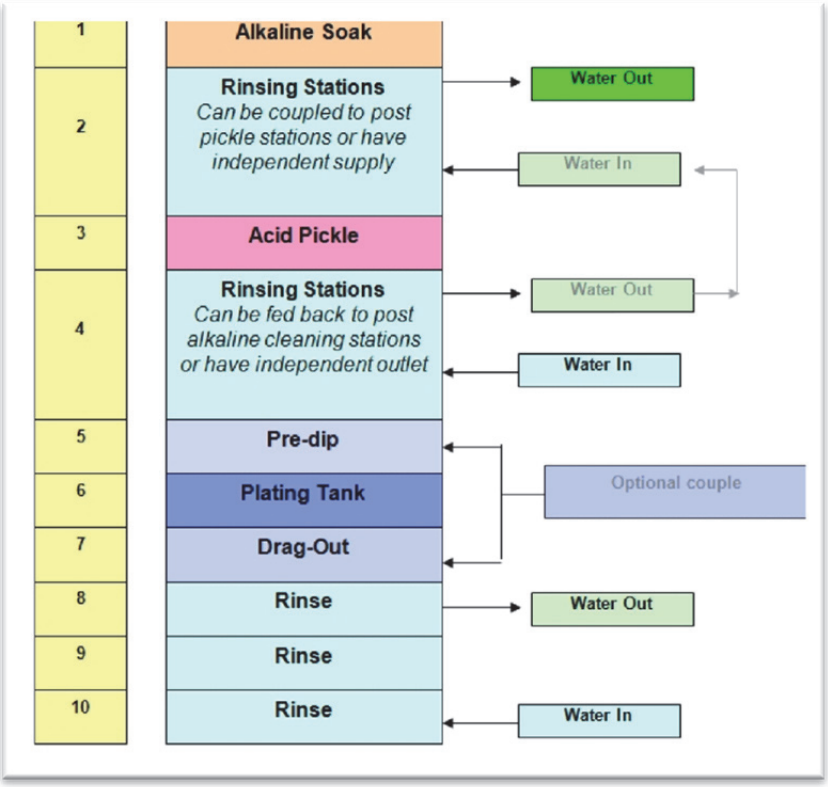

Figure 4 Basic layout for a plating line showing dragout and pre-dip

Copper and copper alloy plating

Copper plating is common for items in daily use such as coins, buttons or zip fasteners. These types of workpieces can be plated in jigs or barrels. Acid-copper plating has become the standard choice for copper plating, whereas pyrophosphate copper electrolytes no longer play an important role. However, copper from an acid electrolyte cannot be deposited directly onto mild steel due to the displacement effect. An underlay of copper from a cyanide based solution must be deposited first. Alkaline non-cyanide variants have also been developed but are not in common use in South Africa.

The effluent generated in acid copper processes can be treated in a wastewater plant for low pH as well as to remove the copper. Pyrophosphate copper effluents have to be treated with lime ($CaCO_3$) because sodium or potassium hydroxides (NaOH and KOH) do not precipitate the copper from the pyrophosphate. Bronze copper effluents can be treated for pH, cyanide and metals in a wastewater treatment plant which contains a cyanide oxidation step.

Nickel electroplating

Nickel electroplating has the primary function to improve the resistance of articles to corrosion, wear and abrasion, although nickel also provides a smooth, highly reflective and corrosion-resistant coating below a range of other coatings for decorative finishes. The most important application of nickel is in nickel/chromium electroplated coatings, commonly called ‘chrome plating’. It consists of a very thin chromium topcoat (1%) over an undercoat of nickel (99%). Brass, gold and silver topcoat systems are used as alternatives to chromium. Nickel can also be used on its own without any topcoat. This is generally only for engineering purposes, .e.g. refurbishment of worn components. Nickel matrixes can be formed in which inert, non-metallic particles, such as silicon carbide, diamond or polytetrafluoroethylene (PTFE) are incorporated by co-deposition to improve engineering properties such as hardness, abrasion resistance and coefficient of friction. Electrodeposited nickel alloys of commercial significance include zinc-nickel, nickel-cobalt and nickel-iron.

Chromium plating

Chromium plating has found wide usage both as a functional coating and as a decorative surface finish because of its typical hardness and wear resistance properties. It is also widely used in packaging applications. Bright chrome is usually applied as a thin layer to prevent corrosion for decorative purposes and can be plated from either hexavalent or trivalent chromium electrolytes. The deposit thickness is generally in the range of 0.1µm to 0.4 µm with a treatment time of between 2 and 13 min. Hexavalent chromium plating contains 80 to 400 g/l chromic acid and 0.8 to 5 g/l sulphate. Trivalent chromium plating, on the other hand, is based on chromium III compounds, and depending on which proprietary formulation is used, may contain only about 20 g/l of the trivalent chromium. Black chromium plating is for decorating black pieces. They are based on chromic acid electrolytes with 350 to 520 g/l chromic acid. Deposit layers are porous and less than 1 µm thick.

Zinc and zinc alloy plating

Zinc and zinc alloy plating are the most widely used electrolytic surface treatments, providing corrosion resistance and/or cheap decorative coating to a wide variety of iron and steel items for the automotive, construction and other industries.

Cadmium plating

Cadmium is similar to zinc both as a metal and as regards plating. There is not a great deal of difference between the two in protecting steel against corrosion. Cadmium plating is mainly used to protect parts made of steel, aluminium or titanium alloys. It is more corrosion resistant than zinc, however the toxicity of cadmium has limited its use to vital technical uses only. Examples include metals in aviation and aerospace, military equipment, mining, nuclear industries and some safety critical electrical contacts. Acidic and alkaline cyanide baths can be used for cadmium plating.

Tin and alloy plating

Tin and most tin alloy plated coatings are non-toxic, ductile, resistant to corrosion, easy to coat, and have high throwing and good distribution properties. The main application of tin plating is in the coating of steel coil for packaging of food, beverages and aerosols. It is also widely used in printed circuit boards, electronic components, appliance chassis and also kitchen utensils. Several electrolytes are used and are available, such as acid stannous sulphate, acid tin fluoroborate, alkaline sodium or potassium stannate (tin compound).

Tin lead plating is a commonly used tin plate alloy. It is used as solder coat in different alloy ratios. As the lead component is toxic, a range of lead-free alternatives has been developed as alternatives.

Non-fluoroboric tin lead electrolytes are available and based on the organic methane sulphonate acid. The wastewaters will contain sulphonic acid. Effluents may be treated in typical wastewater plant. Fluoroborate bath effluents should be pre-treated separately to a typical wastewater treatment plant.

Precious metal plating

Thin layers of less than 1 µm of precious metals can be plated onto metals to make a wide range of items appear valuable. They also provide stain and corrosion resistance. The conductivity, hardness and wear resistance have led to a widespread application in the electric and electronic industries as well. Coatings can be made of silver, gold, palladium and alloys, rhodium and platinum.

Autocatalytic plating

Autocatalytic plating is also known as electroless plating which is a catalytic chemically reduced coating. The fundamental reaction requires the presence of a catalytic metal (which is the metal being deposited) that allows the reaction to proceed. The advantages of using electroless plating are:

- All surfaces are in contact with the fresh solution, the deposit will be uniform over the entire surface, regardless of the surface shape,
- Plated deposits are less porous than electroplating of the same metal,
- racking or fixing is greatly simplified and,
- non-conducting material may be coated.

Autocatalytic plating may include nickel and copper electrolytes on both metals and plastics.

Immersion or displacement coating

Immersion or displacement coatings are non-catalytic chemically reduced coatings. They are formed when the metal to be deposited is precipitated upon its reduction in solution. This can occur chemically from solution or if the metallic article is more active than the ions in the solution. Deposits are often non-adherent and of poor physical quality, although careful attention to solution composition and operating conditions can produce deposits acceptable for certain purposes in printed circuit boards and mirrors.

For mirrors, copper (from the cementation process) can form a complex in the wastewater and is difficult to precipitate in the wastewater treatment plant and will have to be treated specifically. For printed circuit boards, the environmental considerations for gold and silver are as for tin.

Colour anodising on aluminium

Aluminium can be coloured in many shades and colours in conjunction with or after sulphuric acid anodising. There are four general methods, namely immersion-, electrolytic-, interference- and integral colouring.

Immersion colouring is the most widely used colouring method. The anodised workpieces or articles are immersed in a water-based organic or inorganic dye solution before sealing. In electrolytic colouring, the anodised aluminium is placed in an acid solution containing metal salts and an alternating current is applied. The film obtains a colour characteristic of the metal salts used. Electrolytic and immersion colouring can be combined to form new shades. In interference colouring, the appearance is produced by interference effects between two light-scattering layers, i.e. between the electrochemically deposited metal layer at the bottom of pores and the aluminium oxide-aluminium interface beneath. With integral colouring, the aluminium oxide layer is coloured itself during the anodising process. Colouring occurs either by anodising in a solution of special organic acids or by normal anodising in sulphuric acid of special aluminium alloys with substances that are not oxidised such as Al-Si or Al-Fe-Mn. This technique has almost entirely been replaced by electrolytic colouring.

Metals used in electrolytic colouring may require treatment in a wastewater treatment plant prior to discharge. Some organic dyes may require additional wastewater treatment.

Sealing following anodising

Sulphuric acid anodising is normally followed by a sealing process. Sealing improves the corrosion and stain resistance of the oxide layers. It also prevents organic dyes from leaching out and improves the light fastness. Sealing may be carried out in hot or cold processes. With hot sealing, the process is carried out by immersing the anodised parts in hot or boiling deionised water (95 to 96°C) for three minutes per μm thickness. Sealing with steam achieves the same effect. Cold sealing methods have been developed for operating temperatures of 25 to 35°C, and 60°C.

No constituents of concern are present in wastewater effluent and this water may be recycled and used in sealing (AFSA, 2013).

Phosphating coatings

Phosphate coatings are the most widely used conversion coatings and probably the most widely used surface treatment. They are used to treat steel, aluminium and zinc for cold forming, coil coating, rust proofing, bearing surface lubrication, paint base and electrical insulation. Phosphating is an important step in the pre-treatment of parts that have to be powder coated.

Phosphate coatings are micro-porous in nature. They make an excellent undercoat for the powder coating or wet paint that is to follow. The phosphating solution is acidic being based on phosphoric acid. There are different types of phosphate coatings. The most important for powder coaters are iron-phosphate and zinc phosphate coatings, but manganese phosphate is also used in certain cases. Apart from a phosphoric acid base, the solutions will contain ingredients known as accelerators or oxidisers that influence the speed and the structure of the deposit and possibly surfactants.

Chromium conversion coatings

Chromium conversion coatings are used to enhance corrosion protection on various metal surfaces, including electroplated zinc and cadmium, zinc die-castings, tin, aluminium, magnesium and magnesium alloys, copper, brass and bronze, nickel, silver and stainless steel. Chromium conversion coatings are often referred to as 'chromating' because the process originally used only hexavalent chromium. It is an essential step in post treatment of zinc plating.

Metal colouring

Metal colouring is used to obtain a wide range of shades and colours over different metals by heat treatment, chemical immersion or electrolytic treatment. Metal colouring processes are used on brass, copper and steel parts. The most commonly used system is chemical immersion.

Chemical blacking – oxide coatings

Immersion-type chemical oxidation coatings are used mainly for changing the appearance of the metal, as a paint base or for their oil-retention characteristics. Steel, stainless steel, copper, brass and aluminium may be blackened. The original formulations for steel were based on a mixture of sodium hydroxide and sodium nitrate/chlorite ranging from 120 g/l to 840 g/l in concentration and operated at high temperature. Rinse water from this process is likely to require pH adjustment.

Sophisticated proprietary cold blacking products are now available for various metals (CPMFI, 2003).

Brightening

In the brightening of steel, concentrated nitric acid is used to form a very clean surface. Copper and brass are brightened by oxidising a surface layer. Aluminium and some of its alloys can be brightened by chemical or electrochemical processes.

Spent brightening solutions may require treatment for low pH and possibly metal content prior to disposal as effluent.

Etching – alkaline etching of aluminium

The most frequently used method for etching aluminium is aqueous solutions of caustic soda, which may or may not contain additives. It can be used for general cleaning purposes, to produce a stain or matt finish for decorative purposes, for deep engraving or chemical milling.

Wastewater contains caustic soda which may be treated in typical wastewater treatment plants.

Chemical milling

Chemical milling is a process used to remove metal on workpieces by dissolution in a caustic or acid bath without an external source of energy. Chemical milling is mostly used on aluminium alloys, but chemical milling can also be used on titanium alloys, stainless steel and some special alloys with a nickel, cobalt or magnesium base.

2.3.3 Post treatment activities

Post treatment activities include the drying of workpieces. This can be done by using hot water, hot air or air knives. Furthermore, heat treatment can be carried out on pieces to avoid the hydrogen embrittlement formed in pickling, cathodic cleaning, and the electro-deposition of metal.

3. LEGISLATIVE FRAMEWORK FOR THE IMPLEMENTATION OF CLEANER PRODUCTION

The South African legislature, aimed at promoting the implementation of CP initiatives, is fragmented and does not explicitly state CP as an intended objective. Inclusion of sub-clauses pointing to the *preventative* and *precautionary* principles, however, create the platform for the implementation of CP. At the highest level, the concept of CP is addressed in *Section 24* of the Constitution. A list of the legislature relating to the implementation of Cleaner Production is shown in **Table 1**.

An assessment of the status quo of CP in South Africa was undertaken by the Department of Environmental Affairs and Tourism (DEAT) in 2004. In that study, the United Nations Environment Programme (UNEP) definition of CP was used. The definition, which reads as follows, will be applicable to this study as well:

"The continuous application of an integrated preventive environmental strategy to processes, products, and services, to increase overall efficiency, and reduce risks to humans and the environment. Cleaner Production can be applied to the processes used in any industry, to products themselves and to various services provided in society. Specifically for:

> ***Production processes**: Cleaner Production results from one or a combination of conserving raw materials, water and energy; eliminating toxic and dangerous raw materials; and reducing the quantity and toxicity of all emissions and wastes at source during the production process;*
> ***Products**: Cleaner Production aims to reduce the environmental, health and safety impacts of products over their entire life cycles, from raw materials extraction, through manufacturing and use, to the 'ultimate' disposal of the product; and*
> ***Services**: Cleaner Production implies incorporating environmental concerns into designing and delivering services".*

A graphical representation of the CP concept is presented in Figure 5.

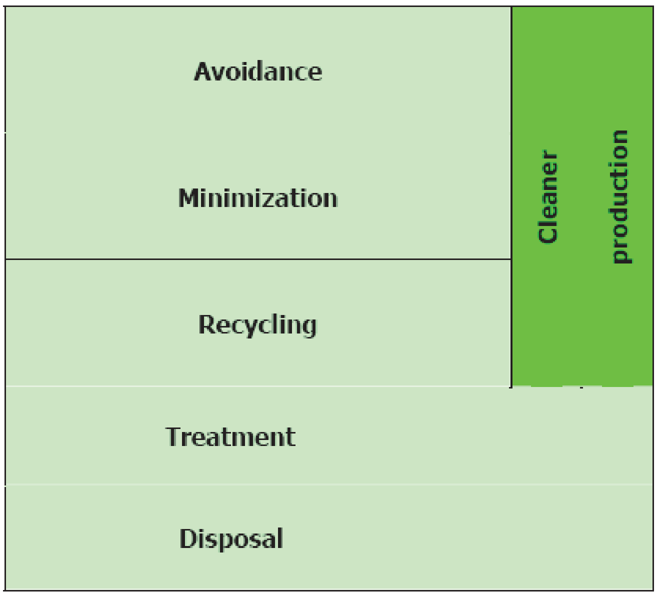

Figure 5 Cleaner production within the hierarchy of waste minimisation
(extracted from the National Cleaner Production Strategy, 2004)

Table 1 Relevant legislature for cleaner production in South Africa (extracted from DEAT, 2004)

Legal/Policy Instrument	Relevance to CP
The White Paper on Integrated Pollution and Waste Management 2000	• Promotion of Cleaner Production and establish mechanisms to ensure continuous improvements in best practice in all areas of environmental management. • Prevention, reduction and management of pollution of any part of the environment due to all forms of human activity, and in particular from radioactive, toxic and other hazardous substances. • Setting targets to minimise waste generation and pollution at source and promoting a hierarchy of waste management practices, namely reduction of waste at source, reuse and recycling with safe disposal as the last resort.
National Environmental Management Act NEMA (1999)	• Section 28(1) of NEMA states that: ‘every person who causes, has caused or may cause significant pollution or degradation of the environment must take reasonable measures to prevent such pollution or degradation from occurring, continuing or recurring, or, …to minimise and rectify such pollution or degradation’
The Environment Conservation Act 73 (1989)	• The EIA Regulations (R1182 and R1183 of 5 September 1997, promulgated in terms of this Act) require that specific procedures are followed, and reports (scoping and/or EIA reports) prepared, for those activities listed in Schedule 1 likely to have a “substantial detrimental effect on the environment”
National Integrated Waste Management Bill, (Draft 9, November 2002)	• Incorporates numerous clauses regarding the need for, and mechanisms to develop and enforce, strategies for waste minimisation, including: o ‘implement and enforce waste minimisation and reuse and recycling initiatives’; o ‘promote the development of voluntary partnerships with industry in respect of waste minimisation, re-use and recycling initiatives’ • Includes the development of National and Provincial Waste Information Systems (WIS) to obtain the information required for the stricter enforcement of the Polluter Pays principle
National Water Act (1998)	• Management must accept total responsibility for waste and pollution arising from their industry. • Places responsibility on the user to purify effluent to an acceptable standard so it can be returned to its original source. • Makes way for a more sustainable demand-management water pricing approach. • Internalisation of costs: Water pricing will now be set to value the resource according to its scarcity, and will also be geared towards full-cost recovery to a much greater extent than was done previously (i.e. all the costs in the provision of water will be incorporated into the water price and related effluent charge, including capital, operating, social and environmental costs).
Occupational Health and Safety Act 181 of 1993	• In terms of this Act, an employer must minimise any substances on site that could be injurious to employee health (Section 10 (2)(a)) and recycle all hazardous chemical substances waste wherever possible (Section 15 (a)).
Regulations for Hazardous Chemical	• An employer must control the exposure of an employee to hazardous chemical substances (Section 10. (2) (a)) by “limiting the amount of an HCS used which may contaminate the working environment” and as far as reasonably

Legal/Policy Instrument	Relevance to CP
Substances (in terms of Occupational Health and Safety Act 181 of 1993)	practical, “recycle all HCS waste” (Section 15. (a)).
The White Paper on the Energy Policy of the Republic of South Africa 1998	• Ensuring that an equitable level of national resources is invested in renewable technologies, given their potential and compared to investments in other energy supply options.
Mineral and Petroleum Resources Development Act (Act no 28 of 2002)	• One of the objectives of the Act is to make provision for equitable access to and sustainable development of the nation’s mineral and petroleum resources. Furthermore, the Act affirms the State’s obligation to ‘protect the environment for the benefit of present and future generations, to ensure ecologically sustainable development of mineral and petroleum resources and to promote economic and social development’.
Air Quality Bill (2003)	• To reform the law regulating air quality in order to protect and enhance quality of air in the Republic, taking into account the need for sustainable development.

Figure 5 shows that the Cleaner Production approach focuses on the upstream component (i.e. source reduction) of the waste minimization hierarchy thus moving emphasis away from improved methods for treatment of waste, towards methods for reducing the amount of waste produced. CP is about:

- Preventing waste and pollution at source
- Minimising the use of hazardous raw materials
- Improving water and energy efficiency
- Reducing risks to human health
- Saving money
- Improving efficient management practices
- Promoting sustainable development

Furthermore, this approach embraces the '*cradle-to-grave'* principle, the '*precautionary principle*' and the '*preventive principle*' and because CP addresses the problem at several levels at once, it is a holistic integrated preventive approach to environmental protection. The CP approach is an integral part of South Africa's *Integrated Pollution and Waste Management Policy*.

3.1 BY LAWS FOR THE VARIOUS PROVINCES

The by-laws for the various provinces differ in as much as they specify varying pollutant loads to the environment as dictated by regional requirements. This will also then affect the ranges of charges for effluent treatment by the various municipalities. A comparison of effluent discharge limits for selected municipalities in South Africa is presented in **Table 2**. It is worthwhile noting that the eThekwini municipality also has a guideline document for the management of industrial effluent emanating from the metal finishing factories. Specifically the guidelines deal with:

- Treatment process chemistry
- Process control
- Engineering design
- Requirements for effluent compliance and monitoring
- Methods of sludge handling, storage and disposal

The document is entitled ***Guidelines for the management of metal finishing industry effluent developed by the Durban chamber of commerce by-laws working group.***

Table 2 Comparison of effluent discharge limits for various municipalities in South Africa

		Cape Town	Johannesburg	eThekwini metro (Durban) <25 Ml/day	Ekurhuleni (Gauteng)	Tshwane
Section A: General						
	Temperature at point of entry 0 °C	0-40	Not specified	<44	Not specified	Not specified
	Electrical Conductivity at 25 °C (mS/m)	500	500 at 20°C	400	500	300
	pH Value at 25 °C	5.5-12	Not specified	6.5-10	6-10	6-10
	Chemical Oxygen Demand (mg/l)	5000	Not specified	Charge	5000	5000
Section B: Chemical substances other than Heavy Metals – maximum concentrations						
1.	Settleable Solids (60 minutes) (mg/l)	50	Not specified	Charge	Not specified	Not specified
2.	Suspended Solids (mg/l)	1000	Not specified	1000	Not specified	Not specified
3.	Total dissolved solids at 105 °C (mg/l)	4000	Not specified	500	Not specified	Not specified
4.	Chloride as Cℓ (mg/l)	1500	1000	500	500	100
5.	Total sulphates as SO_4 (mg/l)	1500	250	250	1800	1800
6.	Total phosphates as P (mg/l)	25	Not specified	Not specified	50 Ortho P	Not specified
	Nitrates as N (mg/l)	Not specified	50	Not specified	200	Not specified
7.	Total cyanides as CN (mg/l)	20	20	10	20	20
8.	Total sulphides as S (mg/l)	50	10	1	10	50
9.	Total phenols as C_6H_5OH (mg/l)	50	10	5	150	
10.	Total sugars and starches as glucose (mg/l)	1500	Not specified	500	1500	Not specified
11.	Oils, greases, waxes and fat (mg/l)	400	Not specified	250 else 50	500	2000
12.	Sodium as Na (mg/l)	1000	500	Not specified	500	Not specified
Section C: Metals and inorganic content – maximum concentrations **Group 1**						
1.	Iron as Fe (mg/l)	50	200	5	20	20
2.	Chromium as Cr (mg/l)	10	20	5	20	20
3.	Copper as Cu (mg/l)	20	20	5	5	20
4.	Zinc as Zn (mg/l)	30	20	5	20	20
Total collective concentration of all metals in Group 1 shall not exceed 50 mg/l						
Section C: Metals and inorganic content – maximum concentrations **Group 2**						
5.	Arsenic as As (mg/l)	5	2.5	5	5	20
6.	Boron as B (mg/l)	5	5	5	5	20
7.	Lead as Pb (mg/l)	5	10	5	5	5
8.	Selenium as Se (mg/l)	5	5	5	5	5
9.	Mercury as Hg (mg/l)	5	1	1	5	5 total 10
10.	Titanium as Ti (mg/l)	5	20		20	20
11.	Cadmium as Cd (mg/l)	5		5	5	20
12.	Nickel as Ni (mg/l)	5	10	5 Total 20	20	20 total 50
Total collective concentration of all metals and inorganic constituents in Group 2 shall not exceed 20 mg/l						
Section D: Prohibited radioactive materials						
Any radioactive wastes or isotopes of such nature or in such concentration as do not meet the requirements laid down by the Council for Nuclear Safety referred to in Section 24 of the Nuclear Energy Act (Act 92 of 1982) as amended.						

4. WATER AND WASTEWATER USAGE

4.1 WASTEWATER TREATMENT OF POTENTIAL RELEASES TO THE ENVIRONMENT

Constituents of concern which are potentially released during metal finishing processes include metals, organic material, cyanides, hypochlorite, chlorine, AOX, surfactants, complexing agents, acids/alkalis, ions, solvents, dusts and general wastes. The emission of pollutants in wastewaters and the production of waste are considered more significant than emissions to air.

Since most surface treatments by metal deposition are water-based, significant quantities of water are used while copious amounts of wastewater are generated. The most effective method for preventing pollutants entering the water environment is in the minimisation of the loss of materials, where these materials are lost by drag-out into rinse waters. Furthermore, wastewater treatment serves to remove the constituents of concern before discharge into the surrounding water bodies. These treatments include neutralisation and precipitation, oxidation and reduction, filtration, absorption techniques, crystallisation, atmospheric evaporation, vacuum evaporation, electrolysis, ion exchange, electodeionisation, acid sorption, membrane filtration, reverse osmosis, diffusion dialysis, membrane electrolysis and electrodialysis. These common techniques are listed in **Table 3** below.

Table 3 Typical treatment regimens for effluent treatment

Treatment type	Description of treatment
Oxidation	• This is specifically for cyanides • Cyanides are oxidised to cyanates or completely destroyed using sodium hypochlorite (NaOCl) or calcium hypochlorite [$Ca(OCl)_2$] • The process is usually batch processing
Reduction	• Wastewaters containing hexavalent chrome are treated with sodium bisulphate or sodium meta-bisulphate • This produces a trivalent chrome compound which is treated to produce chromic hydroxide which precipitates out as sludge
Neutralisation and precipitation	• Caustic soda is usually used to produce nickel hydroxide, copper hydroxide and sodium sulphate. • The hydroxides precipitate out and form sludge • The operation is at pH 8.5 to 9.5 so that other metals present also react and precipitate out
Filtration	• Sand filters are used for cleaning raw water or polishing effluents • Belt filters or filter presses are used with higher solids applications such as wastewater sludges, often in conjunction with coagulants • The filter medium with the filtrate is usually disposed of as a waste
Absorption techniques	• Activated carbon is used to adsorb unwanted organic substances formed from breakdown products in a solution • Activated carbon will also remove a portion of the useful organic chemical additives (e.g. brighteners), which will need replacing • The absorbent material along with the retentate and filter medium is usually disposed of as a waste, although precious metals may be recovered
Crystallisation	• Various evaporation and cooling systems are used to bring solutions to a super-saturation point where solid crystals form and can be separated from solution

Treatment type	Description of treatment
Atmospheric evaporation	• Atmospheric evaporation occurs when solution are heated. It reduces the volume of process solutions and allows drag-out to be returned of fresh chemicals to be added to the process solution • Evaporators are often used with a condenser to recover distilled water
Vacuum evaporation	• Reduced pressure and elevated temperature combine to separate constituents with relatively high volatility from constituents with lower volatility
Electrolysis – plating out	• Transition metals can be removed from wastewater streams by plating out on high surface area electrodes in metal recovery cells
Electrolysis – oxidation	• It is possible to oxidise both unwanted organic by-products and metals in solutions, such as trivalent chromium to hexavalent chromium
Ion exchange – resin	• Ions in solution are selectively removed by exchanging positions with resin-functional groups • The direct ion exchange treatment of wastewater provides a means of concentrating multivalent cations for subsequent treatment on column regeneration or by plating out. • Water from ion exchange can be recycled (Dahl, 1997)
Electrodeionisation	• Ions are removed using conventional ion exchange resins
Acid (resin) sorption	• Acid sorption is configured similarly to ion exchange. Resins are designed to selectively adsorb mineral acids while excluding metal salts (adsorption phase) • Purified acid is recovered for re-use when the resin is regenerated with water (desorption phase)
Ion exchange – liquid/liquid	• Ionic contaminants are removed from process solutions into immiscible primary liquid extraction solutions • Secondary liquid extraction solutions are used to remove the contaminants and to regenerate the primary extraction solution • Water from ion exchange can be recycled (Dahl, 1997)
Membrane filtration	• Membrane filtration can be used for the purification and recirculation of oily water (Dahl, 1997) • Various types of membrane filtration exist that are dependent on the pore size • Microfiltration is a membrane filtration technology that uses low applied pressures with pore sizes in the range of 0.02 to 10 microns, to separate relatively large particles in the macromolecular and micro particle size range • Ultrafiltration passes ions and rejects macromolecules of 0.005 to 0.1 microns and removes organics from process solutions • Nanofiltration is used for larger size rejection reverse osmosis (rejects molecule larger than 0.001 to 0.008 microns) – for partial desalination of rinse water, removal of aluminium from pickling baths and concentration of chromating chemical in rinse water • Purified water can be re-used for the degreasing bath or rinsing

Treatment type	Description of treatment
Reverse osmosis	• Reverse osmosis is effectively a filtration of ions through a semi-permeable membrane at high pressure which desalinates chemically treated wastewater • It provides an alternative means of concentrating metal impurities for subsequent removal • This approach can be capital intensive and any solids or organics have to be removed prior to treatment • The chemicals from zinc-, chrome- and copper plating baths can be re-circulated
Diffusion dialysis	• Diffusion dialysis is a membrane separation process that typically uses an anionic exchange membrane to transport acid anions and protons from waste acid solutions into deionised water streams • The anions and protons are treated in wastewater treatments plants and the acid is recovered
Membrane electrolysis	• Membrane electrolysis used one or more ion-selective membranes to separate electrolyte solutions within an electrolysis cell • The membranes are ion-permeable and selective
Electrodialysis	• Anions and cations are removed from solutions with an applied electric field in cells with alternation anion- and cation-permeable membranes • Various acids from electrolyte solutions can be recycled

The possible treatment(s), specific to each constituent of concern can now be listed (**Table 4**).

Table 4 Possible treatment(s) specific to each constituent of concern

Constituent of concern	Possible treatment
<u>Immiscible organics</u>: Non-halogenated (oils, greases, solvents) and halogenated (oils, degreasing solvents, paint solvents)	• Reduced to solubility limit by physical separation (e.g. flotation) or by liquid/liquid phase separation • Followed by either air stripping (activated carbon) or oxidation to carbon dioxide (using UV irradiation and hydrogen peroxide addition)
<u>Soluble organics</u>: Wetting agents, brighteners, organic ions and ligands	• Soluble organics increase the difficulty in removing metals by flocculation • Concentration may be reduced by oxidation (by UV irradiation and hydrogen peroxide addition • Dissolved organics increase COD; biological treatment may be necessary
Acids and alkalis	• pH adjustment is usually required • pH may be partially neutralised by mixing with other streams
<u>Particulate material</u>: Metal hydroxides, carbonates, powders, dusts, film residues, metallic particles	• May be removed by settling or filtration • Filtration uses a filter- or belt press to produce a cake manageable as a solid
Metals	• For soluble anions the capture of precious metals for re-use, e.g. platinum, gold, silver, rhodium and ruthenium may be achieved by electrochemical recovery or ion exchange • In some cases it may be necessary to reduce the oxidation state of the metal ion as the higher oxidation state may not be readily flocculated and precipitated by pH change

Constituent of concern	Possible treatment
	• Multivalent ions are most conveniently removed by precipitation and pH adjustment
Complexing agents: Sequestering and chelating agents	• May be removed by precipitation with the predecessor of activated carbon process • Microbiological oxidation is also a possibility for removal of complexing agents
Nitrogenous materials: Ammonia, Nitrites	• Ammonia can be removed by steam stripping or by oxidation to nitrogen with sodium hypochlorite • Nitrites can also be oxidised with sodium hypochlorite • Note that AOX may be formed when using hypochlorite solutions
Cyanides	• Cyanide from degreasing may be oxidised by using hypochlorite or chlorine gas at high pH
Sulphide	• When in excess sulphide can be precipitated out as elemental sulphur on oxidation with hydrogen peroxide or iron (III) salts.
Fluorides	• Are readily precipitated out as calcium fluoride at a pH above 7
Phosphated compounds	• Precipitated out as calcium hydroxide phosphate
Other salts	• Other ions such as Cl^-, SO_4^{2-}, K^+, Na^+ and Ca^+ • Sulphate can be readily precipitated as calcium sulphate • Ion exchange, reverse osmosis or evaporation to remove other ions

Sludge waste comprised of solid particles suspended in the waste water is produced during metal finishing processes in the effluent. These solids may be removed from the main effluent (called sludge dewatering) by precipitation or filtering through a filter press, belt press or centrifuge to produce a cake manageable as a solid. When operating at pressures above 15 bar the final cake can have 15 to 35% solids. The filter can then be dried further to lower the water content.

Some waste solutions can be disposed of as liquid or hazardous wastes, or can be recovered or recycled. Examples of wastes that are recovered or recycled include autocatalytic plating, spent etchants and sludges from anodising.

Further steps to abate potential releases to the environment include cleaner production initiatives, which aim to minimise the use of water and material discharged from the processes. It is important to note, however, that the minimisation of water usage can increase the concentration of dissolved salt and various metals, which increases the solubility of metals in the wastewater. Further, it can become difficult to maintain a stable pH in the narrow margins required to minimise the solubility of individual metals when dealing with a mixture. This suggests that when dealing with a mixture of metals it will become increasingly difficult to optimise every parameter.

Further cleaner production initiatives can be referenced in the report entitled ***Source Reduction Measures Employed in the Metal Finishing Sector***.

5. THE RESULTS FROM THE SURVEY

The following sections are based on the feedback obtained from the various facilities who received questionnaires as well as physical factory site visits. It is clear that many facilities are ISO certified or striving towards achieving it, this is especially true for ISO 9000 (quality standards) as this certification unlocks new sources of revenue with new or existing clients, because of the assurance of a high quality products. (For example, the motor industry as they offer up to 7 years warranty on new cars).

The survey of the metal finishing industry resulted in a questionnaire that served as a legislative and a cleaner production (CP) checklist. No company was coerced for visiting, rather they were informed at the SAMFA AGM's of the WRC project and solicited to endeavour to assist the research team. The companies themselves indicated their willingness to participate in the survey. Regional companies were compared and national statistics were aggregated from the provincial data.

The companies replied in the negative for their GIS information to be made public for the purposes of this survey and an overwhelming majority wished to remain anonymous, in fact many would only participate if their anonymity was guaranteed.

Table 5 A summary of the participating facilities and production lines

	WC	Gauteng	KZN	Totals
Facilities	7	7	6	20
Production lines	24	40	20	84

It was noted that of the 84 production lines investigated nationally only reliable data for 35 production lines was accumulated. This was attributed mainly to inadequate controls on data acquisition.

6. RESOURCE CONSERVATION AND CLEANER PRODUCTION

For the purpose of this study, the main resource considered was water, as it is known to be used extensively by the industry for all its rinsing purposes and this does affect the final quality of the workpiece being plated. Cleaner production initiatives were investigated for the industry not just w.r.t. water but for the entire plating process. The questionnaire would serve as a quick reference sheet for all internationally accepted CP techniques as well as an indication of important parameters for the industry.

It has long been thought that in-house plating shops are better financed, have international stakeholders and backing, thus are better equipped, usually ISO certified and have a documented system of operation. This would enable them to lead the way w.r.t. resource conservation and implementation of CP techniques, standards and benchmarks. Thus, it was expected that in-house facilities would be better managed and would have adopted various types of CP for their particular plating lines.

6.1 THE TYPES OF PLATING SHOPS

The percentage of in-house plating shops to jobshops for the country is shown in Figure 6. From amongst the facilities surveyed, it is seen that a greater percentage of plating shops are jobshops. .

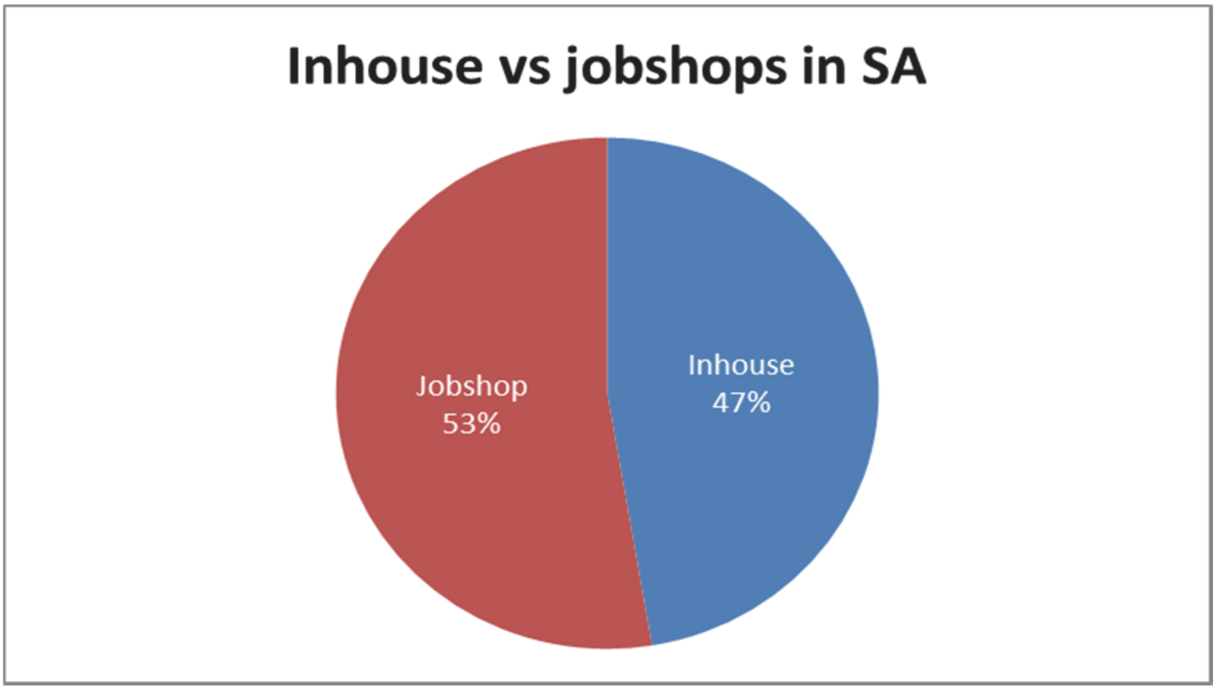

Figure 6 **The national ratio of in-house plating facilities to jobshops**

Provincially, the percentage of in-house platers is equal to that of the jobshops for Gauteng which is the province with the greatest GDP. A relatively even ratio of the two types of plating shops also exist in the WC with no documented facilities that are both in-house and jobshops. A similar trend for KZN as that of Gauteng is noted, which is an equal percentage of plating jobshops to that of in-house platers.

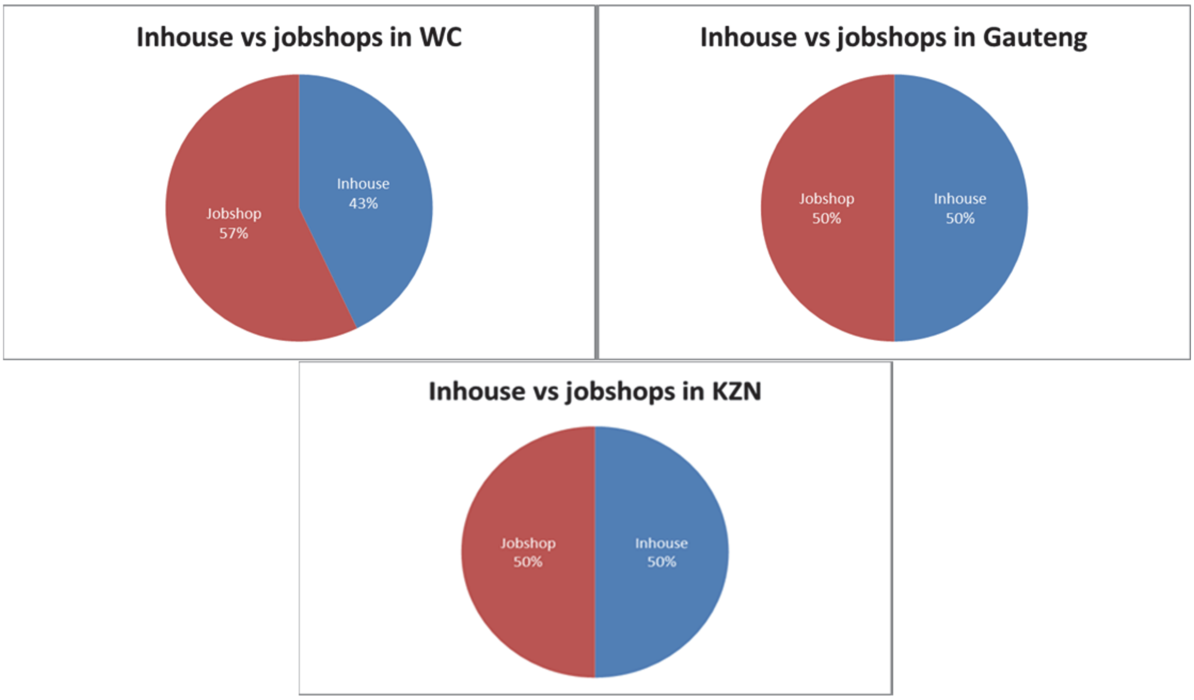

Figure 7 **The provincial ratio of in-house plating shops to jobshops**

6.2 THE CERTIFICATION STANDARDS OF THE INDUSTRY

International Standards are increasingly used to homogenise industries so that equivalent articles may be sourced worldwide without any variance in quality. They help to harmonize technical specifications of products and services making industry more efficient and breaking down barriers to international trade. Standards are thought to bring technological, economic and societal benefits. Thus the conformity to International Standards helps reassure consumers that products meet design specifications, are safe, efficient and environmentally friendly. International Standards are strategic tools and guidelines to help companies tackle some of the most demanding challenges of modern business. They ensure that business operations are as efficient as possible, increase productivity and help company's access new markets. Some of the benefits of standards include:

- Cost savings – Standards help optimise operations and therefore profits
- Enhanced customer satisfaction – Standards help improve quality, enhance customer satisfaction and increase sales
- Access to new markets – Standards help prevent trade barriers and open up global markets
- Increased market share – Standards help increase productivity and competitive advantage
- Environmental benefits – Standards help reduce negative impacts on the environment

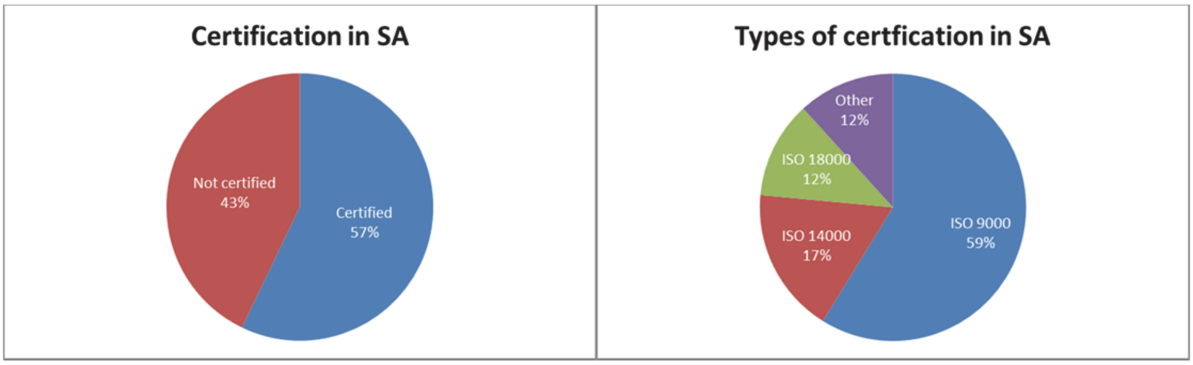

Figure 8 The percentage of facilities certified nationally and the various standards

From Figure 8 it is seen that a larger percentage of facilities are certified for various standards than not certified and of these, the ISO 9000 standard for quality management is most popular, ultimately the demand for this certification is customer driven. Other standards such as ISO 14000 and ISO 18000 are not in widespread use as the ISO 9000. Very few facilities have other international standards and these were limited to the in-house plating facilities with international stakeholders. This ties in well with the premise that in-house facilities have a greater budget and thus are capable of implementing multiple and various certifications.

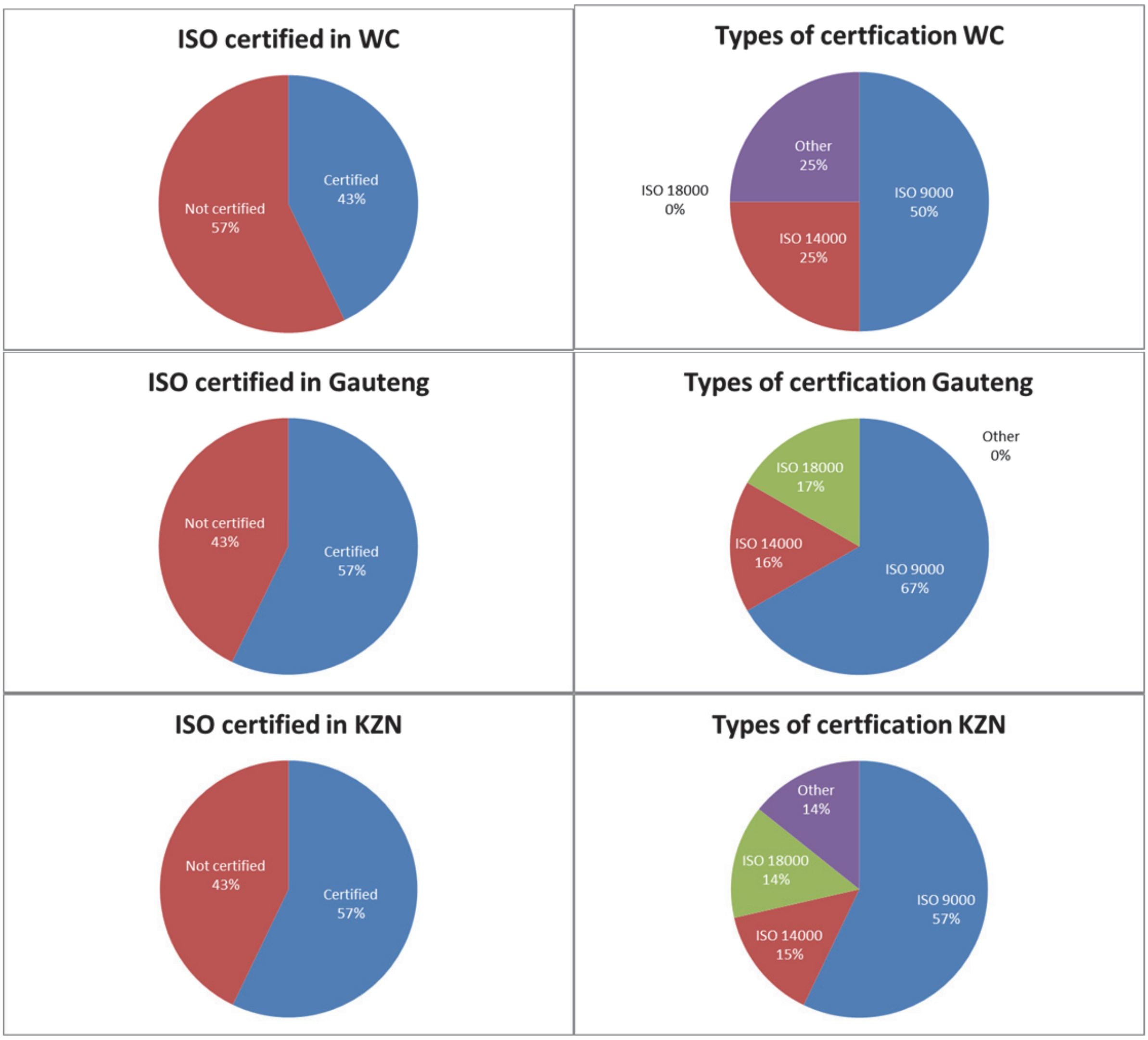

Figure 9 The percentage of certifications provincially

From Figure 9, it is seen that most facilities are not certified in the Western Cape. From the facilities that are certified most (50%) are ISO 9000 certified for quality purposes and none were ISO 18000 certified, (health and safety). The facilities that were ISO 14000 (environmental management) certified were in-house international facilities which lends credibility to the premise that companies with greater financial backing or with international environmentally aware shareholders would usually have standards and systems that enhance quality, health and safety as well as protect the environment. The companies that have 'other' certification are non-ISO international certification equal to or even more rigorous than the ISO standards.

In Gauteng the percentage of companies that are ISO certified is greater than that of the Western Cape. ISO 9000 is the industry standard and a few facilities are ISO14000 and ISO 18000 certified. Only the in-house facilities were ISO 9000 and a combination of ISO 14000 and/or ISO 18000 certified. A few jobshops were ISO 9000 certified but none of them had any additional certification.

Similarly, in Kwa-Zulu Natal more facilities are certified for standards, with the majority being ISO 9000 and a few facilities ISO 14000 and ISO 18000. Only in-house facilities were ISO 9000 and a combination of ISO 14000 and/or ISO 18000 certified. A few jobshops were ISO 9000 certified but none of them had any additional certification.

6.3 THE WATER USAGE BY THE INDUSTRY

It is known that the most water used by the industry occurs during the washing and rinsing processes. It is an unavoidable part of the plating process and inadequate rinsing directly affects the aesthetics and quality of the final product. It is also known that single rinses are water-use intensive, whilst 2 stage rinses are better than single stage rinses from a resource aspect. The 3 stage rinses are the ideal compromise for the industry, from a spatial and financial aspect and for the conservation of water and achievable product quality.

Table 6 tabulates the effect of the number of rinse stages on the consumption of fresh water by the industry. This table does not allocate the associated costs and special constraints required for the installations.

Table 6 The effect of multiple rinses on water consumption

Water used in rinse stages (l/h)					
1 stage	2 stage	3 stage	4 stage	5 stage	6 stage
1000	31.6	10	5.62	3.98	3.16

Calculated from $$Q_n = D \cdot \sqrt[n]{C_0 / C_n} = D \cdot \sqrt[n]{F}$$

Where,

- *n* is the number of rinsing stages;
- *Qn* is the consumption of fresh rinsing water (volume/time) when using counter-current rinsing with n stages;
- *D* is the dragout from the cleaning vat (volume/time);
- *Co* is the concentration of the constituent in the plating bath (mass/volume);
- *Cn* is the concentration of the constituent in the n^{th} rinsing tank that the plating tank can tolerate and maintain acceptable product finish (mass/volume); and
- *F* is the dilution factor (dimensionless).

Thus, considering cost and spatial constraints the ideal compromise for the industry is 3 stage rinses after the process tanks as they most cost effective. Figure 10 shows the types of rinse tanks used by the industry.

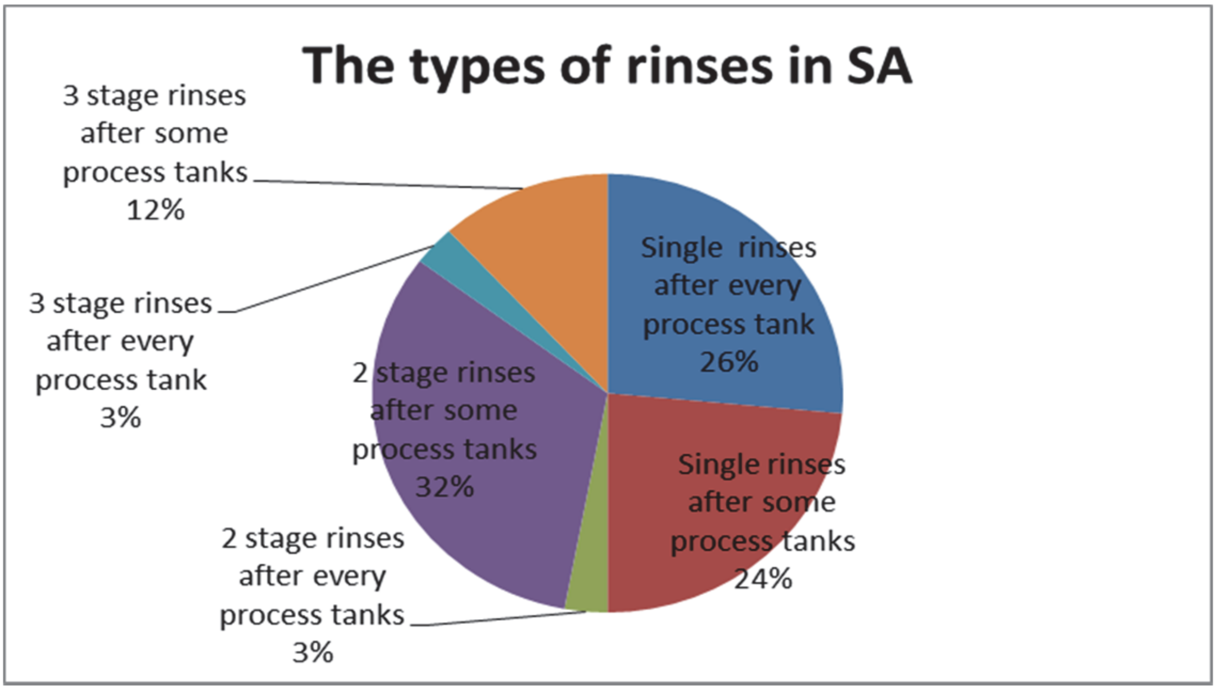

Figure 10 The various types of rinses used nationally by industry

It is seen that 26% of facilities nationally have a single rinse stage after every process stage. Where facilities have a single rinse stage after some process tanks (24%) implies they have 2 stage rinses or 3 stage rinses for the other process tanks. 32% of facilities have 2 stage rinses after some process tanks. It is noted that only 3% of facilities surveyed have either a 2 stage or 3 stage rinses after every process tank, whilst 12% of facilities have opted for a 3 stage rinse after some sensitive process tanks to usually ensure a quality product. A single stage rinse is still the most popular but these were limited to the older plants and where there was a special restraint to investing in multiple stage rinses.

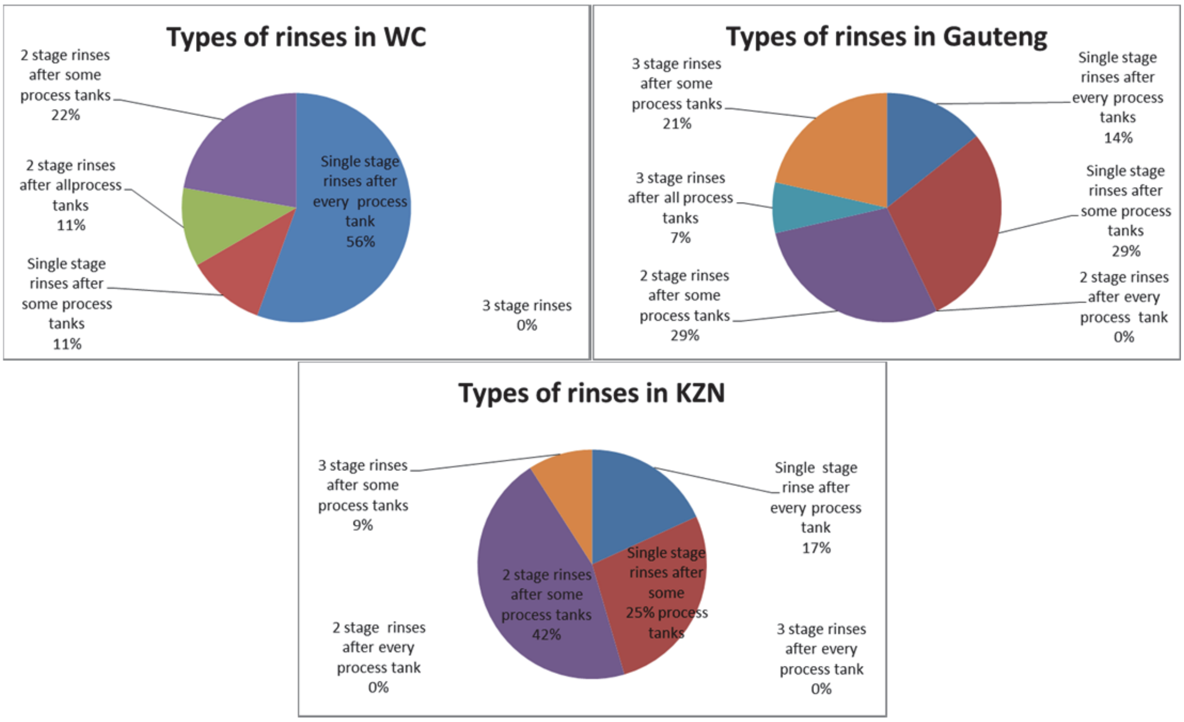

Figure 11 The type of rinses used provincially by the industry

From Figure 11, it is seen that no facility surveyed in the Western Cape uses a 3 stage rinse and that single stage rinses after every process tank was most popular. It is well known that single stage rinses are water-use intensive and this should cause this province to have the worst specific water index (SWI) which is confirmed in the latter sections. This practice had previously been ascribed to archaic plants, bad design and/or space limitations. 2 stages rinses after some process tanks are more popular than after all process tanks and this is probably due to cost and space limitations. It was also found that these were on lines that required a higher product specification.

For Gauteng, 2 stage and 3 stage rinses are extensively used even though the total cost of water is comparable in Gauteng to the other 2 provinces surveyed. Water cost R12.51/kl in the Western Cape, in KZN R14.59/kl and in Gauteng is R13.17/kl for the 2013/2014 financial year. Thus the change to CP initiatives were not directly cost driven but rather some other factor such as improved finish or the adoptions of an ISO 14000 standard. It could also be argued that a multiple stage washing does provide a return on investment in that it reduces the volume of water used and hence its cost. In some instances multiple stage washes were not retrofitted but rather included when the plants were designed or rebuilt.

In KZN single and 2 stage rinses are still the most popular. Some facilities use boreholes/river abstraction thus the cost of water is less. The adoption of multiple stage rinses is thus not driven by the cost of the resource but rather some other incentive. It is clear that these facilities in KZN have a good understanding of resource conservation as well as CP as the percentage of single stage rinses is low.

The province with the worst resource conservation techniques w.r.t. water was the WC as they have by far the most single stage rinses after their process tanks.

6.4 RESOURCE MANAGEMENT IN THE INDUSTRY

In order to quantify the resource's usage efficiency a measure of the usage must be obtained to be used as a baseline for further studies. Water is a valuable resource and the monitoring of its use in the industry has to be gauged before any recommendation may be made on its usage. It is also understood that in order to manage a resource it has to be firstly measured.

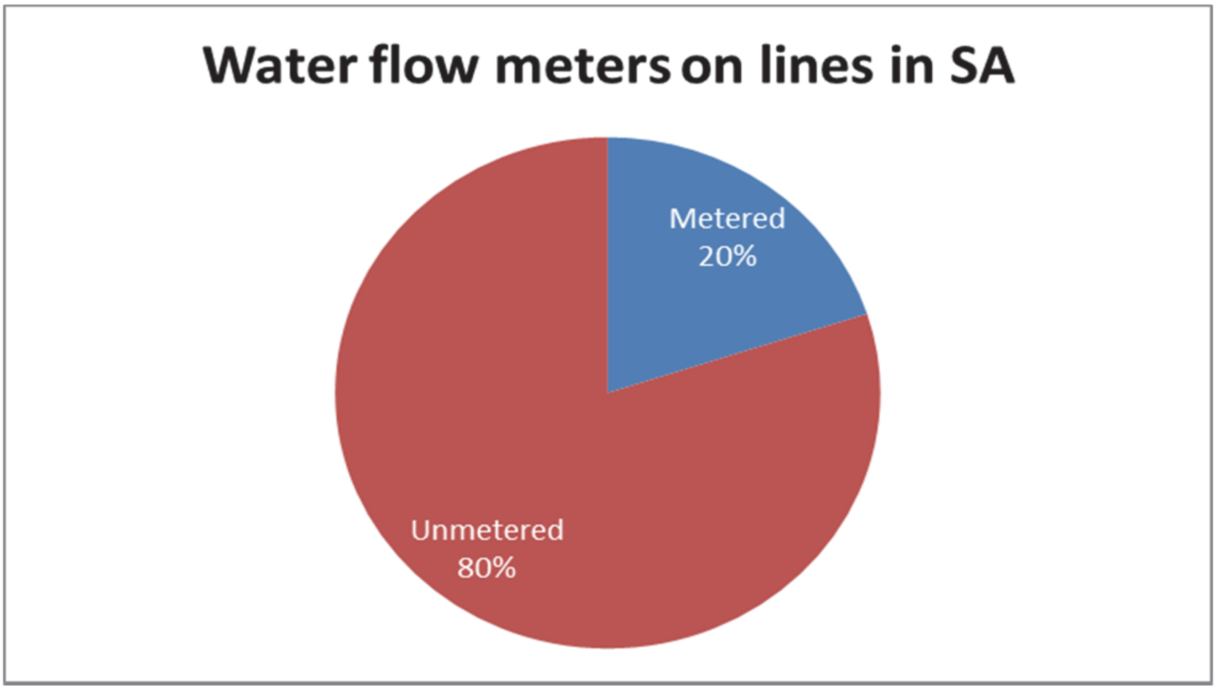

Figure 12 The metering of water used in the plating process nationally

The easiest way to monitor the volume of water used is to have flow-meters on the water process lines. If this is not possible then it is required that the documented water used for the entire facility as per municipality bill be used to estimate the water consumed in process lines. Then a portion of this is allocated to the plating lines and the remainder to the rest of the facility. Although inaccurate, it still provides a good first estimate for the industry. The ideal is that each facility should have water flow meters on the rinse tanks to measure exactly the volume of water used per rinse tank. This would provide the facility with the ability to troubleshoot excessive water consumption and allow for accurate benchmark. It would also indicate process problems and inadequate surface coatings due to inadequate rinsing. This would also allow them to run the plant as close to design specifications as possible and keep the water usage to the theoretical minimum. From Figure 12 it is seen that 80% of the facilities do not measure their water usage and is run using operators gut feel for the final product finish.

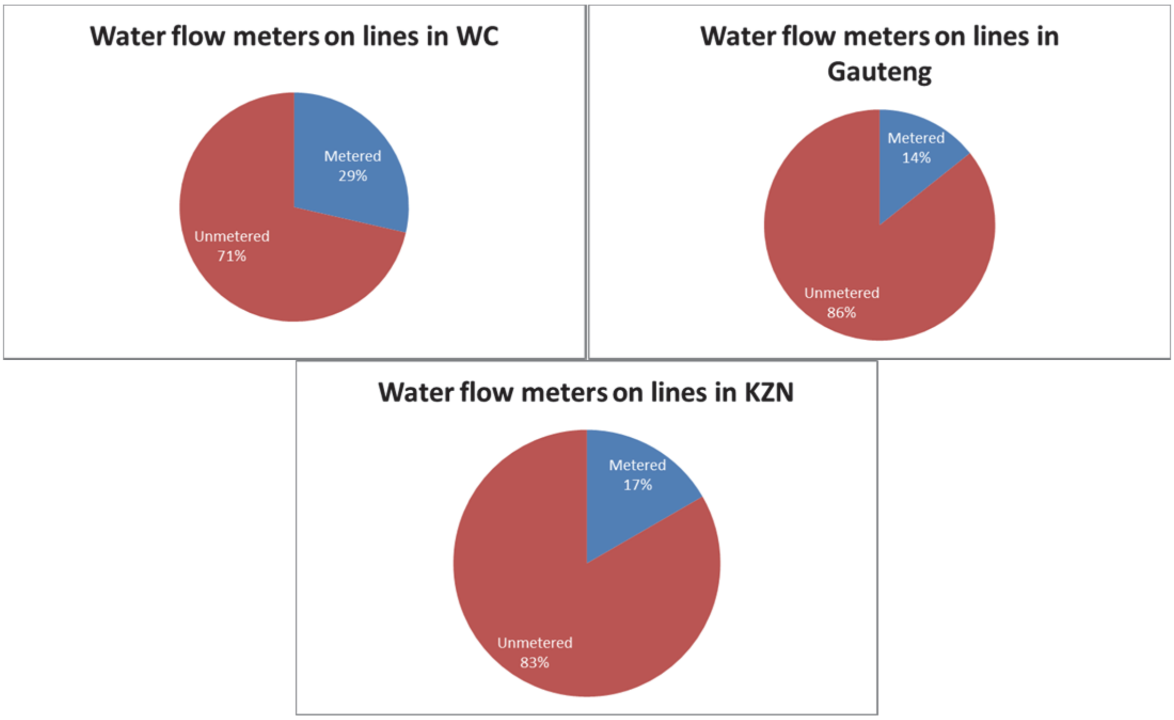

Figure 13 Monitoring of water usage by the industry provincially

Figure 13 shows that very little monitoring of water usage in rinsing lines is utilised by the facilities countrywide. This show that although they consider water to be a commodity, it is not well managed as the industry does not know how much water it uses per rinse tank. This oversight also poses a problem with the accuracy of the calculation of an industry wide specific water index (SWI).

6.5 IMPLEMENTATION OF RUDIMENTARY CP TECHNIQUES

Many CP initiatives are available for the industry and as such many are used by the various facilities. The techniques singled out for this survey concentrates mostly on water conservation, raw chemicals conservation and optimised its usage (to limit water contamination) as well as efficient plant operation in line with best international practices. These are not only limited to low cost solutions but also the international standards such as reverse osmosis (RO), de-ionising units (DI) and other membrane units.

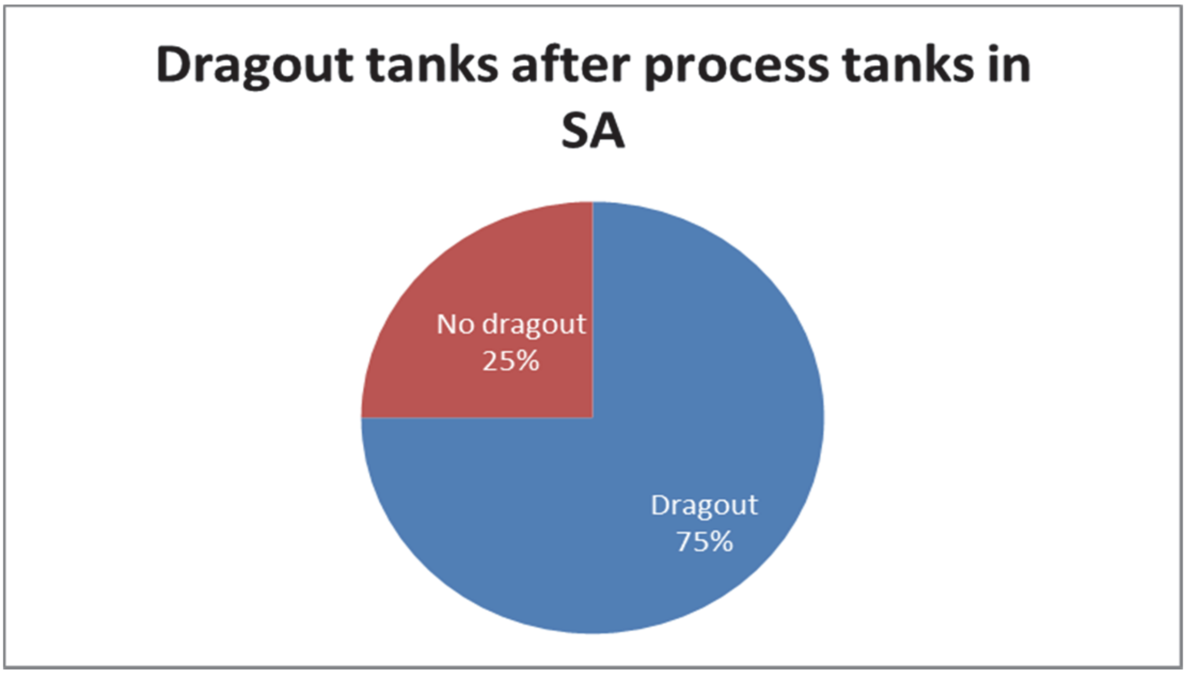

Figure 14 The use of dragout tanks in the industry nationally

Figure 14 graphically shows the national percentage of facilities that use dragout tanks after process tanks. The dragout tank is a rinse tank following a process tank that initially is filled with pure water. As the plating line is operated, the dragout rinse tank remains stagnant and its chemical concentration increases as more work is processed. After a period of operation, the solution in the dragout tank should be used to replenish the losses to the plating bath. If sufficient evaporation has taken place, a portion of the dragout tank solution can be added directly to the plating tank. Dragout tanks conserve chemical resources as they are not discarded to effluent, rather they are concentrated in the dragout tanks and returned to the process tank, saving the facility revenue. This simple principle is not as widespread as would have been thought but is a consequence of antiquated process plants and limited space.

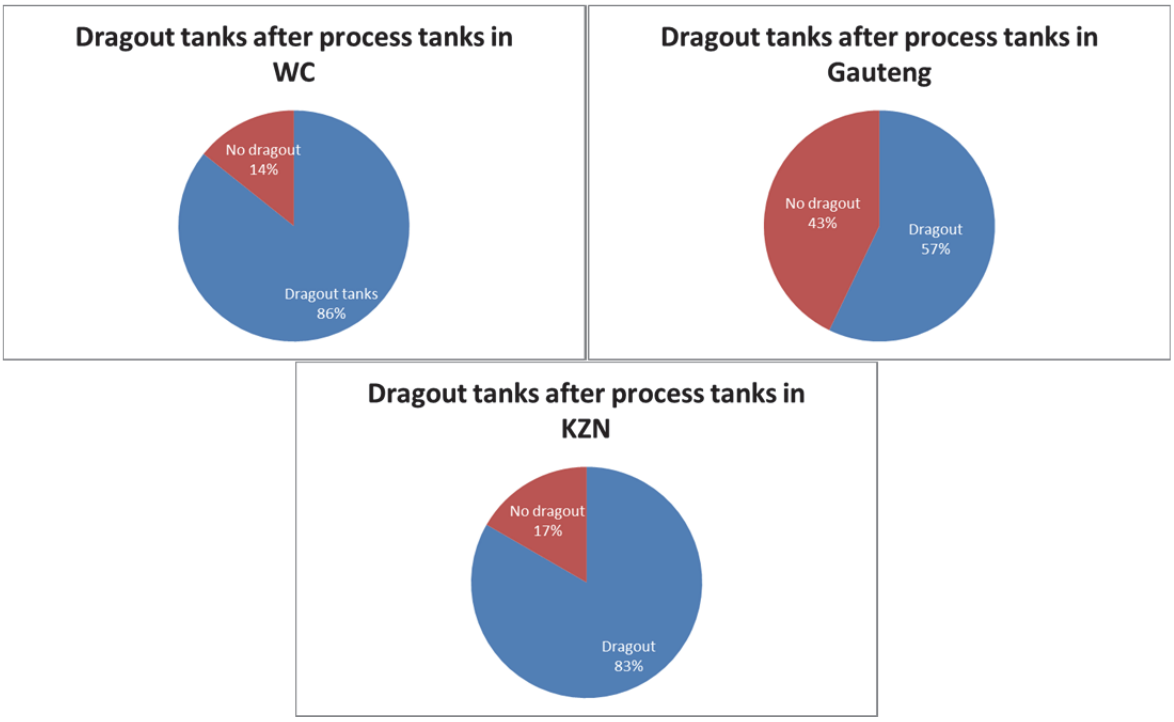

Figure 15 The use of dragout tanks by the industry provincially

From the survey it is seen (Figure 15) that the use of dragout tanks have not proliferated in Gauteng, this was confirmed by the site visits as the established businesses did not have adequate space for additional tanks. It could also be that the operators have long duration drip times for workpieces and dragout accumulation is very slow.

It is clear that the dragout tanks are used as an initial rinse for plated articles. The best international practise dictates that the dragout solution should be returned to plating tank to decrease fresh plating chemical use.

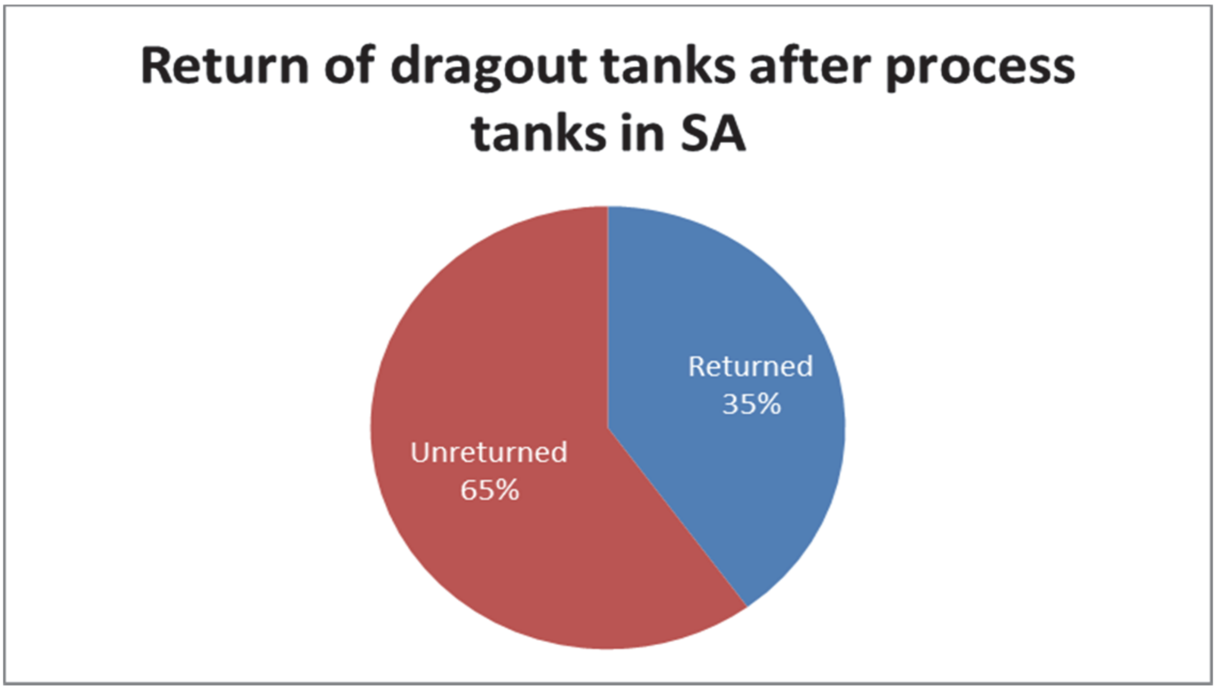

Figure 16 The return of dragout to process tanks nationally

The CP technique of returning the dragout solution to process tanks for the entire country is shown in Figure 16. It is seen that a large percentage of dragout is not returned to the process tanks and this is considered a bad practise and contrary to international best practice, constitutes a loss in revenue for the facility as valuable chemicals are discarded as waste.

Figure 17 shows the provincial breakdown of this practise. Upon inquiring from some facilities in Gauteng, it was confirmed that they had returned dragout solution to plating tanks but they had formed the opinion that it adversely affected the quality of the finish. This is counterintuitive to international best practise. It is advised that the facilities reinvestigate this CP technique as many facilities in KZN do return dragout and have not experienced any deterioration in quality of the final product.

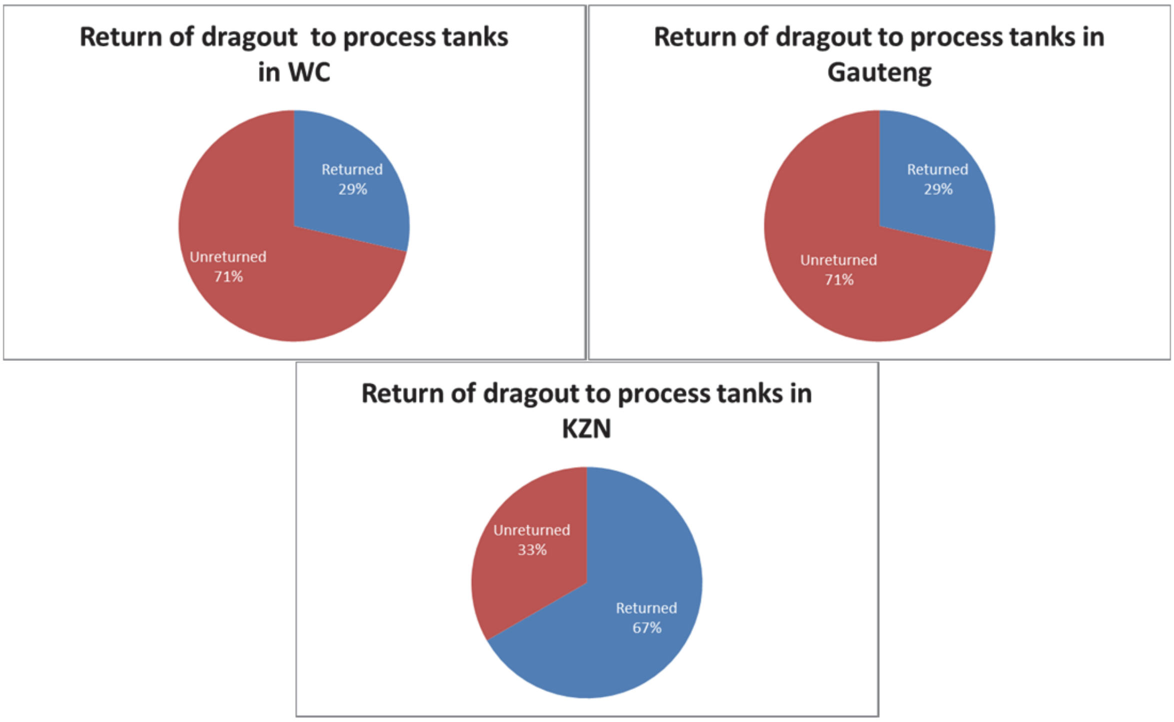

Figure 17 The return of dragout solution to process tanks provincially

If the use of water is controlled according to Best Available Practices (BAP) then the waste water system required for the facility is simplified tremendously. Efficient effluent treating is not possible unless the water flow is effectively controlled. With controlled flows, the cost of the waste water system is greatly reduced and the likelihood of reclaiming rather than sludging the waste is greatly increased. Multiple use rinsing, also called cascade or counterflow rinsing saves a tremendous amount of water when used with adequate flow controls.

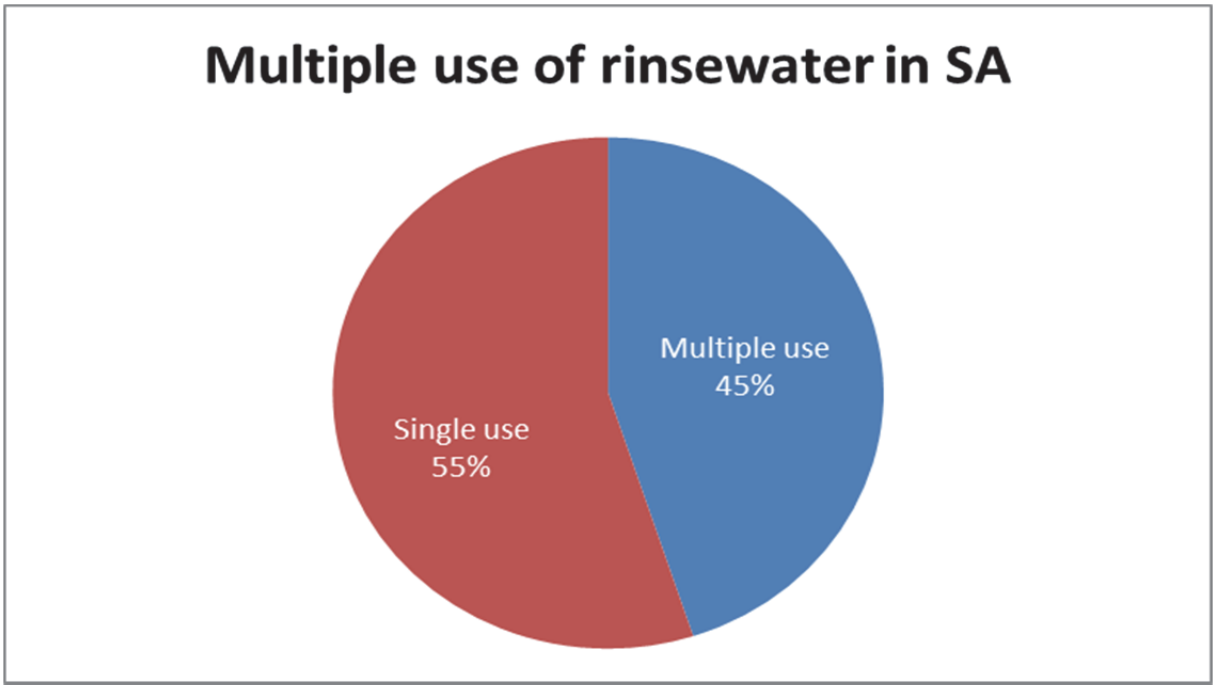

Figure 18 The multiple use of rinse water nationally

This technique of multiple use of rinsewater is an internationally accepted practise and has yet to establish a greater foothold in SA as a CP technique and subsequent capital cost savings, as seen in

Figure 18. This is especially true for a proposed new facility as they can plan for the flow of workpieces and in the case of existing facilities it may be retrofitted and the practice incorporated.

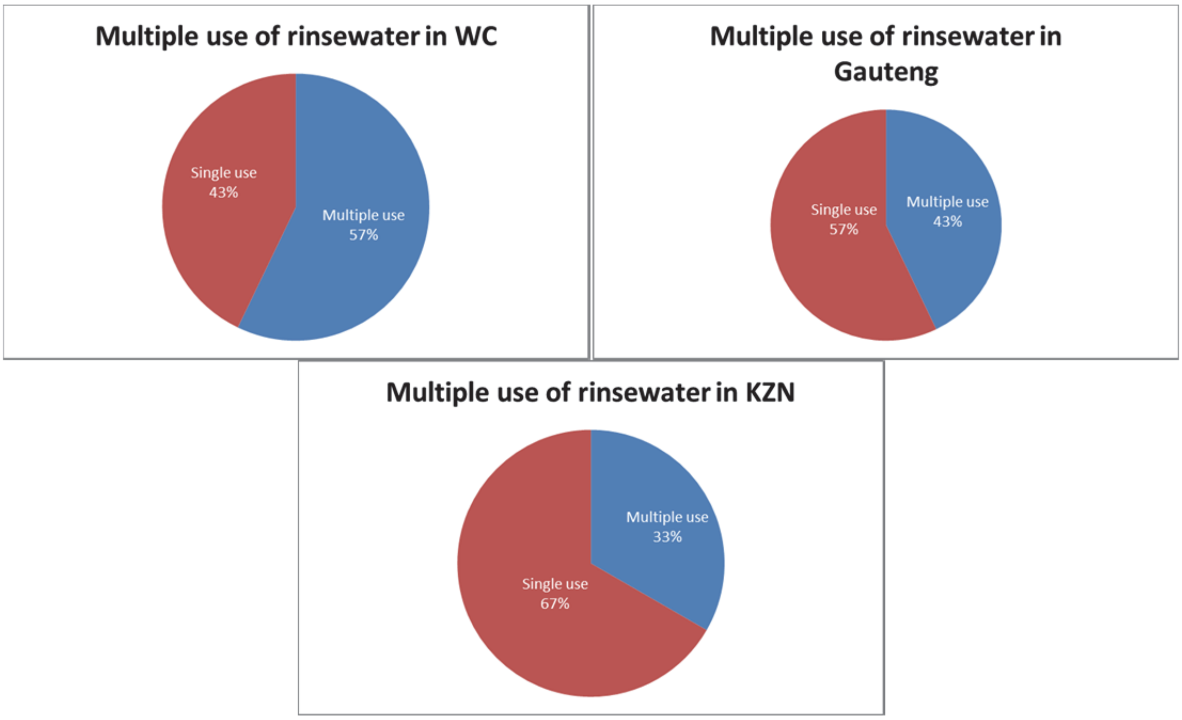

Figure 19 The practise of multiple use of rinse water provincially

From Figure 19, the WC leads the provinces by applying multiple use of rinse waters. This technique saves water as well as vaulable space and thus the facility may have a smaller footprint. It is possible that this techniques works for them as they have single stage rinses which is water-use intensive and thus capable of handling the multiple pollutant loads. It could also be the reason why there are so few 2 and 3 stage rinses as these reduce the effective water flow, hence increasing the concentration of contaminants producing off-specification products.

At the time of this survey there were 2 companies nationally (one in the WC and other in Gauteng) that had dual stage membrane/RO treatment for their effluent and subsequent reuse of water. This low number is primarily due to the high cost of the units.

From Table 7 it is seen that many expensive CP options (RO and DI) are available for the industry and these are avoided, but the cheaper CP alternatives are likewise not extensively used. The operators of these facilities are knowledgeable on their process as 45% nationally surveyed acknowledged that they did not see any CP initiatives that they were unaware of. This clearly indicates that there is an underlying barrier preventing the implementation of these techniques. It may be argued that these could be financial, space limitations or expertise for the adopted measures.

Table 7 Additional best practise CP measures used by the industry

CP measure	Western Cape (%)	Gauteng (%)	KZN (%)	Nationally (%)
Combining of pre-dip tank with drag out tank so that drag in = drag out	0	0	0	0
Reverse Osmosis units installed on rinses (e.g. nickel) for direct recovery of water and process solution	0	0	0	0
DI Units for the removal of metal ions from rinses so that water may be reused.	14.29	0	0	5
Acid extender chemicals used in pickles so that metals can be filtered out of the pickles	0	0	16.67	5
Ultra-filtration on hot soak cleaners for oil and sludge removal to extend tank life	0	0	0	0
Oil skimming apparatus included in soak or electrolytic cleaners (e.g. belt or wheel technology)	0	0	16.67	5
Oil skimmer compartments as part of the hot soak cleaner tank system.	0	0	33.33	10
Control of withdrawal speed of auto carriers to a slow rate to minimise carryover of solution on components	0	14.29	33.33	15
Jig design to maximise drip off time and drainage	28.57	14.29	50	30
Jigs coated with proper resins to ensure that coating goes only onto the parts.	28.57	14.29	83.33	40
Lip extraction systems that are able catch aerosols for return to the tank as solution	0	14.29	16.67	10
The installation of hanging rails above manual process tanks to facilitate adequate drip off	0	14.29	0	5
Drip Guards between tanks so that dripping from jigs moving overhead is guided to tanks	14.29	0	66.67	25
Electrolytic Recovery of Metals from spent solutions for re-use in the plant	0	0	0	0
Did you notice any CP* options that you were unaware of, or had not considered before?	57.14	57.14	16.67	45

7. CHEMICALS AND PRODUCT MANAGEMENT

In order to gauge the efficacy of the industry w.r.t. its chemicals usage and product management, the questionnaire addressed this and was a template for a Chemical Management Action Plan (CMAP) which is compulsory for any company in the Western Cape. This was accomplished by addressing the quantity of reagents and chemicals as well as the subsequent disposal of effluent and sludge generated by the industry.

A certificate of analysis (CoA) is defined as an authenticated document issued by an appropriate authority and certifies the quality and purity of pharmaceuticals, and animal and plant products being exported.

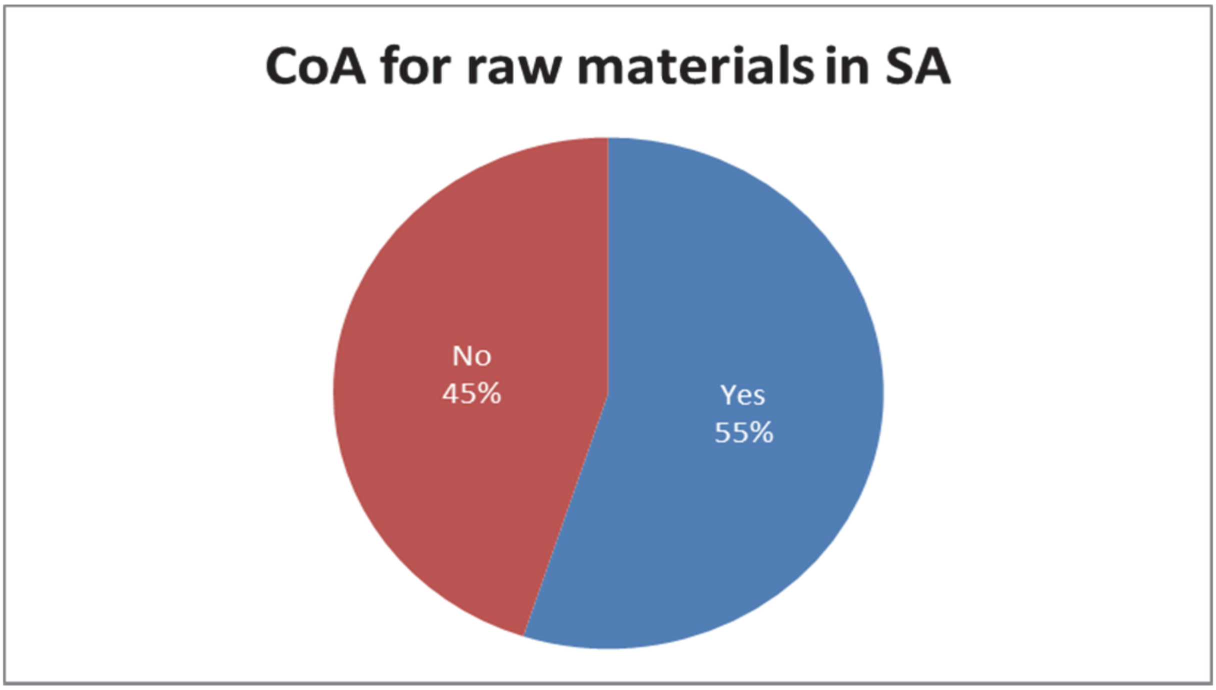

Figure 20 The prevalence of the use of CoA by the industry nationally

It is good practice for the facility to purchase chemicals from a supplier that supplies a certificate of analysis (CoA) so that quality of the product is matched to the theoretical quality predicted by the stoichiometry of the reactions. It is noted that 55% of facilities demand CoA's but 59% are ISO 9000 compliant but this is plausible as they could be doing their own analysis.

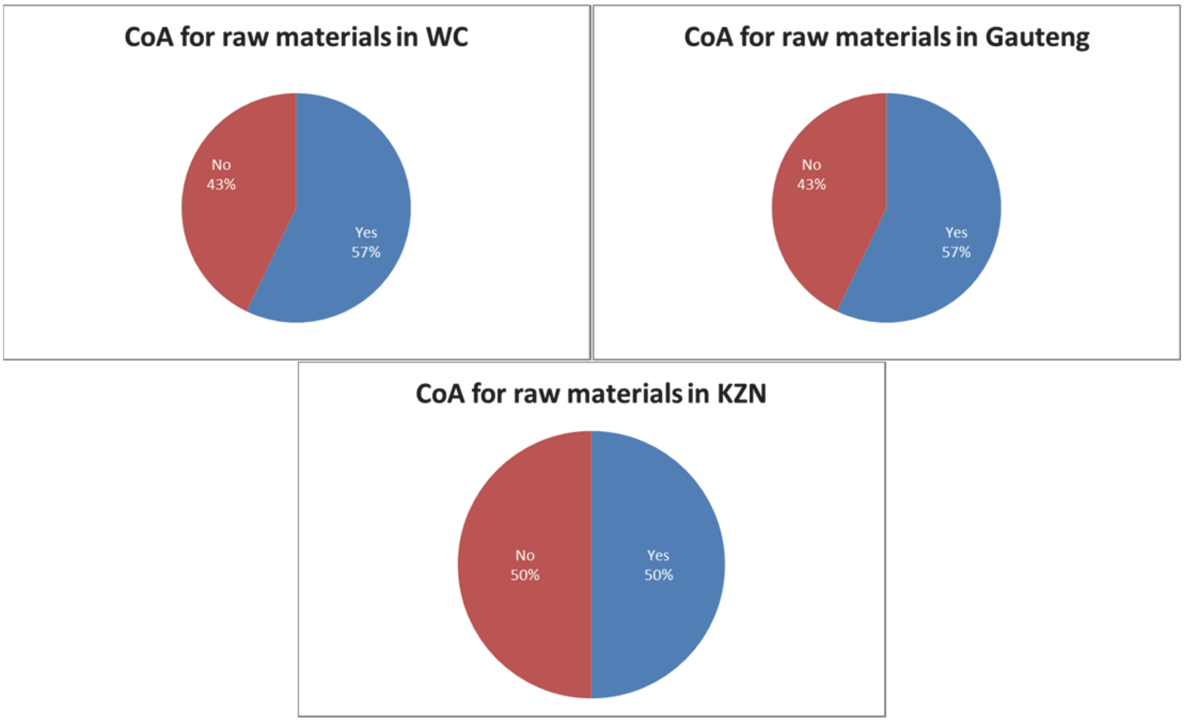

Figure 21 The prevalence of use of a CoA in the industry

It is seen that on average the industry (Figure 21 and Figure 20) does demand CoA from its suppliers but the prevalence of this practice should be increased as it would help with tracing the causes of off-specification products, auditing purposes as well as accurate certification.

From a safety aspect it is pertinent that all chemicals on site have a materials safety and data sheet (MSDS) that lists amongst others the chemical structure, hazards and emergency 1st aid in case of exposure. Figure 22 shows that the use of MSDS's are widespread but this practice should be at 100% and be part of the safety manual and standards that every worker should have access too.

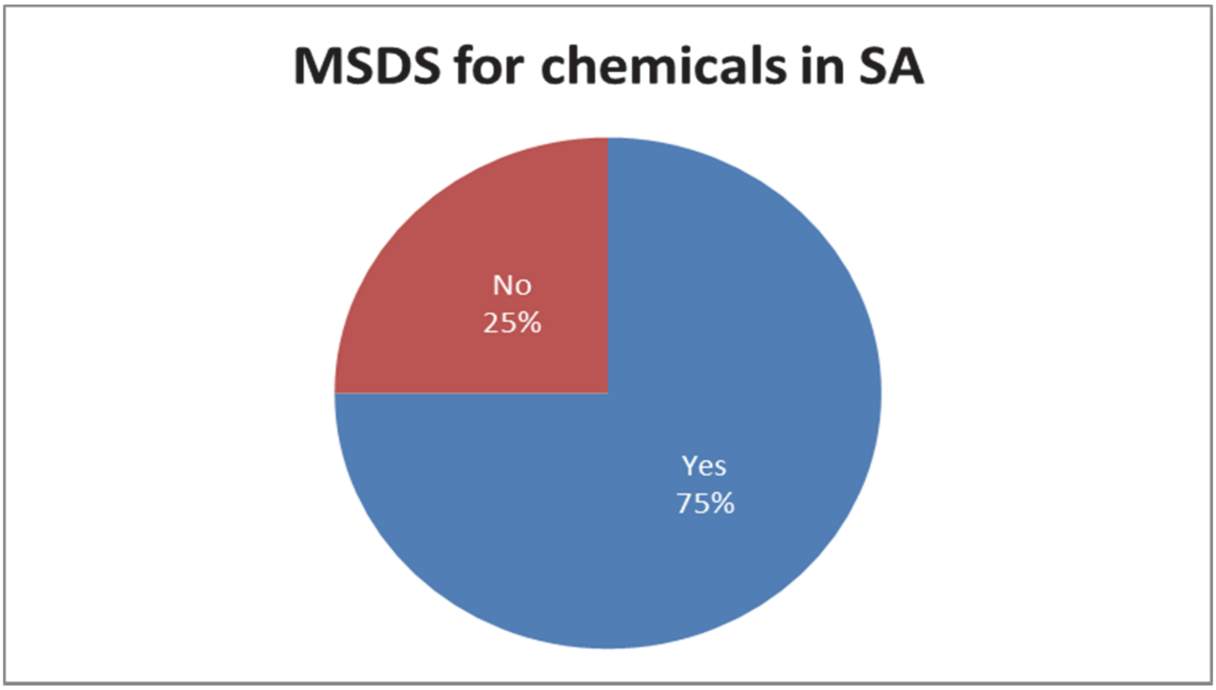

Figure 22 The national prevalence of a MSDS for chemicals by the industry in SA

For this industry many facilities do not have purpose built laboratories to do their chemical testing and analysis of their process tanks and other chemicals and are thus dependent on their chemical vendors for this purpose.

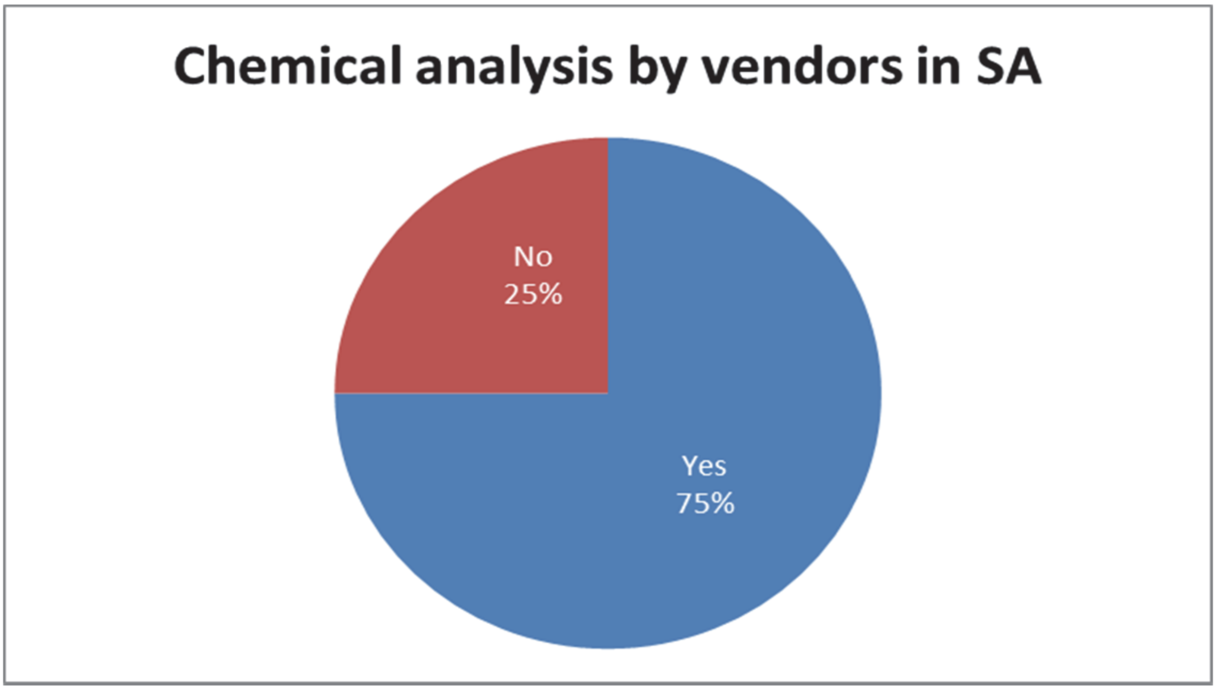

Figure 23 The national reliance on vendors for chemical analysis in SA

Figure 23 shows that a greater number of facilities do not have laboratories or do not have the expertise to analyse underlying chemical reactions in the plating industry. Thus, many facilities are entirely dependent on their chemical vendors for analysis of their tanks and baths.

Table 8 shows the questionnaire and answers for the current chemical management practices within in the industry. This questionnaire would also serve as a Chemical Management Action Plan (CMAP) for facilities operation within the Cape Metropole, where a CMAP is compulsory.

Table 8 Chemical management practices within the industry

Chemical management practice	Western Cape Yes (%)	Gauteng Yes (%)	KZN Yes (%)	Nationally Yes (%)
Do you have Material Safety Data Sheets [MSDS] for all products used?	71.4	71.4	83.3	75
Do you demand Certificates of Analysis for chemical raw materials purchased?	57.1	57.1	50	55
Do you have raw materials in stores that are unusable for one or another reason?	0	28.6	33.3	20
Do you have a system in place to safely dispose of unusable products?	85.7	71.4	83.3	80
Do you have any certificates of Safe	85.7	57.1	83.3	75

Disposal on file?				
Do you have separate stores to keep incompatible chemicals apart?	71.4	57.1	50	60
Do you work with any flammable solvents?	71.4	57.1	50	60
Do you have an approved solvents store?	57.1	57.1	50	55
Do you have any purpose built stores to house hazardous chemicals?	57.1	57.1	83.3	65
If you are in the Western Cape do you have a Metro approved CMAP* in place?	57.1	N/A	N/A	N/A
Process tanks chemical management				
Do you perform some of your chemical analysis using in-house facilities?	57.1	28.6	66.7	50
Do you rely on supply houses to look after your analysis?	85.7	57.1	83.3	75
Do you maintain a file of chemical analysis reports for all process tanks?	100	71.4	83.3	85
Do you use automatic chemical dosing units in process tanks?	71.4	71.4	50	65
Do you use automatic dosing in some process tanks	14.3	14.3	33.3	20
Do you have contaminated unusable plating/process solutions on your site?	14.3	28.6	50	30
Do you agree that disposal of contaminated solutions is an expensive exercise?	85.7	71.4	66.7	75
Does a contractor immediately dispose of process solutions that become unusable?	42.9	28.6	16.7	30
Do you store them to treat yourselves	0	14.3	33.3	15
Do you store for the contractor	28.6	28.6	16.7	25
Do you treat it immediately yourselves	42.9	28.6	16.7	30
Sludge management				
Does your rinse water flow directly to the sewer without treatment?	14.3	14.3	0	10
Do you operate a well-designed effluent treatment plant that caters for all discharges?	71.4	57.1	83.3	70
Is your plant home built	42.9	0	66.7	35

Is it partially home built	57.1	42.9	16.7	40
Is it a turnkey product	0	42.9	0	15
Which of the following operations are included in your waste treatment system Neutralise and settle	71.4	57.1	83.3	70
Membrane technologies	0	0	0	0
Cyanide oxide	28.6	42.9	16.7	30
Chrome 6 reduction	0	14.3	16.7	10
Sludge consolidation	57.1	42.9	50	50
Bag filters	0	0	16.7	5
Filter press	28.6	42.9	50	40
Other	0	28.6	0	10
Are you recycling the treated water from the effluent plant for reuse?	0	14.3	0	5
Do you make use of a certified waste removal contractor?	28.6	57.1	83.3	75

It is noted that in the WC and Gauteng there are facilities that discharge directly to the sewage system without prior treatment. This places an additional burden on the municipal waste water treatment plant (MWWTP) of the catchment.

Very few facilities nationally (5%) are recycling treated effluent for re-use on their process lines. This is an indictment on the cost of the RO units and technology used to perform this.

8. THE UTILITIES COSTING FOR THE INDUSTRY

It had been speculated that the increasing cost of utilities would drive the introduction of CP measures and allow the facilities to remain economically competitive. At first glance it is seen that the cost of water is considered a running expense and little thought is given to reducing its volume or its reuse within the process.

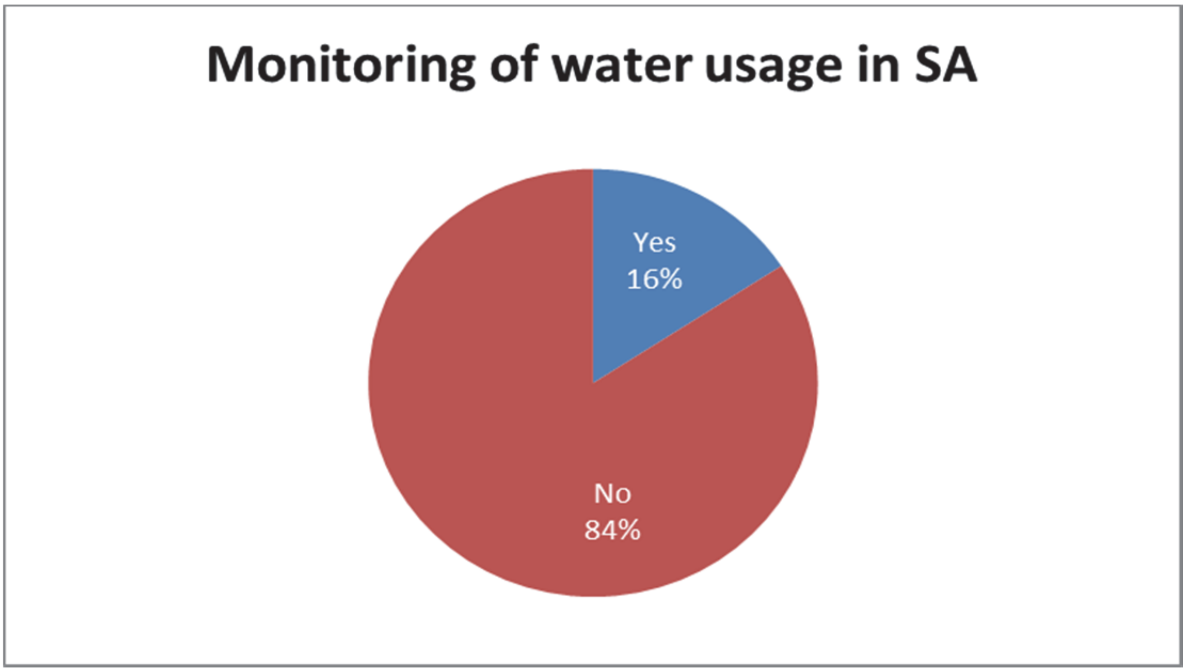

Figure 24 The monitoring of water usage by the industry nationally

It is good business practice that a facility knows the cost of its raw materials so that it can accurately determine a manufacturing cost and hence the overall profit per unit. It is for this reason they should keep a separate account of the water used in the processing to the rest of the facility. Figure 24 shows a bleak picture as only 16% of the industry knows at any one time how much water they are using for metal finishing. This valuable resource of water is seen as mere utility, not accurately measured and the uptake of CP initiatives to reduce its use or to recycle is limited. Even if the facility could estimate how much water is used in the plating lines it still does not know by how much it can reduce it to still meet a quality specified product per least volume of water. Effective measurement is paramount before changes can be implemented. At best the industry estimates that between 50-95% of the overall water is used by the plating process lines.

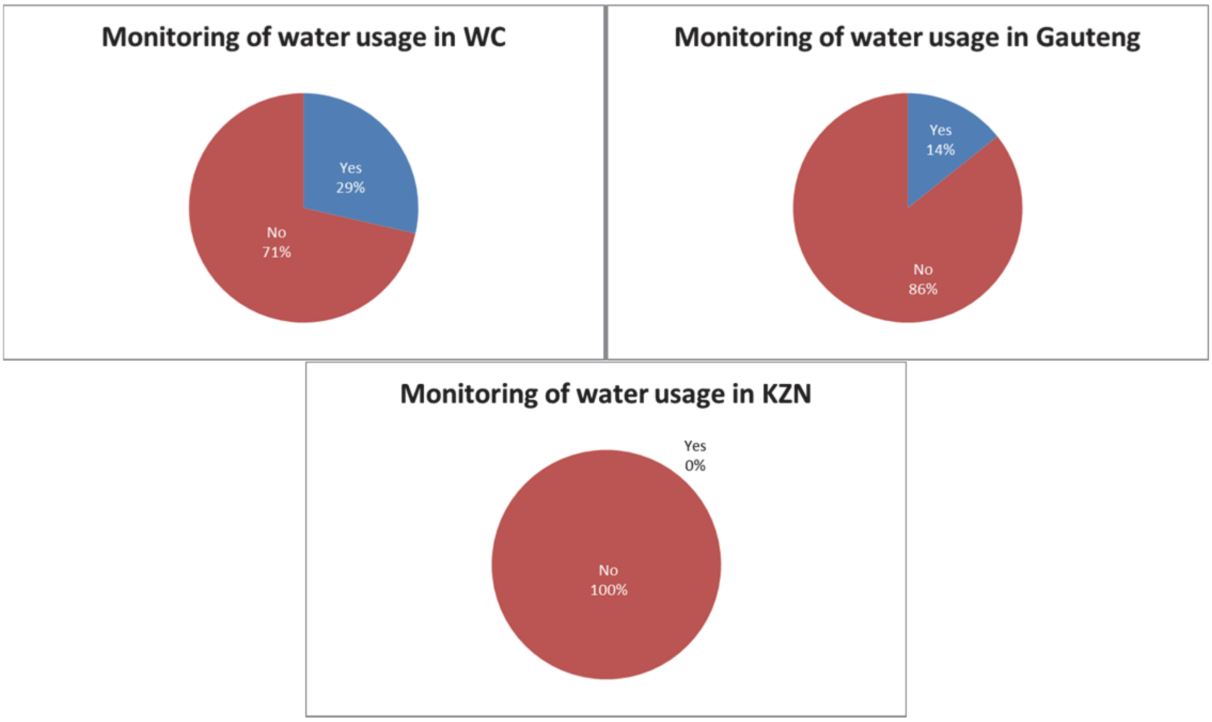

Figure 25 The provincial monitoring of water usage by the industry

A greater majority of the facilities do not know how much water is used in the plating lines. They do know how much the entire facility uses but cannot accurately differentiate between the plant and non-plant operations.

Every facility that is connected to the municipality sewage system should be monitored monthly for discharge compliance by the legislated municipality and collect effluent samples, but this was not the case and a few facilities were not monitored at all.

It is noted that not all the facilities are effluent compliant and that their waste water treatment plants (WWTP) are not all functioning satisfactorily. Historically, when the facility was built the plant worked well and the effluent was compliant but as the facility expanded and plating lines increased the WWTP did not keep up with the growth of the plant. It is thus currently operating over-capacity and cannot produce a compliant effluent. This could be due to an oversight, financial or space limitation. This oversight need to be addressed as a matter of urgency within the industry. The option of treating the effluent further and recycling water back to the plant is a viable option as a form of pseudo-CP. This could be effected with RO units or some novel new approach. Other new technologies that may be considered are:

1. Siemens membrane technology followed by RO treatment
2. Electro Chemical technology with metalliferous electrodes which liberate highly active ionic species that precipitate/immobilize complexes followed by RO.
3. Vacuum distillation technology that allows reliable and effective processing of industrial waste water in one process step.

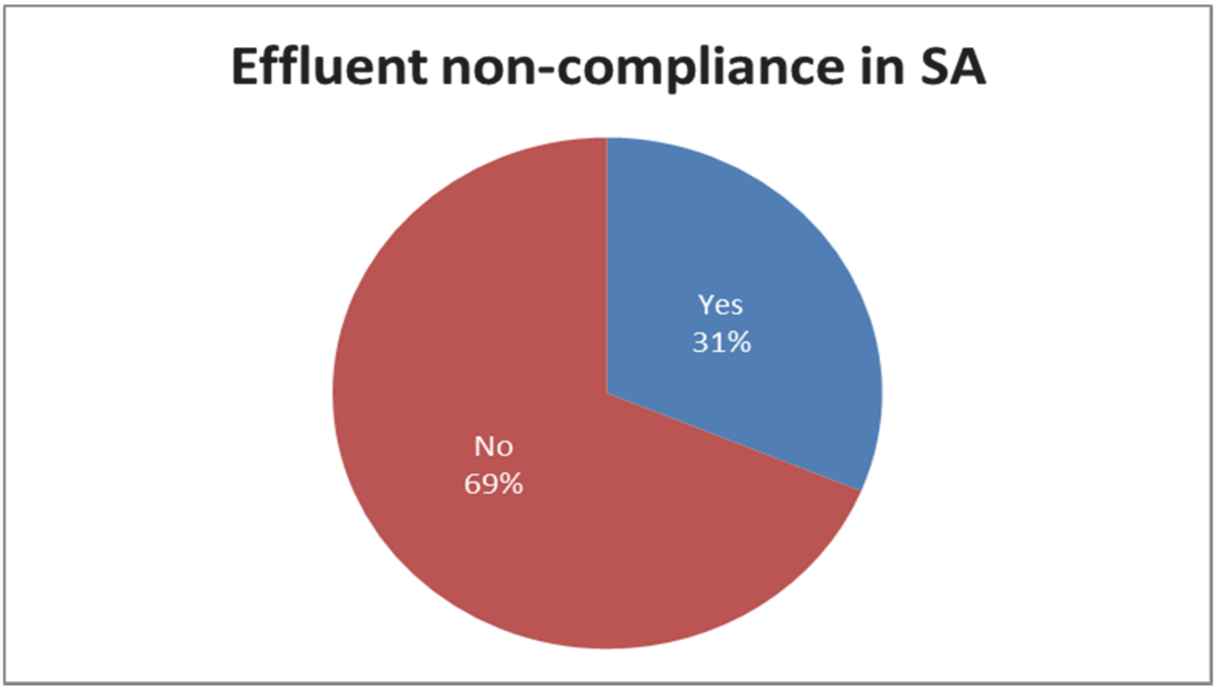

Figure 26 The past year's effluent non-compliance by the industry in SA

Of those that were sampled very few in KZN were compliant for the past year (2013) when they were sampled. The Western Cape had the best compliance, but it was also the province with the most facilities that were not being sampled so the 100% compliance is somewhat misleading. It is also the province with the greatest water usage and hence could be complying due to dilution of their effluent. A definitive statement regarding non-compliance can, however, only be made once the data obtained from the survey is combined with information from the local municipalities.

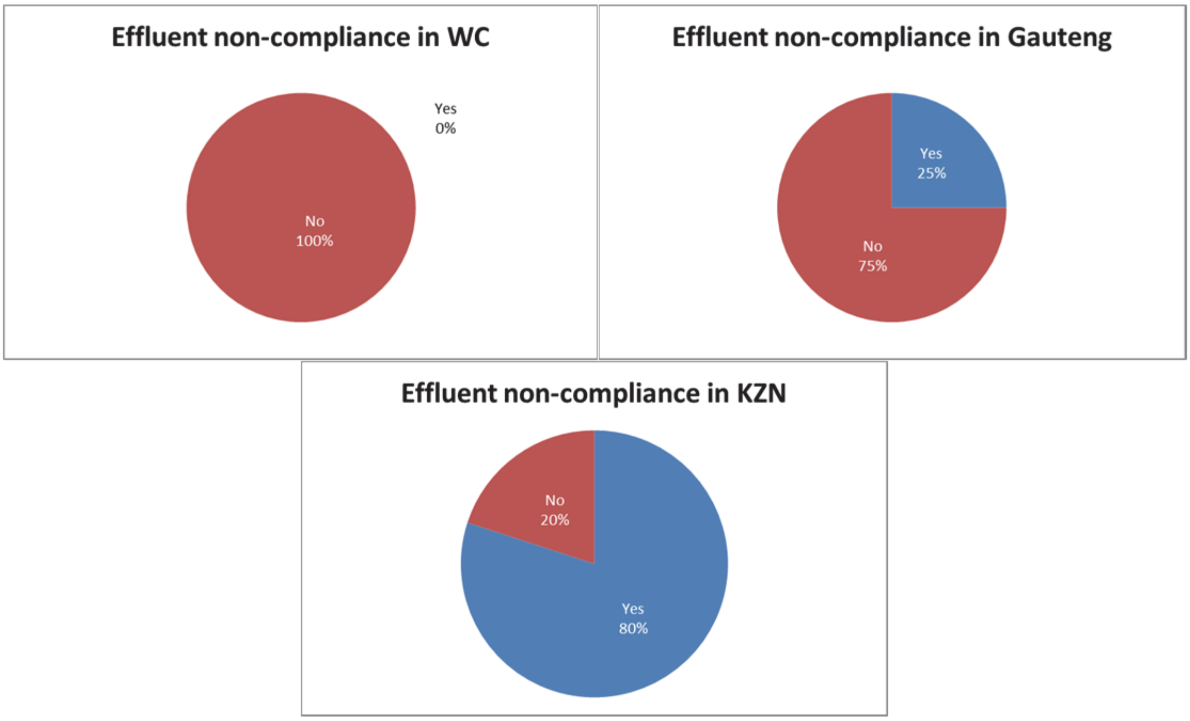

Figure 27 The incidences of effluent non-compliance by the industry in 2013

Figure 26 and 27 show the average for effluent non-compliance for the past year (2013) and these were categorised as heavy metals, high pH, high TDS, conductivity and high Cr(vi) in the effluent.

This figure shows that the vast majority (69%) of facilities comply with the effluent by-laws of their provinces with the exception of KZN as it had the most infringements. It was seen that the effluent non-compliance was not attributed to regular running operations of the facility but rather special circumstances such as an inefficient WWTP, spills and dumps that got entrained in the effluent.

Table 9 shows the utilities used by the industry and their related costs. Industry has been enjoying a reduced cost for electricity but the current electricity crisis in SA is bound to change this and alternatives to electricity will have to be considered especially in the form of gas, heat pumps or solar energy for heating. The cost of water varies with province and the WC has the highest cost per kilolitre and facilities located there would benefit from implementing CP that saves water.

Table 9 Cost of utilities for the industry

Utility	Western Cape (R/unit)	Gauteng (R/unit)	KZN (R/unit)
Water including sewage surcharge	12.51	13.17	14.59
Electricity	0.98	1.12	1

As is the case with water, the industry does not accurately know how much electricity they are using for their plating lines. The primary source of heating for the process bath is electric heaters. Currently only one facility uses an alternative energy source (burning paraffin/diesel to generate steam) and benefits tremendously from the reduction in cost.

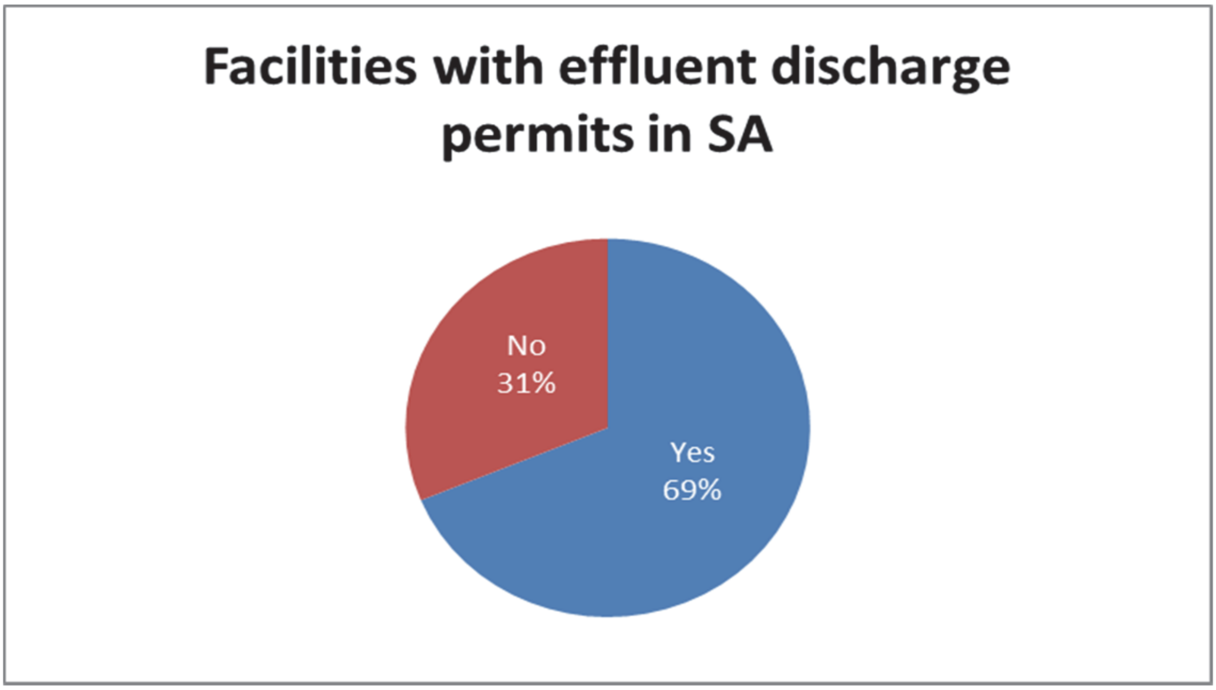

Figure 28 Effluent discharge permits for SA

The industry needs to become more legislatively compliant nationally as almost a third of facilities surveyed are operating without having effluent discharge permits.

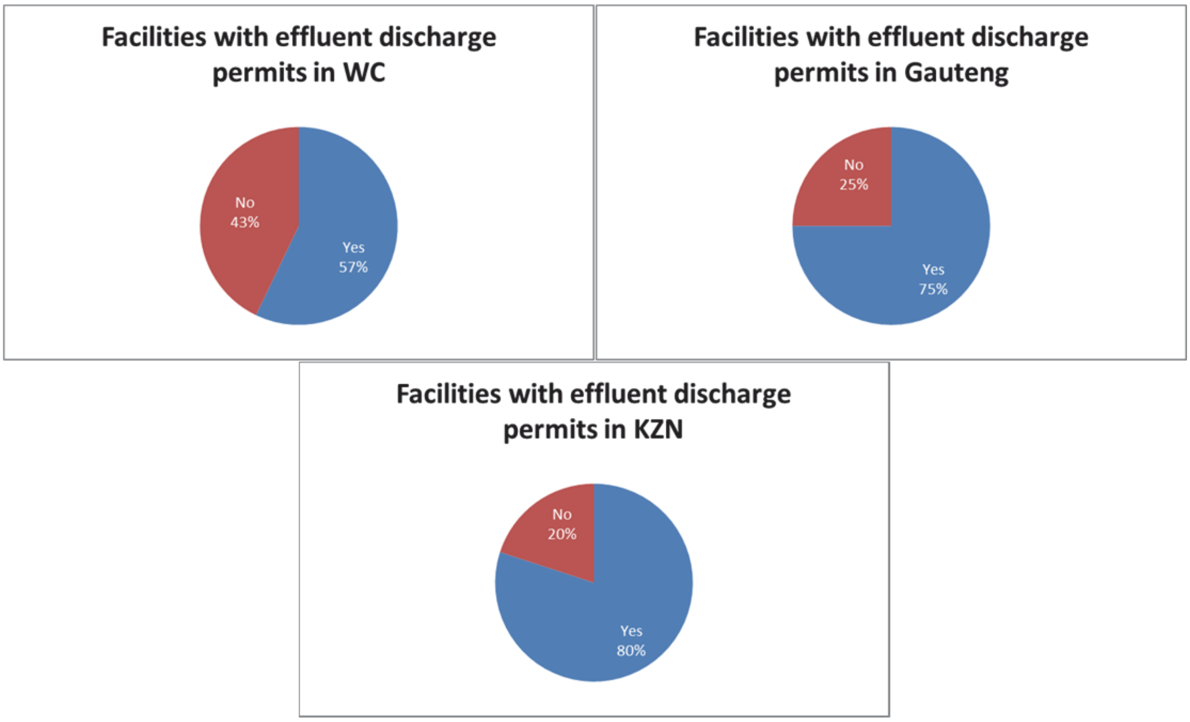

Figure 29 Facilities with an effluent discharge permit

Figure 24 shows that there is some non-compliance as to the discharge permit, with the greatest percentage in the Western Cape. This has to be ratified as a matter of urgency.

9. THE DEVELOPMENT OF A SWI FOR THE INDUSTRY

In order to accurately compare the water consumption of different facilities, a specific water intake (SWI) should be standardised. This would allow the comparison of water/area of workpiece processed between different plating facilities. The greater majority of the facilities visited (and others in the industry) do not accurately know the area processed at any time. This presents a complication and it is thus supposed that a SWI could be calculated from the deposition thickness and mass of anodes and metal bearing compounds used, assuming the facility measures its water use. It was previously highlighted that the majority of the facilities surveyed do not measure the volume of water used in the processing part of their plants but have the municipal records for the entire facility. The facilities were thus requested to proportion a percentage of their total volume of water used to that used by the process lines. Thereby a SWI could be deduced.

An example is a facility that used 1000 kl of water for the month and plates zinc from an alkaline non cyanide solution to a thickness of 20 microns and used 100kg of zinc anodes for the same time period.

The density of zinc is 7.135 g/ml per 1 m^2 plated
Or 71.35 mg/micron per dm^2 plated = 7.135 g/micron per m^2
Thus, for a thickness of 20 microns we have 142.7 grams Zinc per m^2 (100 dm^2=1 m^2)
Therefore, for 100kg of Zn it implies 701 m^2 was plated
The facility assumed 80% of their water is used in plating (800kl/month or 800 m^3)
Therefore a SWI for this facility is 800/701 m^3/m^2 or 1.14 m^3/m^2 for this facility. This means that this facility uses 1140l per m^2 of workpiece plated.
This SWI relies on the facility to provide an assumption of how much water is used in the plating line.

On the basis of these calculations various facilities may be directly compared and discrepancies within the process may be highlighted for the benefit of the industry.

9.1 THE SWI FOR THE ELECTROPLATING INDUSTRY

A total of 84 plating lines were visited but only data for 35 plating lines was collected and verified. The 35 lines surveyed varied from in-house to job shops, many of them having multiple process lines plating various metals. Many facilities have to meet quality and customer's specifications and this was the focus of their business and water usage was of a secondary importance. They usually have multiple stages to produce higher quality product and subsequently have more rinse stages. This is especially true for in-house facilities. At first glance, it would seem that the SWI should not apply but a company that plates 5 microns has a greater throughput volume as well as having a greater dragout into the rinse tanks thereby requiring a greater volumetric flow rate of water. A facility that plates thicker deposits will have a slower moving process line with fewer stops in the dragout and rinse tanks thus requiring lower flow rates. Unless the rinse tanks have flow controls on them to match the plating rate it is not possible to achieve the optimum SWI for the line.

International benchmarks for water usage are:

- a cleaned effluent discharge of 50 l/m^2 of treated surface area and with effluent containing less than 0.1% of the metal used (BREF, 2006)
- an industry benchmark of about 40 l/m^2 (BREF, 2006)
- A maximum of 8 l/m^2 at each rinse stage. This equates to 40 l/m^2 with five rinse stages. is met by approximately 80% of French surface treatment companies where the volume of treatment vats is greater than 10 m^3 (BREF, 2006)

Figure 30 shows the calculated SWI based on the input from the facilities. It is evident that some data provided had not been quality checked and produced results outside the expected. The figure shows the provincial variation to elucidate that no real variation by province exists. From the figure, it is seen that a few data points are excessively high and in Table 10 these high values are addressed.

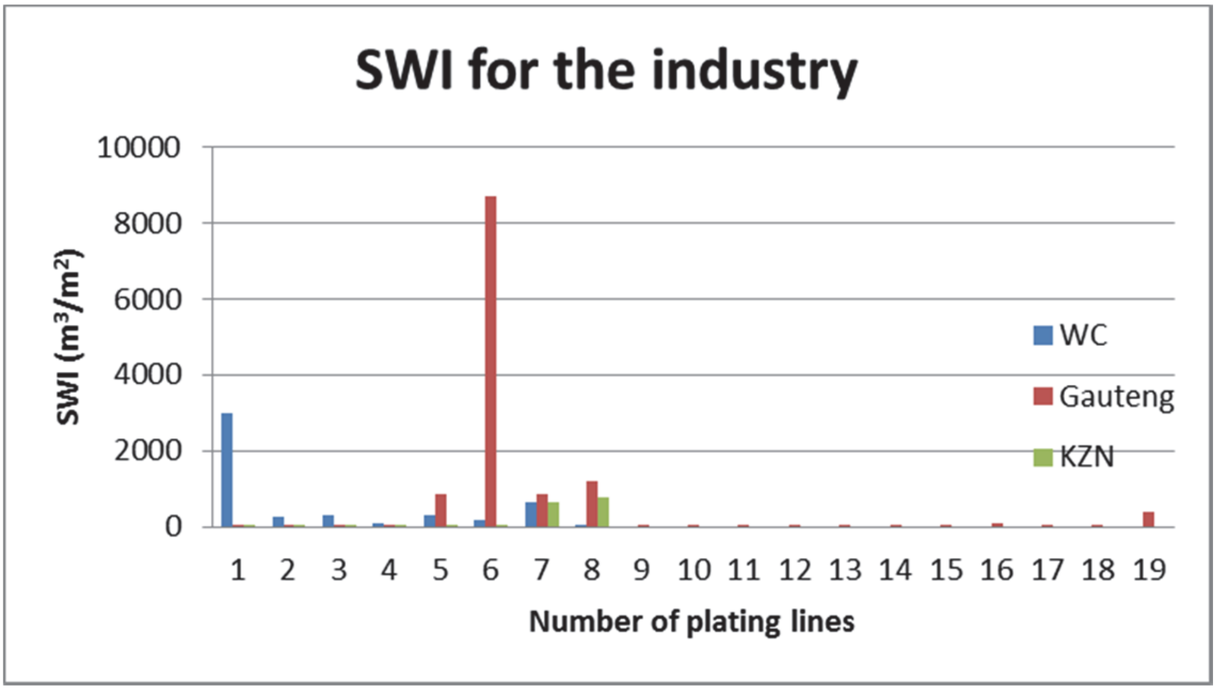

Figure 30 The SWI for the ind**ustry**

Upon revisiting some of the facilities exhibiting excessive SWI's it was ascertained that it was mostly due to incorrect data and they were subsequently removed from the data pool for further calculations. This data is shown in Table 10 as well as the reason why it was discarded.

Table 10 The calculated SWI for the industry based on data collected in the survey

Line number	Province	SWI (l/m^2)	Used for SWI	Notes
1	Gauteng	4.76		
2	Gauteng	28.54		
3	Gauteng	7.88		
4	Gauteng	31.54		
5	Gauteng	872.48	No	This facility acknowledges it uses excessive water to meet product standard. It has currently embarked on a process to recycle 100% of its water and become a 0% water discharger
6	Gauteng	8717.31	No	
7	Gauteng	886.67	No	
8	Gauteng	1197.86	No	
9	Gauteng	4.23		
10	Gauteng	14.01		
11	Gauteng	8.33		
12	Gauteng	8.33		
13	Gauteng	4.45		
14	Gauteng	14.02		
15	Gauteng	22.27		
16	Gauteng	89.29		
17	Gauteng	80.00	No	Powder coater. It cannot be directly compared to an electroplater
18	Gauteng	16.86		
19	Gauteng	399.57		This facility acknowledges it uses excessive water to dilute to meet effluent standards. This is currently being rectified.
Provincial average		**653.07**		
Corrected average		**46.72**		
20	KZN	9.50		
21	KZN	8.48		
22	KZN	56.60		
23	KZN	56.60		
24	KZN	31.35		
25	KZN	23.52		
26	KZN	635.29	No	Small operation, suspect a data error
27	KZN	801.96	No	Minimal data supplied, suspect an error
Provincial average		**202.91**		
Corrected average		**31.01**		
28	WC	3000.00	No	Minimal data supplied, suspect an error
29	WC	262.58		Large operation. Installing RO to recycle water
30	WC	307.23		
31	WC	105.49		
32	WC	331.46		
33	WC	165.81		
34	WC	636.49	No	Suspect bad data
35	WC	71.34		
Average		**610.05**		
Corrected average		**207.32**		
National average		**488.68**		
Corrected National average		**95.02**		

Once the data had been quality controlled Figure 31 was produced. It shows that many facilities are below the international plating benchmark of 40l/m^2 for a SWI. The Western Cape was the lowest performing province and had the highest SWI at an average of 207 l/m^2 plated workpiece. The national average is 95 l/m^2 per plated workpiece. This shows that a high SWI could be attributed to the use of single rinse stage within the WC as they have the most facilities that have single rinses after process tanks and thus use the most water. This excessive water could further serve to dilute their effluent and subsequently meets their effluent discharge limits.

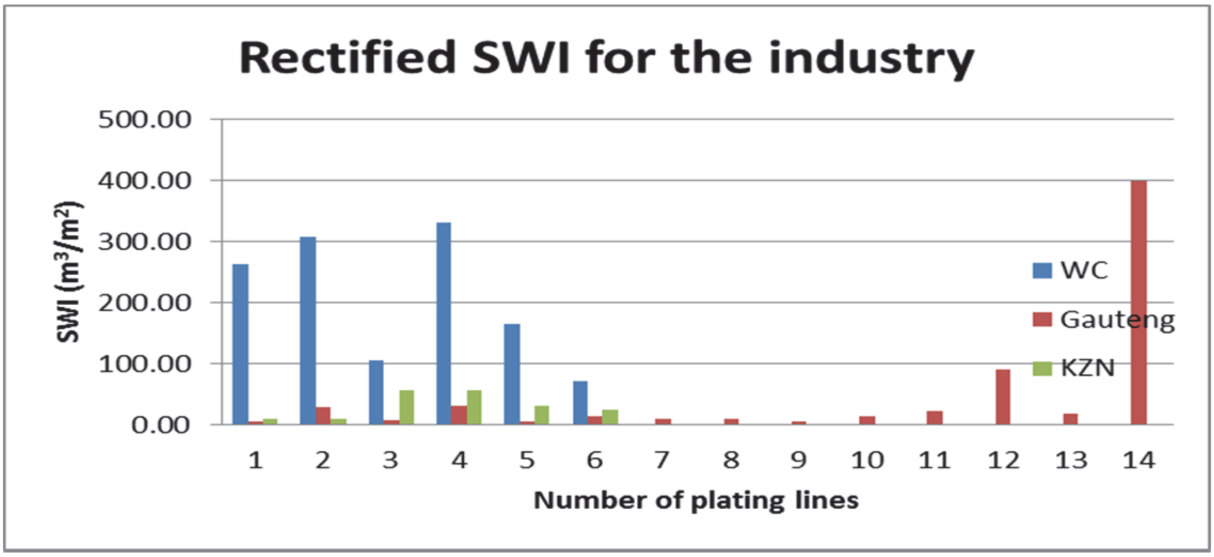

Figure 31 The SWI for the industry with erroneous data removed

In reconciling the calculated low SWI and CP techniques used by the industry the following table resulted, based on the completed questionnaire of the survey.

Table 11 Commonly used CP methods used to ensure low SWI values in facilities

Province	SWI (l/m^2)	Possible reasons for the low SWI
Gauteng	4.23	2 and 3 stage rinses after some tanks
Gauteng	14.01	2 and 3 stage rinses after some tanks
Gauteng	8.33	2 and 3 stage rinses after some tanks
Gauteng	8.33	2 and 3 stage rinses after some tanks
Gauteng	4.45	2 and 3 stage rinses after some tanks
Gauteng	14.02	2 and 3 stage rinses after some tanks and multiple use of rinsewater
Gauteng	22.3	2 and 3 stage rinses after some tanks and multiple use of rinsewater
Gauteng	89.3	2 and 3 stage rinses after some tanks and multiple use of rinsewater
Gauteng	16.86*	2 stage rinses after some tanks and multiple use of rinsewater
Gauteng	399.57*	2 stage rinses after some tanks and multiple use of rinsewater
KZN	9.50	2 stage rinses, dragout tanks, return of dragout, multiple use of rinsewater and semi-automatic rinse management
KZN	56.6	2 and 3 stage rinses after some tanks and multiple use of rinsewater
KZN	56.6	2 and 3 stage rinses after some tanks and multiple use of rinsewater
KZN	31.4	2 and 3 stage rinses after some tanks and multiple use of rinsewater
KZN	23.5	2 and 3 stage rinses after some tanks and multiple use of rinsewater
KZN	8.48	2 stage rinses, dragout tanks, return of dragout
WC	105.5	2 stage rinses and multiple use of rinsewater
WC	262.6	2 stage rinses after all tanks and multiple use of rinsewater

* This facility acknowledged the use of excess water to dilute effluent to meet legislation

Binnie in 1987 found a SWI for the electroplating industry ranging from 0.03 m^3/m^2 to 1.29 m^3/m^2 with a mean of 0.31 m^3/m^2. This study found an industry range of 0.00423 m^3/m^2 to 0.399 m^3/m^2 and average of 0.095 m^3/m^2. This shows a significant change within the industry w.r.t water usage as it has decreased on average threefold from the 1987 survey.

Table 12 SWI comparisons from 1987 to 2014

Time period	**Range of SWI (l/m^2)**	**Mean (l/m^2)**
Binnie 1987	30-1290	310
This study	4.23-399.57	95.02

This table excludes the off-spec data

From Table 12, it is seen that the industry had improved tremendously and consumes less water today than it had in the 1980's. It is also seen that many facilities are below the international benchmark of 40 l/m^2 with the majority in Gauteng and KZN. No facility surveyed in WC meets this criterion.

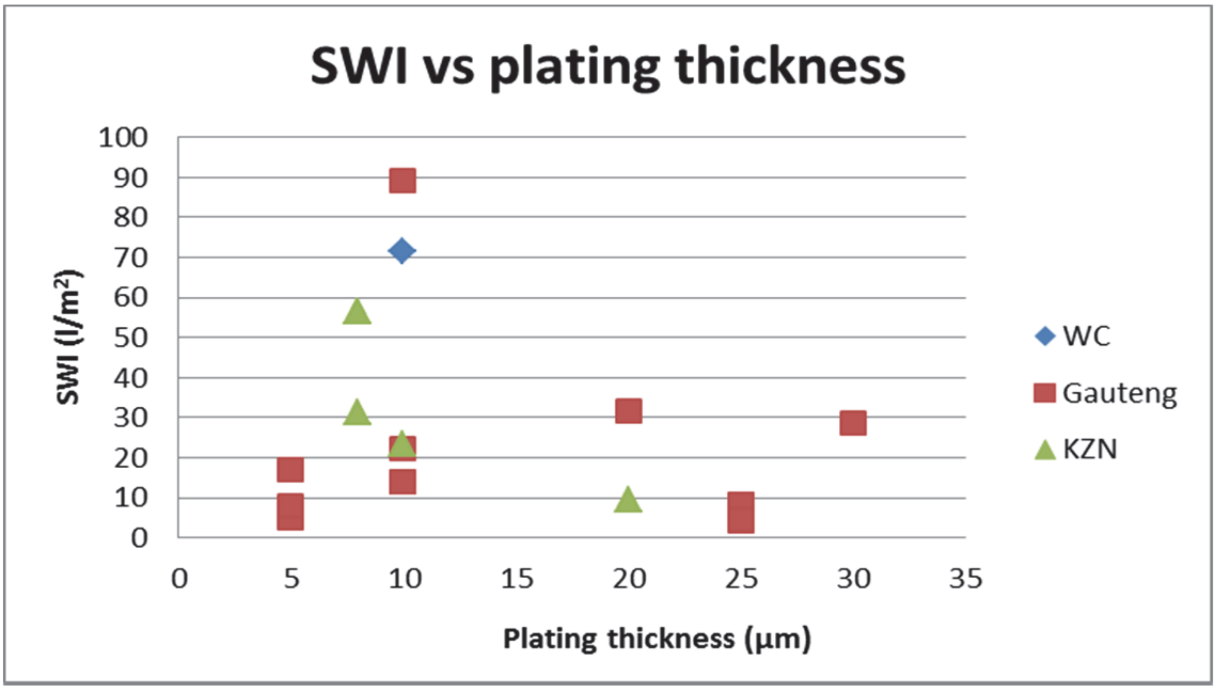

Figure 32 SWI comparison to plating thickness

From Figure 32, it is seen that for increasing plating thicknesses the SWI does not vary by much and the possible variations could be explained by various rinse water flow rates used in the different facilities, could be an operator error or that no water flow control procedures are followed. It is clear from the figure that the majority of operations have similar SWI's irrespective of the surface area plated. The SWI is not affected by provincial location and thus various facilities SWI's may be compared directly.

10. CLEANER PRODUCTION SURVEY OF THE MAJOR SUPPLIERS OF CHEMICALS AND EQUIPMENT

To gain an alternative perspective on the implementation of CP measures in the industry a smaller survey with the vendors of metal finishing plant and chemicals was also undertaken. This survey covered 6 suppliers, 3 from Gauteng, 1 each from the Western Cape and KwaZulu-Natal and a national supplier. It should be noted that the suppliers estimate the size of the industry between 200 to 300 factories while the official SAMFA subscription is in the order of 100 with an estimated 70% being actual platers. The major findings from this survey are as follows, where the percentage refers to the percentage of the total number of factories (200-300):

- Zinc plated solutions that are still cyanide based = 63%
- Post zinc plating passivation treatments that are still Cr (VI) based = 70%
- Operating Cr (III) plating plants = 0%
- Alkaline non-cyanide copper plants = 0.5%
- Recovering solution from plating tanks = 36%
- Most popular rinse configuration following the plating tanks:
    - Single = 75%
    - Dual counterflow rinses = 22%
    - Triple counterflow rinses = 3%

The vendors who formed part of this survey are the most popular suppliers in South Africa and between them they have the majority share of the market.

11. DISCUSSION

A reliable estimate of the number of metal finishing installations in SA is extremely difficult to establish. This estimate is made more difficult as a considerable amount of metal finishing work is performed in-house as an essential part of an overall manufacturing activity and the remainder of the metal finishing work is undertaken on a contract basis by specialist companies or jobshops.

A questionnaire to suppliers that service the electroplating industry revealed that these vendors estimate that there are about 300 plating shops including in-house and job shops in South Africa today, contrary to what can be inferred from sampling undertaken by the municipalities and from the SAMFA membership.

Having partnered with SAMFA it was easy to obtain the facilities buy-in to the survey and overall project, in fact at the provincial AGM's the SAMFA members were in favour of the survey. Even so, it soon dawned that this type survey remains a daunting task as all the facilities were very busy in this current uncertain economic climate and their priorities were the success of the business firstly then, if time allowed, would the facility assist with the gathering of the relevant information required.

Many site visits were completed and questionnaires were delivered to the authorised personnel at the relevant sites. Since many of these facilities did not have the data to complete a comprehensive questionnaire, a 'lite' version of the questionnaires was also circulated. This 'lite' version of the questionnaire enabled the project team to collect the minimum amount of data necessary to calculate an SWI for the facility.

Many businesses feel that government is failing them with relaxed imports, stringent labour laws etc. and the exposed corruption within government compounds these feelings. They thus had a great deal of indifference for the study and sew it only as a quest from government to increase the water tariff. The aforementioned, compounded with a weak rand and uncertain future the facilities are more interested in securing their next contract rather than completing a survey that could count against them in the near future.

It is noted that many facilities are equivalent to their international counterparts not just in quality standards but also with respect to achievable benchmarks relating to SWIs. These achievements were usually met by the bigger players in the industry i.e. those that were subsidiaries of international companies or those that supplied goods at international standards. For many of the smaller facilities it was a case of using utilities and paying for it, passing the cost of it onto the customer. In many instances the major utility bill was electricity as it is used extensively for heating of process baths.

From amongst the facilities surveyed, it is seen that a greater percentage of plating shops are job shops. This is borne out by information from our vendors who volunteered that as many as 70% of electroplating shops were in fact job shops. The percentage of all plating facilities that can be classified as jobshops can thus be assumed to be between 53% and 70%

International Standards are strategic tools and guidelines to help companies tackle some of the most demanding challenges of modern business. They ensure that business operations are as efficient as possible, increase productivity and help company's access new markets. The ISO 9000 standard for quality management is most popular and ultimately the demand for it is customer driven. Other standards such as ISO 14000 and ISO 18000 are not as popular. Very few facilities have other international standards but these are limited to the in-house plating facilities. This ties in well with the premise that in-house facilities have a greater budget and thus are capable of implementing multiple and various certification.

In the WC it is seen that 26% of facilities surveyed have a single rinse stage after every process stage but these were limited to the older plants and where there was a spatial restraint to investing in multiple stage rinses. This caused the WC to have the worst SWI. For Gauteng, 2 stage and 3 stage rinses are extensively used even though the total cost of water (water plus industrial surcharge) is less in Gauteng than the other 2 provinces. Thus the change to CP initiative was not directly cost driven but rather some other factor such as improved finish or the adoptions of an ISO 14000 standard. It could also be argued that a multiple stage washing does provide a return in that it reduces the volume of water used and hence the cost. In KZN single and 2 stage rinses are still the most popular. Some facilities use boreholes/river abstraction thus the cost of water is less.

Figure 13 shows that very little monitoring of water usage in rinsing lines is instituted by the facilities countrywide. This shows that although they consider water to be a commodity, it is not well managed as the industry does not know how much water it uses per rinse tank. This oversight also poses a slight problem with the calculation of an industry wide specific water index (SWI).

The industry uses dragout tanks following plating tanks as an initial rinse for plated articles. The best international practice dictates that the dragout solution should be returned back to the plating tank to decrease fresh plating chemical use. It is seen that a large percentage of dragout is not returned to the process tanks and this is considered poor practice and contrary to international findings, constituting a loss in revenue for the facility as valuable chemicals are discarded. Upon inquiring from the facilities as to this practice, it was confirmed that they had returned dragout solution to plating tanks but they perceived that it had adversely affected the quality of the finish. It is advised that the facilities reinvestigate this CP technique as many facilities do return dragout and have not experienced any deterioration in quality of the final product.

The technique of multiple use of rinse water is an international practice that has yet to establish a greater foothold in SA as a CP technique and capital cost saving, as seen in Figure 18. This is especially true for a proposed new facility as they can plan better for the flow of articles and in the case of existing facilities it may be retrofitted

At the time of this survey there were 2 companies nationally (one in the WC and other in Gauteng) that had RO treatment for its effluent and subsequent reuse of water. This low number is primarily due to the high cost of the units.

45% of the facilities surveyed nationally acknowledged that they did not see any CP initiatives on the questionnaire that they were unaware of. This clearly indicates that there is another underlying barrier preventing the implementation of these techniques. It may be argued that these could be financial, space limitations or expertise for the adopted measures.

It is good practice for the facility to purchase chemicals from a supplier that supplies a certificate of analysis (CoA) so that quality of the product is matched to the theoretical quality predicted by the stoichiometry of the reactions. It is odd that 55% of facilities have CoA's but 59% are ISO 9000 compliant but this is plausible as they could be doing their own analysis. It is seen that on average the industry (Figure 21 and Figure 20) does demand CoA from its suppliers but the prevalence of this practice should be increased as it would help with tracing the cause of off-specification products, auditing purposes and accurate certification.

The use MSDS's is widespread but this practice should be at 100% and be part of the safety manual and standards that every worker should have access too. A greater number of facilities do not have laboratories or do not have the expertise to analyse underlying chemical reactions in the plating industry. Thus, many facilities are entirely dependent on their chemical vendors for analysis of their tanks and baths.

In the WC and Gauteng there are facilities that discharge directly to the sewage system without prior treatment. This places an additional burden on the MWWTP of the catchment. Very few facilities nationally (5%) are recycling treated effluent to be used as makeup water or process water. This is an indication of the relatively high cost of the RO units and technology used to perform this.

A greater majority of the facilities do not know how much water is used in the plating lines. They do know how much the entire facility uses but cannot accurately differentiate between the plant and non-plant operations. Even if the facility could estimate how much water is used in the plating lines it still does not know by how much it can reduce it to still meet a quality specified product per least volume of water. Effective measurement is paramount before changes can be implemented.

Every facility that is connected to the municipality sewage system should be monitored monthly for discharge compliance by the legislated municipality and collect effluent samples, but this was not the case and a few facilities were not monitored. The vast majority (69%) of facilities comply with the effluent by-laws of their provinces. *Infringements generally are not attributed* to regular running operations of the facility but rather special circumstances such as an inefficient WWTP or spills and dumps that got entrained in the effluent.

The industry has been enjoying a reduced cost for electricity but the current electricity crisis in SA is bound to change this and alternatives to electricity will have to be considered especially in the form of gas, heat pumps or solar for heating of process tanks. The cost of water varies with province and the WC has the highest cost per kilolitre and facilities located there would benefit from implementing CP that saves water. Currently only one facility uses an alternative and benefits tremendously from the reduction in cost.

Observations from the sample study are that some operators in the industry need to pay more attention to relevant legislation as it is clear that there are operations that are clearly in breach of their obligations.

For increasing plating thicknesses the SWI does not vary by much and the possible variations could be explained by various rinse water flow rates considered necessary in the different facilities or could be due to operator error or that no water flow control procedures are followed. Thus the calculated SWI's are independent of plating thickness.

12. CONCLUSIONS

Based on the survey results and the preceding discussion, the following conclusions can be drawn.

- A reliable estimate of the number of metal finishing installations in SA is extremely difficult to establish. This estimate is made more difficult as metal finishing work is performed in-house as an essential part of an overall manufacturing activity and the remainder of the metal finishing work is undertaken on a contract basis by specialist companies or job shops. If metal finishing companies are not listed with SAMFA or are not sampled by a municipality then it is possible to operate undetected, because of the unregulated access to plating chemicals.

- The results from the survey show that there are more job shops than in-house plating facilities nationally with greater than 57% certified for ISO standards (quality, environment, health and safety) as well as other international standards. The majority (59%) of facilities are ISO 9000 certified for quality. Since the in-house facilities typically have access to bigger budgets they are normally more compliant in all respects. Jobshops on the other hand are reliant on smaller work orders and will not necessarily invest capital in non-revenue generating procedures, irrespective whether these may reflect responsible operation.

- Many facilities are equivalent to their international counterparts not just in quality standards but also with respect to achievable benchmarks relating to SWIs. These achievements were usually met by the bigger players in the industry i.e. those that were subsidiaries of international companies or those that supplied goods at international standards.

- It is seen that 26% of facilities have a single rinse stage after every process stage. A single stage rinse is still popular, but these were limited to the older plants and where there was a special restraint to investing in multiple stage rinses. Notwithstanding the space constraints, dual counterflow rinsing results in significant savings in water consumption and has to be included as a minimum.

- For Gauteng, 2 stage and 3 stage rinses are extensively used even though the total cost of water (water plus industrial surcharge) is less in Gauteng than the other 2 provinces. It is R12.51/kl in the Western Cape, KZN is R14.59/kl and Gauteng is R13.17/kl. Thus the change to this CP initiative was not entirely cost driven but rather some other factor such as improved finish or the adoption of an ISO 14000 standard.

- It is noted that not all the facilities are effluent compliant and that their WWTP are not all functioning satisfactorily. The option of treating the effluent further and recycle water back to the plant is a viable option as a form of pseudo-CP. This could be effected with RO units or some novel new approach.

- The industry uses dragout tanks as an initial rinse for plated articles. The best international practise dictates that the dragout solution should be returned to plating tank to decrease fresh plating chemical use. It is seen that a large percentage of dragout is not returned to the process tanks and this is considered poor practice and contrary to international findings, constituting a loss in revenue for the facility as valuable chemicals are discarded. The fact that several companies are implementing the initiative successfully indicates that it is not detrimental to the quality of the final product if managed judiciously.

13. RECOMMENDATIONS

- Legislation should be enacted that obliges any one operating in the metal finishing industry (and any other industry using chemicals that may end up in the environment) to apply for a certificate, without which, they may not make purchases of any industrial chemical product. This will provide a mechanism for the quantification of the size of any industry using chemicals.

- Legislation should also be enacted to oblige vendors to keep a register of chemicals that were supplied to certificated operators and a report should be submitted to the authorities overseeing this legislation on a regular agreed basis.

- Whenever a facility is refurbished or rebuilt as many of the CP techniques described in this and prior documents should be built into the new facility.

- All facilities should be encouraged to use 2 or 3 stage countercurrent rinse tanks where possible.

- All facilities should relook at their WWTP as many are working over-capacity due to plant expansions.

- The industry needs to measure water usage on plating lines and this is easily and cheaply accomplished by using water meters.

- Dragout from the dragout tanks is returned internationally and in some facilities nationally, thus the facilities that are opposed to this practice needs to relook at their process.

- Similarly, multiple reuses of rinse waters is a water saving technique and more facilities need to investigate this possibility.

- A study needs to be completed critically examining the barriers to implementing CP techniques.

- Industry should demand certificates of analysis from all vendors to ensure quality products and for certification purposes.

- 100% use of MSDS should be enforced within the industry.

- No facility should be allowed to discharge untreated effluent to the municipal sewage system.

- All facilities should be monitored for effluent compliance as often as possible by the authorities.

- Facilities need to measure current water usage in plating lines and try to reduce it to the such that they also use 95 l/m^2 or even less per line.

14. REFERENCES

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APPENDIX A: FORMAT OF THE QUESTIONNAIRE

Water and Wastewater Management in the Metal Finishing

Revision of Natsurv 2 for the South African Water Research Commission

Project Questionnaire

UNIVERSITEIT STELLENBOSCH UNIVERSITY

40 Years of Excellence WATER RESEARCH COMMISSION

ELECTROPLATING PROCESSES

INSTRUCTIONS FOR COMPLETING THIS SET OF FORMS

Software: This form is based on Microsoft Excel 2007-2010, and to work properly you ideally need to have one of those versions of MS Office installed. The form does not contain viruses or any malicious content, and will not harm your computer.

Viewing Options: The landscape pages tabbed Line 1, Line 2, Line 3 and Line 4 have been set to open at 90% of full size viewing. All other pages default to 100%. You may change the viewing size by using the +- buttons or the slider beneath the worksheet in the right hand corner.

Saving the Form: Please save this form immediately *[preferably under a new name]* to a location on your computer where you can easily find it again - for instance to the desktop. It is unlikely that you will complete the entire questionnaire in one session as there will be information you need to look up in your records. When you have completed it, you may email it to wrcsurvey@afrihost.co.za.

Built in Help: To make things as easy as possible, especially when filling in the process information called for on the pages specific to Process Lines [Tabs marked Line 1, Line 2, Line 3 and Line 4 there is a fly out help panel at the top of every column indicated by a small red mark like the one on the right of this panel. Similar panels can be called up at other points in the other worksheet pages.

Confidentiality: The information that you provide in this form is absolutely confidential. Your company details will not be divulged to any other party, including the Water Research Commission. Companies will be identified as Company A, Company B etc. You may elect not to provide certain information if you feel uncomfortable about sharing a specific figure or set of figures. Ultimately, the information will be aggregated to gain a national perspective which is the ultimate aim of this study.

However, please consider that for the study to be really meaningful and of benefit to the sector, including possible focused interest from Government relative to potential funding of industry upliftment programs, the more accurate the report that emanates from this study the better the prospects for the industry.

This form is designed for electroplating processes only. If you operate anodising, phosphating or hot dip galvanizing plant, these lines are covered with purpose designed forms which are available for those processes.

This questionnaire is divided up into several pages. The number of pages that you need to complete depends entirely on the number of process lines that you operate. Provision is made for up to 4 separate process lines.

You will be able to complete many of the questions by simply clicking in the appropriate check boxes alongside the questions. In other cases you will need to type in your response in the appropriate text entry box alongside the question.

The form has been designed only for completion on a PC operating on the Windows Platform, preferably with Office 2007 or later installed. It will not be practical to attempt to print and complete manually as there are interactive cells that change instructions dependent on electronic input.

The survey consists of 6 pages followed by one additional page for each process line that you operate at your facility. There is also a dedicated comments page right at the end where you may provide additional input that you feel may help to clarify some of your responses in the form.

If you operate two process lines, you will complete both Line 1 as well as Line 2. So if you had 4 process lines you would complete all the way up to Line 4.

The page tabbed as Example shows how a typical completed page describing a particular process line may look [like those tabbed Line 1 - 4]. If you have any difficulties completing the form, please contact head office for assistance. Tel: 021 761 8537 or email mfasa@spectrapage.co.za

1

Water & Wastewater Management in the Metal Finishing Industry

Revision of Natsurv 2 for the South African Water Research Commission

Project Questionnaire

40 Years of Excellence
WATER RESEARCH COMMISSION

Company Name			
Address:			
		Postal Code	
Email Address:			
Representative responsible for this form:		Date:	
Telephone:		Mobile:	

SECTION A

1 Which category/categories of metal finishing operations are you engaged in at these premises?

☐ Electroplating ☐ Powder Coating ☐ Anodising ☐ Hot Dip Galvanizing

☐ E-Coating Other - Please Specify: -

2 How many persons are directly engaged in electroplating operations? [Exclude office & support staff]

3 Is this facility an in-house operation working on own production, or a jobbing shop contractor providing a service to industry? ○ In-House ◉ Jobbing Shop ○ Both

4 In the designated fields below please describe **only the electroplating process lines** that you operate in the appropriate boxes below. Examples: Cyanide Zinc, Acid Zinc, Zinc Nickel Alloy, Decorative Nickel Chrome, etc

Description of Process Line 1:

Please indicate in the check boxes below which metals are plated on Line 1.

☐ Zinc ☐ Cadmium ☐ Copper ☐ Nickel ☐ Chrome ☐ Brass ☐ Tin ☐ Gold ☐ Silver ☐ Other

Description of Process Line 2:

Please indicate in the check boxes below which metals are plated on Line 2.

☐ Zinc ☐ Cadmium ☐ Copper ☐ Nickel ☐ Chrome ☐ Brass ☐ Tin ☐ Gold ☐ Silver ☐ Other

Description of Process Line 3:

Please indicate in the check boxes below which metals are plated on Line 3.

☐ Zinc ☐ Cadmium ☐ Copper ☐ Nickel ☐ Chrome ☐ Brass ☐ Tin ☐ Gold ☐ Silver ☐ Other

Description of Process Line 4

Please indicate in the check boxes below which metals are plated on Line 4.

☐ Zinc ☐ Cadmium ☐ Copper ☐ Nickel ☐ Chrome ☐ Brass ☐ Tin ☐ Gold ☐ Silver ☐ Other

1

Please continue to Page 2

B RESOURCE CONSERVATION & CLEANER PRODUCTION

1 Is your operation certified to ISO standard/s? ○ Yes ◉ No

2 If so, please check relevant tick boxes: ☐ ISO 9000 ☐ ISO 14000 ☐ ISO 18000

3 Please detail any other certification attained: [ ]

4 Which of the following terms are you acquainted with: ☐ Cleaner Production ☐ Water Footprints ☐ Water Pinch ☐ Life Cycle Assessments ☐ Energy Pinch

5 Please indicate rinse configurations in use on your lines. Tick the box/es that apply:

a Single independent rinses ○ None ○ After all Plating Tanks ◉ After some Plating Tanks

b Two stage counterflow rinses ○ None ○ After all Plating Tanks ◉ After some Plating Tanks

c Counterflow rinses with 3 or more stages ◉ None ○ After all Plating Tanks ○ After some Plating Tanks

c ☐ Dedicated water meters on rinse lines that are monitored and recorded to manage flow

d ☐ In-tank spray rinse manifold to wash down process solution directly in process tank on exit

e ☐ Independent spray rinses (stand alone or as part of a rinse or drag out system)

f ☐ Automatically controlled rinse management systems based on conductivity controllers

g ☐ Semi-automatic rinse management systems based on proximity switches and timers

h ☐ Manually controlled rinse management based on visual controls (eg flow meters)

6 Please tick alongside any of the following cleaner production options in place:

a ☐ Drag out tanks installed following process tanks

b ☐ Return of drag out to process tanks on hot processes

c ☐ Return of dragout from cold processes for re-use. If so, do you concentrate it first? ○ Yes ◉ No

d ☐ Multiple use of rinse water (e.g. post acid pickle rinse also used for post alkali rinse)

e ☐ Combining of pre-dip tank with drag out tank so that drag in = drag out

f ☐ Reverse Osmosis units installed on rinses (eg nickel) for direct recovery of water and process solution

g ☐ DI Units for the removal of metal ions from rinses so that water can be reused.

h ☐ Acid extender chemicals used in pickles so that metals can be filtered out of the pickles

i ☐ Ultra filtration on hot soak cleaners for oil and sludge removal to extend tank life

j ☐ Oil skimming apparatus included in soak or electrolytic cleaners (eg belt or wheel technology)

k ☐ Oil skimmer compartments as part of the hot soak cleaner tank system.

l ☐ Control of withdrawal speed of auto carriers to slow rate to minimise carry over of solution on components

m ☐ Jig design to maximise drip off time and drainage

n ☐ Jigs coated with proper resins to ensure that coating goes only onto the parts.

o ☐ Lip extraction systems that are able catch aerosols for return to the tank as solution

p ☐ The installation of hanging rails above manual process tanks to facilitate adequate drip off

q ☐ Drip Guards between tanks so that dripping from jigs moving overhead is guided to tanks

r ☐ Electrolytic Recovery of Metals from spent solutions for re-use in the plant

7 Looking through questions in B - 1 above, did you notice any CP* options that you were unaware of, or had not considered before? ○ Yes ◉ No

8 Please enter into the text box below any measures that you have employed to conserve resources that were not covered in the check list above. *[Click inside box to enter text]* 2

[ ]

Press Enter to complete your entry. F2 to Edit.

***CP - Cleaner Production**

Please continue to Page 3

Revision of Natsurv 2 for the South African Water Research Commission

Project Questionnaire

SECTION C - Chemical Products Management

Please answer the following questions relating to the management of chemicals:

1 Do you operate a formal stock control system for chemical products? ( ) Yes (•) No

2 Do you perform regular stock takes to establish your stock position? (•) Yes ( ) No

3 How often do you physically take stock? : (•) Weekly ( ) Monthly ( ) Quarterly ( ) Annually

4 Do you have Material Safety Data Sheets [MSDS] for all products used? ( ) Yes (•) No

5 Do you demand Certificates of Analysis for chemical raw materials purchased? ( ) Yes (•) No

6 Do you have raw materials in stores that are unusable for one or another reason? ( ) Yes (•) No

7 Do you have a system in place to safely dispose of unusable products? ( ) Yes (•) No

8 Do you have any certificates of Safe Disposal on file? ( ) Yes (•) No

9 Do you have separate stores to keep incompatible chemicals apart? ( ) Yes (•) No

10 Do you work with any flammable solvents? (•) Yes ( ) No

11 Do you have an approved solvents store? ( ) Yes (•) No

12 Do you have any purpose built stores to house hazardous chemicals (•) Yes ( ) No

13 If you are in the Western Cape do you have a Metro approved CMAP* in place? (•) Yes ( ) No

**Chemical Management Action Plan*

SECTION D - Process Tanks Management

1 Do you perform some of your chemical analysis using in-house facilities? (•) Yes ( ) No

2 Do you rely on supply houses to look after your analysis? ( ) No ( ) Partially (•) Totally

3 Do you maintain a file of chemical analysis reports for all process tanks? (•) Yes ( ) No

4 Do you use automatic chemical dosing units in process tanks? (•) No ( ) Some Tan ks ( ) All Tanks

5 Do you have contaminated unusable plating/process solutions on your site? (•) Yes ( ) No

6 Do you agree that disposal of contaminated solutions is an expensive exercise? (•) Yes ( ) No

7 How do you dispose of process solutions that become unusable?

( ) Use approved contractor to handle treatment and disposal immediately ( ) Store on site till we can afford to treat ourselves & dispose of

(•) Store until we can afford contractor to remove and treat ( ) Treat on site immediately - Approved contractor removes treated material

SECTION E - Effluent and Sludge Management

1 Does your rinse water flow directly to the sewer without treatment? ( ) Yes (•) No

2 Do you operate a well designed effluent treatment plant that caters for all discharges!? (•) Yes ( ) No

3 Is your plant: (•) Totally Home Built ( ) Partially Home Built ( ) Turnkey from Supplier

4 Which of the following operations are included in your waste treatment system: ☐ Neutralise and Settle

☐ Neutralise pass through membrane plant ☐ Cyanide Oxidation ☐ Chrome 6 Reduction ☐ Sludge Consolidation Tanks

☐ Bag Filters for Sludge ☐ Filter Press ☐ Other Systems - Specify: [ ]

5 If you have a treatment system that includes a settlement tank, what is its volume? [ ] Lt

6 Are you recycling the treated water from the effluent plant for reuse? ( ) Yes (•) No

7 Please move on directly to Question 8

☐ None ☐ Filtration ☐ Filter and Deionise ☐ Filter and RO* Treat ☐ Other - Specify: [ ]

8 Do you make use of a certified waste removal contractor? (•) Yes ( ) No

9 How many times does a contractor remove waste in one year? Please enter a number here: [ ]

3

**RO - Reverse Osmosis*

Please continue to Page 4

SECTION F - Cost and Compliance - Water & Effluent

1	Do you keep separate account of water used in plating processes verus rest of plant?	◯ Yes ◉ No	
2	If you don't apportion, please estimate percentage used in plating versus other uses?		%
3	If you know, what is the approx monthly consumption of water in all plating lines?		Kl
4	What is the total average montly volume of water for your entire factory, all inclusive?		Kl
5	What do you pay per kilolitre of water (including industrial surcharges, etc)	R	/Kl
6	For the last full quarter, what was the water bill for your entire operation, all usage?	R	
7	How much did you spend on hazardous waste removal over the last full quarter?	R	
8	Is the Metro or any other water authority collecting samples of your discharges?	◉ Yes ◯ No	
9	Which authority samples you? - e.g JHB Water, Ethekwini, Cape Metro		
10	How many times per month are you currently being sampled?		
11	Have you been reprimanded for non compliance with Metro regulations in the past year?	◉ Yes ◯ No	
12	How may fines did you pick up over the past year? [Optional Response]		
13	What was the Rand value of the fines that you attracted? [Optional Response]	R	
14	Have you had to pay the Metro for additional sampling due to past bad samples?	◯ Yes ◉ No	
15	If you are being billed for extra sampling, what does this cost per month now?*	R *Optional Response*	
16	If you have had recent bad samples, please tick alongside your most common failings:		

☐ Metals over limits ☐ Low pH ☐ High pH ☐ COD over limit ☐ High Dissolved Salts ☐ High Cyanide ☐ High Chrome 6

Please detail alongside any other contraventions: [Enter] to complete entry. F2 to Edit

SECTION G - Energy Sources and Cost

1	What are you paying per kWh for electricity at the moment?	R	/kWh
2	Do you keep separate account of electricity used for plating versus rest of plant?	◉ Yes ◯ No	
3	If you do, what is your average bill per month for metal finishing operations?	R	
4	If you don't apportion, what is the total electricity bill per month for the whole factory?	R	
5	If you don't apportion electricity, estimate what percentage is used for plating?		%
6	What do you use for heating of tanks: (you may make multiple selections)		

☑ Electric Immersion heaters ☐ Gas fired boiler and in-tank coils ☐ Heat Pumps ☐ Solar heated hot water coils in tank

Other systems, please provide details: [Enter] to complete entry. F2 to Edit.

7 What is you primary energy source for heating? (eg electricity, gas, heat pumps, solar power, etc)

8 If you have been making an effort to reduce energy costs, please detail briefly below the type of initatives you have taken. *For example: Using eductors instead of air to agitate a nickel plating tank.*

4

[Enter] to complete entry. F2 to Edit.

Please continue to Page 5

5

Section H - Environmental, OHS and Legal Requirements

1 Do you operate a vapour degreaser tank? (●) Yes ( ) No

2 Which health and safety measures do you employ to prevent exposure to vapour?

[x] None [ ] Extraction & Recovery [x] Closed Top Tank in ventilated area

3 Do you operate other process tanks that generate fumes or aersols in their vicinity? (●) Yes ( ) No

4 Do you have a method to prevent fumes/aerosols being inhaled by workers? (●) Yes ( ) No

5 Which methods are used to reduce exposure?

[ ] Floating spheres on liquid surface [x] Chemical Fume Suppressants [ ] Extractor fan/s in ceiling or walls

[x] Extraction Canopy above tank/s [ ] Tank side extraction ducting [ ] Natural ventilation thru open windows & doors

6 Do you have a valid permit to operate and discharge industrial effluent? ( ) Yes (●) No

If you do not, you will need to apply to Metro for one

7 Are you in the process of applying for a discharge permit? (●) Yes ( ) No

8 When you purchase chemical products how are these goods transported to you?

( ) a) Always rely on a supplier to deliver (●) b) Sometimes collect with own transport

9 Do you know you need to comply with Transport of Dangerous Goods regulations? (●) Yes ( ) No

10 Do you always comply with regulations when doing your own transport of chemicals? (●) Yes ( ) No

11 Do you have an emergency response plan that is documented and with the detail specifically explained to all employees, especially to new recruits? (●) Yes ( ) No

12 Is a Safety Manual available to all employees that details the types of protective apparel they should wearing, and correct use thereof, when performing specific tasks? (●) Yes ( ) No

13 Do you have an evacuation diagram posted in prominent areas of the workplace? (●) Yes ( ) No

14 Are areas bunded to retain worst case spillage that may occur through tanks or containers bursting in any operational area of your premises? (●) Yes ( ) No

15 Do you have chemicals and apparatus on site to deal with chemical incidents/spills? (●) Yes ( ) No

16 Do you keep a register of all incidents related to spill, incidents, etc? (●) Yes ( ) No

17 Do you have all the safety signage required by law displayed in your workplace? (●) Yes ( ) No

18 Do you have the required number of trained first aiders on site? (●) Yes ( ) No

19 Have your first aiders had specific training in dealing with chemical incidents? (●) Yes ( ) No

20 Do you use cyanides on site like Sodium, Potassium, Copper, Zinc compounds? (●) Yes ( ) No

21 Which of the following antidote systems do you have on site?

[ ] a) None [x] b) Medical Oxygen Kit [ ] c) Amyl Nitrate Capsules [ ] d) Injection Kit - dicobalt edetate

[ ] e) Injection Kit for sodium nitrite/thiosulphate f) Other?

22 Have you ever needed or used CN antidotes that you may have had? (●) Yes ( ) No

23 Was the intervention successful?

[ ] Yes [x] No [ ] Patient survived, but maybe despite the treatment

24 Which kits selected in Question 21 were used? c) d) e) or f)?

25 Do you arrange annual medical checks for staff working on electroplating lines? ( ) N/A (●) Yes ( ) No

26 How would you regard the most recent report that you received? ( ) Satisfactory (●) Unsatisfactory

27 Are you in the process of taking action prevent future unsatisfactory results? (●) Yes ( ) No

Section I - Time Frames to Achieve Compliance

If you have indicated that you are not in compliance with regulations in response to some of the above questions, a **Red X** will appear alongside the relevant yellow fields below. If this form is to double as a CMAP submission you'll need to estimate a date by which you aim to have achieved compliance.

Compliance Issues	Target Date for Compliance	Compliance Issues	Target Date for Compliance
Arrange a valid Discharge permit		Compliance with Transport Regulations	
Emergency Response Plan		Safety Manual for Workers	
Evacuation Diagram		Bunding where necessary	
Chemical Spill Kit/Equip		Incident Register	
Correct Safety signage in place		Right No. of 1st Aiders	
1st Aiders trained for HazChem		CN Antidote Kit (if needed)	
Safety Measures for TCE Degreaser		Fume extraction methods needed for relevant tanks	
Arrange Medical checks for staff		React to Medical Reports	

5

Please continue to Page 6

6 Section J - Training

If you have been asked to submit a CMAP [Chemicals Management Action Plan] to the Cape Metro, then you may elect to provide them with a copy of this survey. SAMFA has been informed that if it is completed correctly, it will be accepted as a CMAP.

1 Are you a member of the South African Metal Finishing Association? ◯ Yes ◉ No

2 Have you, any of your supervisory or operator staff attended any of the SAMFA courses below? Please Tick if Yes: ◯ Yes ◉ No

- ☐ Electroplating Theory and Practice
- ☐ Electroplating Process Specifics
- ☐ Zinc Plating 2 Day Seminar
- ☐ Health and Safety in Metal Finishing
- ☐ Effluent Management and Compliance

3 Please enter into the text box below any courses from any institution that you, or any of your senior operators, supervisory or management staff have undertaken:

Examples: Qualification from Metal Finishing Institutions or First Aid, Fire Fighting, etc. Please provide the Institution's Name.

[Enter] to complete entry. F2 to Edit

7 Section K - Quality Control

1 How do you establish the thickness of plating layers that you apply?

- ☑ Calculate based on data sheet estimates (microns per minute at given current density)
- ☐ Make use of Thickness Testing instruments

2 If you do make use of thickness testing instruments, please describe these in the text box below:

[Enter] to complete entry. F2 to Edit

3 Do you have a heat treatment oven suitable for hydrogen de-embrittlement of work? ◯ Yes ◉ No

4 Do you test for adhesion by exposing samples to a temp of 150 degrees C for 10 min? ◯ Yes ◉ No

5 Do you have a microscope to examine substrates and plated surfaces for defects? ◯ Yes ◉ No

6 Which other tests are you able to apply? If applicable, please list these in the text box below:

[Enter] to complete entry. F2 to Edit

You may now begin entering Process Line specific details on the pages tabbed as Line 1 through to LIne 4. Please complete one page for each major process line that you operate.

There is an Example Sheet following the tab for Line 4 to show how typical process details may look. There is also a dedicated page at the end for any addtional comments you may wish to include.

SECTION A

Please complete this section and then carry on to Section B beneath

Please enter only numeric values into Column J. The µ labels are already in place.

Helpful instructions are provided when hovering over the alphabetic ID of each column - A, B, C, D, etc.

A	B	C	D	E	F					G			H				I				J	
				Process Type					Note colour coded instructions	Rinse Configuration			Indicate running rinses that share water inputs, if any. Four inputs are catered for.				Indicate rinses or chemical tanks shared with other process lines.					
Tank No.	Tank Description	Number of Stations	Process Sequence	Opt. Steps	No Selection	Plating	Chem Dip	Rinse/Other		Static	Single	C/flow	A	B	C	D	1	2	3	4	Enter average deposit thickness in µ - Figures only	Tank Description *Copy of Column B*
1				☐	◉	○	○	○	<Select a Button	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	µ	
2				☐	◉	○	○	○	<Select a Button	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	µ	
3				☐	◉	○	○	○	<Select a Button	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	µ	
4				☐	◉	○	○	○	<Select a Button	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	µ	
5				☐	◉	○	○	○	<Select a Button	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	µ	
6				☐	◉	○	○	○	<Select a Button	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	µ	
7				☐	◉	○	○	○	<Select a Button	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	µ	
8				☐	◉	○	○	○	<Select a Button	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	µ	
9				☐	◉	○	○	○	<Select a Button	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	µ	
10				☐	◉	○	○	○	<Select a Button	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	µ	
11				☐	◉	○	○	○	<Select a Button	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	µ	
12				☐	◉	○	○	○	<Select a Button	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	µ	
13				☐	◉	○	○	○	<Select a Button	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	µ	
14				☐	◉	○	○	○	<Select a Button	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	µ	
15				☐	◉	○	○	○	<Select a Button	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	µ	
16				☐	◉	○	○	○	<Select a Button	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	µ	
17				☐	◉	○	○	○	<Select a Button	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	µ	
18				☐	◉	○	○	○	<Select a Button	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	µ	
19				☐	◉	○	○	○	<Select a Button	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	µ	
20				☐	◉	○	○	○	<Select a Button	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	µ	
21				☐	◉	○	○	○	<Select a Button	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	µ	

Please indicate the category of plating alongside: ◉ Rack Plating only ○ Barrel Plating Only ○ Rack & Barrel plating combo

Enter Numbers only

Please click a button to select one of the options below that best describes the layout of this process line:

◉ a) Tanks laid out contiguously in straight line or horse shoe format served by automatic overhead carrier.

○ b) Tanks laid out contiguously in straight line or horse shoe format served by manually operated overhead carrier.

○ c) Tanks laid out contiguously in straight line or horse shoe format with jigs or barrels carried by operator from tank to tank

○ d) Tanks separated from each other by some distance requiring operators to convey work from tank to tank manually and/or by overhead hoist.

SECTION B

1	If you have data, calculate water consumption on this line for the reporting period or select Opt 2 below.	Kl	Monthly water usage on this line calculated through percentage. Kl
2	This figure is the total volume per month for the whole factory as entered on Page 4 - F4. Please indicate what % of that you allocate to this line:	%	
3	If you know the surface area processed through this line per month, please provide the figure:	m2	

Process	Compound	Quantity Used Kg		Anode Type	Weight Used Kg
Process	Compound	Quantity Used Kg		Anode Type	Weight Used Kg

SECTION A

Please complete this section and then carry on to Section B beneath

Description of Line 4: Nickel Chrome

Helpful instructions are provided when hovering over the alphabetic ID of each column - A, B, C, D, etc.

Please enter only numeric values into Column J. The μ labels are already in place.

A	B	C	D	E	F					G			H				I				J	
					Process Type				Note colour coded instructions	Rinse Configuration			Indicate running rinses that share water inputs, if any. Four inputs are catered for.				Indicate rinses or chemical tanks shared with other process lines.				Enter average deposit thickness in μ - Figures only	Tank Description *Copy of Column B*
Tank No.	Tank Description	Number of Stations	Process Sequence	Opt. Steps	No Selection	Plating	Chem Dip	Rinse/Other		Static	Single	C/Flow	A	B	C	D	1	2	3	4		
1	Hot Soak	1	1	☐	○	○	◉	○	Select in I column only	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	μ	Hot Soak
2	Rinse	2	2,3	☐	○	○	○	◉	Select in cols G, H & I:>	○	○	◉	☑	☐	☐	☐	☐	☐	☐	☐	μ	Rinse
3	Acid Pickle	1	4	☐	○	○	◉	○	Select in I column only	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	μ	Acid Pickle
4	Rinse	2	5,6	☐	○	○	○	◉	Select in cols G, H & I:>	○	○	◉	☑	☐	☐	☐	☐	☐	☐	☐	μ	Rinse
5	Pre-dip	1	7	☐	○	○	○	◉	Select in cols G, H & I:>	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	μ	Pre-dip
6	Copper Strike CN	1	8,9	☐	○	◉	○	○	Enter microns in Col J	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	3.00 μ	Copper Strike CN
7	Drag out	1	10	☐	○	○	○	◉	Select in cols G, H & I:>	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	μ	Drag out
8	Rinse	2	11,12	☐	○	○	○	◉	Select in cols G, H & I:>	○	○	◉	☐	☐	☐	☐	☐	☐	☐	☐	μ	Rinse
9	Pre-dip	1	13	☑	○	○	◉	○	Select in I column only	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	μ	Pre-dip
10	Acid Copper Plate	1	14	☑	○	◉	○	○	Enter microns in Col J	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	5.00 μ	Acid Copper Plate
11	Drag out	1	15	☑	◉	○	○	○	<Select a Button	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	μ	Drag out
12	Rinse	2	16,17	☑	○	○	○	◉	Select in cols G, H & I:>	○	○	◉	☐	☐	☐	☐	☐	☐	☐	☐	μ	Rinse
13	Pre-Dip	1	18	☐	○	○	○	◉	Select in cols G, H & I:>	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	μ	Pre-Dip
14	Nickel Plate Brite	1	19	☐	○	◉	○	○	Enter microns in Col J	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	7.00 μ	Nickel Plate Brite
15	Drag out	2	20	☐	○	○	○	◉	Select in cols G, H & I:>	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	μ	Drag out
16	Rinse	2	21,22	☐	○	○	○	◉	Select in cols G, H & I:>	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	μ	Rinse
17	Pre-Dip	1	23	☑	○	○	○	◉	Select in cols G, H & I:>	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	μ	Pre-Dip
18	Chrome (Decorative)	1	24	☑	○	◉	○	○	Enter microns in Col J	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	0.25 μ	Chrome (Decorative)
19	Drag Out	2	25,26	☑	○	○	○	◉	Select in cols G, H & I:>	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	μ	Drag Out
20	Rinse	2	27,28	☐	○	○	○	◉	Select in cols G, H & I:>	○	○	◉	☐	☐	☐	☐	☐	☐	☐	☐	μ	Rinse
21	Hot Rinse	1	29	☐	○	○	○	◉	Select in cols G, H & I:>	◉	○	○	☐	☐	☐	☐	☐	☐	☐	☐	μ	Hot Rinse

Enter Numbers only

Please indicate the category of plating alongside: ◉ Rack Plating only ○ Barrel Plating Only ○ Rack & Barrel plating combo

Please click a button to select one of the options below that best describes the layout of this process line:

○ a) Tanks laid out contiguously in straight line or horse shoe format served by automatic overhead carrier.

◉ b) Tanks laid out contiguously in straight line or horse shoe format served by manually operated overhead carrier.

○ c) Tanks laid out contiguously in straight line or horse shoe format with jigs or barrels carried by operator from tank to tank

○ d) Tanks separated from each other by some distance requiring operators to convey work from tank to tank manually and/or by overhead hoist.

SECTION B

1 If you have data, calculate water consumption on this line for the reporting period or select Opt 2 below: Kl

2 56 Kl — This figure is the total volume per month for the whole factory as entered on Page 4 - F4. Please indicate what % of that you allocate to this line: 33 %

3 If you know the surface area processed through this line per month, please provide the figure: m2

Monthly water usage on this line calculated through percentage. 18.48 Kl

Process	Compound	Quantity Used Kg	Anode Type	Weight Used Kg
Copper	Copper Cyanide	12 Kg		37 Kg
	Copper Sulphate	25 Kg		
	Copper Pyrophos	Kg		
Nickel	Nickel Sulphate	12 Kg		55 Kg
	Nickel Chloride	8 Kg		
	Nickel Sulphamate	Kg		
Chrome	Chromic Acid	10 Kg	Inert Anodes	
Bronze	Sodium Stannate	1 Kg	Tin	4 Kg
	Copper Cyanide	9 Kg	Copper	30 Kg
Process	Compound	Quantity Used Kg	Anode Type	Weight Used Kg