AN INVESTIGATION OF A WASTE MINIMISATION CLUB FOR THE METAL FINISHING INDUSTRY

By

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ABSTRACT

Take care how you place your moccasins upon the earth, step with care, for the faces of the future generations are looking up from the earth waiting for their turn for life – Lyons, 1988

Increasing levels of pollution and the increase in demand for water and other resources by industry led to a number of policies and regulations being developed and revised in South Africa. According to the Constitution of the Republic of South Africa (Act 108 of 1996), everyone has the right to an environment that is not harmful to health or wellbeing. In order to have the environment protected and sustained for future use, it became necessary to move away from the traditional fragmented approach to pollution and waste management and focus on an integrated strategy aimed at achieving a balance between ecological sustainability and socio-economic development.

In the Durban Metropolitan Area (DMA), the Durban Metropolitan Council (Metro) incorporated pollution prevention in their bylaws, which contained stringent discharge limits for heavy metal concentrations. This posed a potential problem for metal finishers who were concerned about complying with these discharge standards. In addition, the metal finishing industry was considered to be a significant contributor to the pollution load in the DMA, and therefore needed to find suitable solutions to dealing with environmental problems, especially waste management. Waste minimisation was believed to be a good tool for this industry to utilise in order to reduce its pollution load. It was seen from the literature and case studies from international initiatives that waste minimisation results in an improvement in process efficiency and reductions in production costs and environmental impacts, generally at minimal costs.

A waste minimisation club was initiated for the metal finishing industry in the DMA in June 1998. The club consisted of twenty-nine members of which the majority were small and medium sized companies. The club was run over a period of thirty months. A core group of sixteen companies actively participated in the activities of the club.

During the period of investigation, a total of 391 waste minimisation options were identified for club members and 147 of these options were implemented. This resulted in a total financial saving in excess of R 4 million for the duration of the club's existence. The saving represents combined savings in water, chemicals, metals, energy, effluent treatment, and waste disposal. Corresponding environmental benefits were achieved including a reduced demand for water, reduced toxicity of effluent from chemical and metal reduction, and a reduction in energy requirements.

Four companies were investigated in detail and presented as case studies. These companies showed that the payback on implementing waste minimisation options was mostly immediate. The size of the companies was not critical in determining the level of success from running waste minimisation programmes. Success depended mainly on commitment from companies and motivation of project champions.

It was found that the greatest barriers to implementing waste minimisation, as identified by companies, were a lack of time, resources, and commitment. Companies joined the club mainly for benefit of reducing costs and complying with legal standards.

Aside from successfully raising awareness and promoting the concept of waste minimisation, the waste minimisation club also resulted in an improvement in the relationship between the metal finishing industry and the Metro, and among club members.

Based on the results achieved by club members, and from managing the club, it was evident that the club was effective in promoting waste minimisation in industry. For the future running of clubs, it is recommended that waste minimisation assessment training be given to all employees of a company. It would also be more useful if companies reported savings on a more regular basis and more formally. In addition it is recommended that club membership should be limited to between ten and fifteen companies to facilitate improved management of the club.

PREFACE

The work presented in this thesis was carried out in the School of Chemical Engineering, University of Natal (Durban), under the supervision of Professor C.A. Buckley, and Ms S. Barclay.

This study represents original work by the author unless specifically stated to the contrary in the text, and has not been submitted in any form to another university.

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LIST OF ABBREVIATIONS

DEAT	Department of Environmental Affairs and Tourism
DMA	Durban Metropolitan Area
DWAF	Department of Water Affairs and Forestry
EMS	Environmental Management System
ICPPIC	International Cleaner Production Information Clearinghouse
IPPC	Integrated Pollution Prevention and Control
ISO	International Organisation for Standardisation
MFI	Metal Finishing Industry
NEMA	National Environmental Management Act
NWMS	National Waste Management Strategy
OECD	Organisation for Economic Co-operation and Development
PRG	Pollution Research Group
SME	Small and Medium Sized Industry
UNEP	United Nations Environmental Programme
UNIDO	United Nations Industrial and Development Programme
US EPA	United States Environmental Protection Agency
WMC	Waste Minimisation Club
WRC	Water Research Commission

CHAPTER 1 - INTRODUCTION

It is not for nothing that various pundits have suggested that future wars may well be fought over water, not only in Southern Africa but indeed globally.

Prof Kader Asmal

Minister of Water Affairs and Forestry (1994-1999)

The depletion of essential resources, and the deterioration and destruction of natural processes is of major concern in the world today. These changes are mainly a result of poor agricultural practices, industrialisation, and urban growth. The exhaustion of water resources has been of particular concern, and it has been said that nearly one third of the world's population will experience a water shortage in the next twenty-five years.

1.1 WATER: THE SOUTH AFRICAN SITUATION

South Africa is a semi-arid country, plagued by droughts. The mean annual rainfall is approximately 475 mm. This is much lower than the world average of 860 mm. A total of 80 % of this rainfall falls during summer. The country sits eleventh from the bottom on an index of 50 countries with the least annual renewable water availability per capita. In 1955 there was about 3 500 kL water per person per annum, in 1990 this was 1 200 kL and the figure is expected to drop to 700 kL by 2005. The water stress level is regarded as 1 700 kL per person with 1 000 kL representing the critical level. [Perkins, 1996]

A rapidly rising population together with the drive to supply water to rural communities means water demand is increasing at a fast rate. South Africa possesses 10 % of Southern Africa's water resources but uses 80 % of the total amount consumed in the region. As a legacy of the past, approximately twelve million people did not have access to potable water in South Africa. This has been reduced by three million. In Kwazulu Natal, the situation is made more difficult by a dispersed rural population living far away from water sources. [Perkins, 1996]

New policy and legislation dictates that water is a national asset. The new Water Act (Act 36 of 1998) places emphasis on conservation and the most efficient utilisation of water in the public interest. It is therefore essential for South Africa to manage water demand in an economically, socially and environmentally sustainable way to ensure sufficient water for everyone for years to come.

1.2 SUSTAINABLE DEVELOPMENT

Sustainable development is *development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs.* [World Commission on Environment and Development, 1987]

Sustainable development requires a long-term perspective for planning and policy development; dictates actions that build on and reinforce the interdependence of our economy and our environment; and calls for new integrative approaches to achieve economic, social, and environmental objectives. It has emerged in recent years as a focal point for policy makers concerning the long-term economic and environmental outlook. [World Business Council for Sustainable Development, 1997]

To strive towards sustainability, it is essential to achieve reductions in the exploitation and consumption of natural resources, and a reduction in the emission of waste products to the environment. Society can then reach a state where it will not be exceeding the carrying capacity of the supporting ecosystems. Measures necessary to achieve ecological sustainability include environmental legislation and regulation, economic incentives, waste minimisation and cleaner production, and training and education. [DEAT, 1998]

Sustainable development principles are firmly embedded in various South African policies and legislation that have been developed since 1994. According to the Constitution of the Republic of South Africa (Act 108 of 1996), all its citizens have the right to a clean and unpolluted environment, which is not detrimental to human health. It also states that the environment must be protected to secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development. As a consequence, the importance of sustainable development is acknowledged in the country's Reconstruction and Development Programme (Act 107 of 1997). An important instrument that will contribute substantially towards the promotion of sustainable development in South Africa, is the National Environmental Management Act (Act 107 of 1998). Legislation such as the White Paper on Integrated Pollution and Waste Management (DEAT, 1999), the National Environmental Management Act, and the National Waste Management Strategy (1998), once fully enacted and implemented will create a holistic approach to waste management, which aims at sustainability.

1.3 AGENDA 21 AND LOCAL AGENDA 21

Agenda 21 is the global action plan for socially, economically, and environmentally sustainable development. It was adopted at the United Nations Conference on the Environment and Development in Rio de Janeiro in June 1992, and is aimed at improving the relationship between development and the Earth's natural resource base. [Hindson, King, and Peart, 1996]

Agenda 21 has targeted cities as key areas for action in the drive to achieve sustainable development. The conference proposed that the principles of Agenda 21 be implemented at the local authority level. This programme is known as Local Agenda 21. In South Africa, the cities of Johannesburg, Durban, and Cape Town have initiated Agenda 21 programmes. At the provincial level, provinces such as KwaZulu-Natal and the Northern Province initiated provincial Local Agenda 21 campaigns to encourage broadscale local authority involvement in Local Agenda 21 initiatives. The former Durban City Council adopted the programme in August, 1994. The City of Durban was then accepted as a full member of the International Council for Local Environmental Initiatives (ICLEI) in 1994. ICLEI is an international organisation responsible for coordinating Local Agenda 21 initiatives worldwide. [Hindson et al, 1996] The goal of Durban's Local Agenda 21 programme is the development of an environmental management system that guides the city towards an environmentally sustainable development path.

1.4 ENVIRONMENTAL PROBLEMS IN THE DURBAN METROPOLITAN AREA

The Durban Metropolitan Area (DMA) covers an area of approximately 1 300 square kilometres and is the largest urban area in the province of KwaZulu-Natal (South Africa). It is also the largest city and port on the east coast of Africa. The natural systems in DMA have been transformed by human settlement and exploitation. The economy has impacted directly and indirectly on natural systems through resource use, patterns of consumption, and by generating industrial and domestic waste. Uncontrolled waste results in air, water, land, and soil pollution, and is unsustainable. [Hindson et al, 1996]

1.4.1 Water Resources and Waste

The DMA's freshwater resources are under pressure from growing needs for potable water and waste disposal. Freshwater supplies are not assured as rainfall is poorly distributed and irregular, and evaporation losses are relatively high across the catchments. There are fourteen rivers traversing the DMA, most of which have been heavily modified through dams and canalisation. The capacity of the DMA's major water supply, the Mgeni River, has been almost completely harnessed for urban use. Sections of other rivers have also been severely polluted by industrial and/or human effluents. The DMA's growing population and increased provision of waterborne sanitation has resulted in the production of increasing volumes of sewage requiring disposal. Much of this is treated and discharged either to the sea or into nine of the DMA's rivers. [Hindson et al, 1996]

Major problems also exist with solid waste. In the DMA, approximately 960 000 tonnes of waste is landfilled annually. Approximately 875 000 tonnes consists of general urban solid waste including domestic, non-hazardous industrial waste, and builders' rubble. The DMA has six operational landfill sites of which four are classified as general waste sites (G) and two are low hazard (H:h) co-disposal sites. The lack of high hazard (H:H) waste disposal sites implies that industry needs to transport their waste to other provinces usually at extremely high costs. In some cases, it leads to illegal dumping. Poor disposal of waste in some areas of the DMA has had significant negative impacts on many aspects of the natural environment as well as negatively impacting on the health of some communities and tourism. Existing landfills are approaching saturation, and it is proving difficult to find suitable alternative sites. [Hindson et al, 1996]

The sustainability of major economic sectors of the metropolitan area, which generate waste, is therefore questioned

The Durban Metropolitan Council (Metro) is actively involved in promoting integrated waste management for the metropolitan area. This includes promoting recycling and waste minimisation where feasible, identifying safe sites for future land disposal and improving management of existing landfill sites. The Durban Metropolitan Environmental Policy sets out a range of objectives to address the metropolitan area's waste management issues in the future. This is supported by new national and provincial policy in promoting an integrated approach to waste management.

1.4.2 Problems facing Durban Metal Finishers

Small and medium sized enterprises (SMEs) are prevalent in the DMA, and collectively contribute a large proportion of the area's industrial waste. The major reasons for this high waste generation from SMEs are inefficient technologies and a lack of awareness in terms of process control. The metal finishing industry in particular consists mainly of SMEs, and this industry has been identified by the Metro as one of the most polluting in the manufacturing sector due to the hazardous nature of the waste it generates. The industry also consumes large quantities of water and chemicals. Therefore stringent regulations have been introduced by Metro to reduce the environmental impact of metal finishing companies. Failure to comply with these regulations may result in fines for the site involved. Conventional end-of-pipe treatment is not sufficient to deal with the pollution problem. It represents an additional cost to the overall process and is not necessarily effective in obtaining compliance with strict discharge standards. Cleaner production is seen as the more effective approach towards reducing environmental impact while complying with regulations since it involves pollution prevention rather than waste treatment. Metal finishers are also finding it increasingly difficult to dispose of their sludge due to its high metal content and the lack of landfill sites in the DMA that can accept hazardous waste. Applying pollution prevention methods leads to less waste requiring disposal, and a lower sludge metal content.

1.5 WASTE MINIMISATION AND WASTE MINIMISATION CLUBS

High waste generation results in increased end-of-pipe treatment costs as well as losses in raw materials, water, and energy. These factors along with stringent regulations serve as incentives for companies to begin implementing waste minimisation. Industry is being placed under pressure to upgrade operations and use cleaner technology. Several policies and regulating laws in South Africa address the concepts of pollution prevention and waste minimisation. The National Waste

Management Strategy (1998) has identified waste minimisation as an important instrument in aiding sustainable development in the country.

Waste Minimisation is concerned with reducing waste generation at source and not with end-of-pipe treatment systems for waste streams. Waste minimisation results in an improvement in process efficiency, reduction in production costs and pollution load. However due to a lack of awareness, guidance and knowledge, waste minimisation has not been an option considered by most SMEs.

By establishing waste minimisation clubs for SMEs, the concept of waste minimisation can be promoted within industry. The concept of such clubs is relatively new in South Africa. These clubs generally consist of companies from the same industry and/or situated in the same geographical area [Johnstone, 1995]. The clubs serves as a forum for companies to discuss issues of relevance, in particular pertaining to waste minimisation. Clubs have been successfully established and run in countries such as the United Kingdom and The Netherlands.

1.6 PROJECT OBJECTIVES

Environmental legislation in this country favours the adoption of pollution prevention strategies by industry. As mentioned in section 1.4, the metal finishers in the DMA have been targeted by local authorities for strict regulation with respect to their effluent production. This issue combined with the additional environmental problems facing the industry implied that the industry needed a cost effective method to reduce the volume and toxicity of its waste.

Thus the main objective for this project was ***to promote waste minimisation within industry by establishing and sustaining a waste minimisation club for the metal finishing industry in the Durban Metropolitan Area.***

Several secondary objectives were expected to be fulfilled by the running of the club, including:

- reducing the demand for water by industry,
- improving water quality through pollution prevention,
- assisting companies in complying with discharge standards,
- develop the concept of waste minimisation clubs for South Africa,
- analyse club results to improve running of future clubs.

The approach used to fulfill these objectives will be discussed in **Chapter 3** followed by the results.

1.7 HYPOTHESIS

Waste minimisation clubs have been successfully run in other countries. They have aided in promoting waste minimisation within industry resulting in a decrease in industrial environmental impact while helping companies achieve financial savings. It is therefore hypothesised that:

A waste minimisation club is an effective technique to promote waste minimisation within South African industry

In addition further subsidiary hypotheses have been tested during the course of the project including that:

- engineering students are useful to conduct audits,
- companies would be interested in benefits to the environment,
- follow up site visits would be essential to keep up to date with company progress,
- club members would have sufficient time to attend meetings regularly,
- companies would be committed to implementing waste minimisation,
- small and medium sized companies would find it difficult to implement a monitoring and targeting programme,
- club members would want to continue the club in the future,
- the size of the company would be critical in determining the success achieved with waste minimisation, and
- the highest number of options identified would be for housekeeping improvements.

1.8 RESEARCH PROCEDURE

An extensive literature review was first carried out to become familiar with the concepts of sustainable development, cleaner production, waste minimisation, waste minimisation methodology, and the metal finishing industry. This was essential in order to be able to apply these concepts and understand them during the practical stages of the project. The major source of information was books, followed by publications and manuals pertaining to the metal finishing industry and waste minimisation. A waste minimisation club was initiated and established in June 1998. Waste minimisation assessments were then carried out at companies where options to reduce waste were identified. Companies' progress was monitored and surveys were carried out to determine what improvements had been made and whether the club was achieving success. Regular club meetings were held to discuss issues of relevance to members, and to obtain feedback from companies on their waste minimisation programmes. Site visits were also conducted to observe changes and provide additional assistance to project champions. Four companies were chosen for detailed analysis and are presented as case studies to demonstrate the success of implementing waste minimisation at different types of companies.

1.9 THESIS STRUCTURE

Figure 1.1 is a graphical representation of the thesis structure. **Chapter 2** contains a detailed literature review covering cleaner production, waste minimisation in general, environmental regulations, waste minimisation clubs, the metal finishing industry (including associated wastes and challenges facing the industry), and waste minimisation specific to this industry. **Chapter 3** discusses the practical approach undertaken to establish and run the club, conduct waste minimisation assessments and gather information. It also presents a profile of the metal finishing industry in South Africa, and discusses the characteristics of club members. The results obtained from the case studies are presented in **Chapter 4**. In **Chapter 5**, the overall results of the project are presented. This includes financial and environmental benefits, social interaction, problems experienced, as well as lessons learnt. **Chapter 6** discusses the findings of the project and presents the conclusions and recommendations.

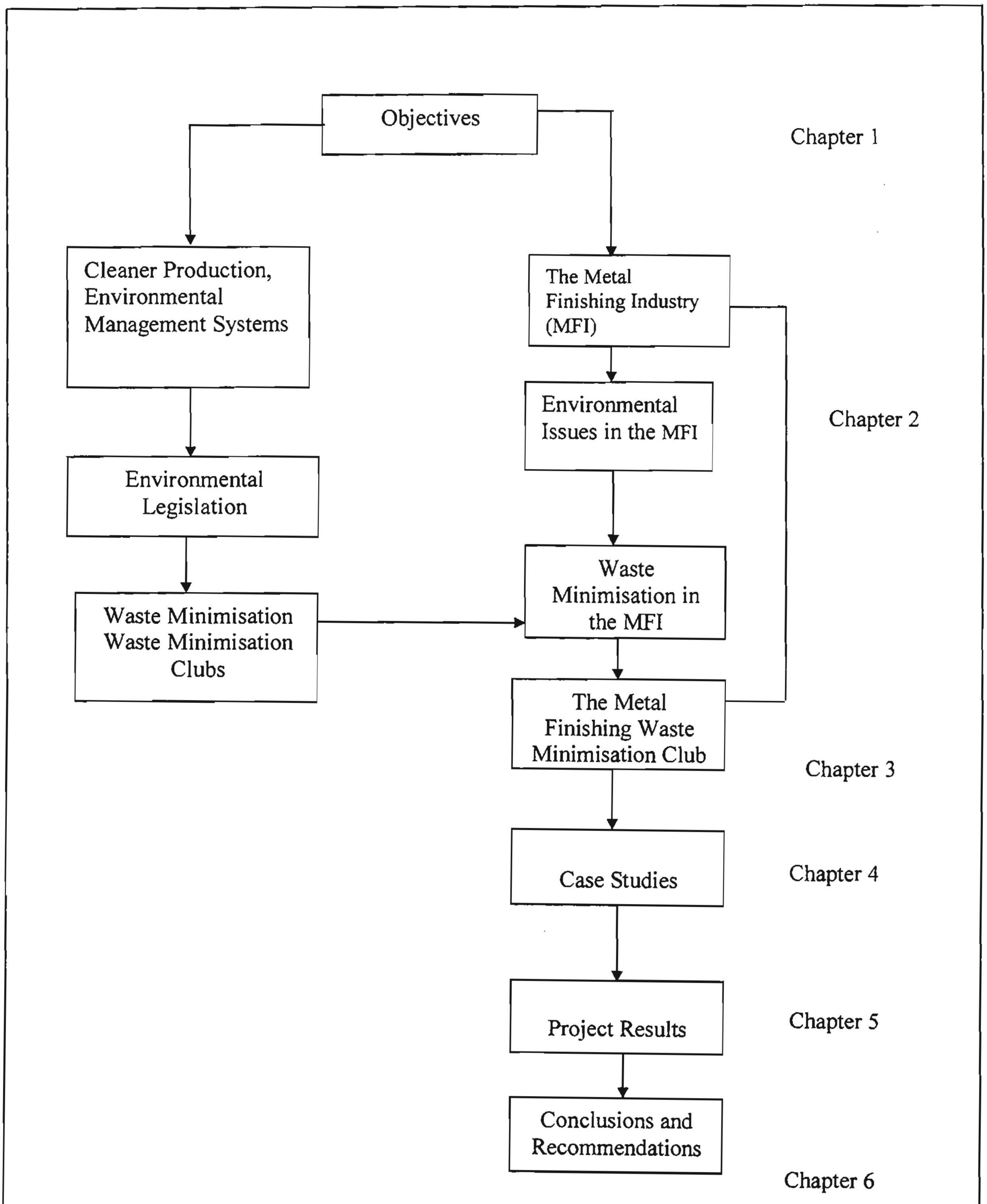

Figure 1.1 Structure of Thesis

CHAPTER 2 - LITERATURE SURVEY

The search for a sustainable development path calls for new ways of understanding the environment and development, and new ways of acting on these problems – Hindson et al, 1996

The application of industrial processes has far reaching and degrading effects on the environment. In the past, industry has dealt with waste by employing costly end-of-pipe treatments prior to discharge to the environment. This however did not alleviate the problem of pollution. In order for industry to follow a sustainable development path, they need to consider preventative options that result in a reduction in waste emissions rather than options that treat waste after its generation. In recent years, cleaner production and waste minimisation have emerged as more effective methods of dealing with pollution of the environment, and following a path of sustainable development.

A literature survey was conducted on waste prevention options and in particular options pertaining to the metal finishing industry. In this chapter, cleaner production, and environmental management systems are introduced and explained. An overview of South African and international environmental regulations and policies is given to emphasise the importance of cleaner production. Detailed discussions of waste minimisation, the metal finishing industry, and waste minimisation in the metal finishing industry are also included.

2.1 CLEANER PRODUCTION

The concept of Cleaner Production was introduced by the United Nations Environment Programme Industry and Environment (UNEPIE) in 1989.

Cleaner production is defined as the continuous application of an integrated preventive environmental strategy to processes, products, and services to increase efficiency and reduce risks to humans and the environment. [UNEP, 1995]

It applies to:

- production processes: conserving raw materials and energy eliminating toxic raw materials and reducing the quantity and toxicity of all emissions and wastes,
- products: reducing negative impacts along the life cycle of a product from raw materials extraction to its ultimate disposal, and
- services: incorporating environmental concerns into designing and delivering services.

Cleaner production requires changing attitudes towards responsible environmental management, creating conducive national policy environments and evaluating technology options. Other preventive approaches, such as eco-efficiency and pollution prevention, serve similar goals. The goal of cleaner production is to avoid generating pollution in the first place. This strategy frequently cuts costs, reduces risks and identifies new opportunities. Cleaner production can be the most efficient way to operate processes, produce products and to provide services. Costs of wastes, emissions and environmental and health impacts can be reduced and benefits from these reductions and new markets can be realised. The adoption of cleaner production practices therefore leads to ecologically and economically sustainable development since pollution and waste are reduced at source.

Cleaner production is a broad concept. The major aspects of which include:
- waste minimisation,
- maximising resource utilisation,
- life cycle assessment,
- minimising usage of harmful chemicals, and
- minimising environmental impact. [UNEP, 1995]

It involves rethinking conventional methods to achieve improved production processes and products. The process focuses on waste avoidance and reduction as the first option in dealing with waste problems. Once all avoidance and reduction options have been eliminated, options for on-site reuse and recycling can be considered. This is illustrated in Figure 2.1.

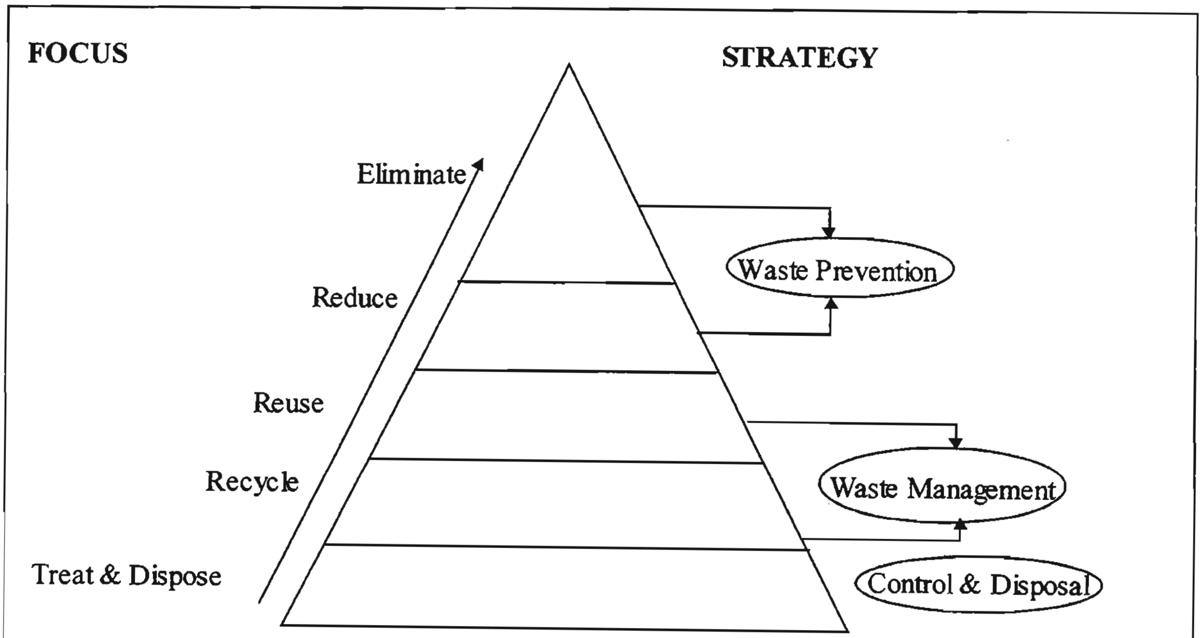

Figure 2.1 The Cleaner Production Hierarchy [UNEP, 1998]

The ultimate goal of cleaner production is the eventual elimination of all waste. However this is generally not possible, but significant reductions in waste is possible through the implementation of cleaner production tools. The treatment and disposal of waste should only be considered when all options to eliminate, reduce and recycle waste have been investigated. This option is therefore at the bottom of the hierarchy as illustrated in Figure 2.1.

Information about cleaner production is growing rapidly. A series of Cleaner Production Assessment (CPA) Industrial Sector Guides is being developed by the UNEP, covering eight different industrial sectors namely meat processing, fish processing, dairies, foundries, metal finishing, textiles, tanneries, and breweries. These contain a step-by-step description of the production following the unit processes, a list of cleaner production options for each unit process, key figures or efficiency indicators for the production, and generic CPA methodology for industry. The International Cleaner Production Information Clearinghouse (ICPIC) was also initiated by UNEP and is a useful form of information exchange. The United Nations Industrial Development Organisation (UNIDO) also promotes cleaner production as a means for industry to be environmentally responsible. UNIDO works with governments to devise policies and strategies, while designing and supporting programmes for cleaner production education. [Aquatech, 1997]

2.1.1 Advantages of Implementing Cleaner Production

Adopting cleaner production practices leads to a number of advantages, the most common of which are described below [UNEP WG, 1998]:

Saving Money

Cleaner production leads to financial savings since the amount of money spent on wasted resources, waste treatment, and disposal and compliance costs is greatly reduced. Cleaner production strategies typically cost less than treatment and disposal technologies. Strategies such as general housekeeping and process improvements can be implemented at low cost and can have immediate benefits. Substantial process modifications or technology changes will require some capital investment but generally with short payback periods.

Preventing Pollution and Reducing Resource Consumption

The basis of cleaner production is the reduction of water, resource and energy consumption and the minimisation of waste. By emphasising the reduction of waste at the source rather than controlling pollution after its generation, many pollution problems can be eliminated.

Complying with Environmental Regulations

Cleaner production tools assist in complying with strict environmental legislation, and results in reduced liability, reduced monitoring costs and improved control over one's business.

2.1.2 Contents of a Cleaner Production Plan

An effective cleaner production plan should contain details of:

- current waste management practices,
- material, energy, and resource inputs,
- material, waste, and energy outputs,

- impacts of the production process on environmental values,
- opportunities and actions to be taken to avoid and reduce waste,
- opportunities and actions to be taken to recycle waste,
- recommendations of any life cycle assessment conducted,
- targets and goals, and
- a monitoring and reporting programme.

This will ensure efficient running of a company's cleaner production programme, and enables the goals of the programme to be achieved.

2.2 ENVIRONMENTAL MANAGEMENT SYSTEMS

An Environmental Management System (EMS) is a system used to control and improve environmental performance in response to changing internal and external factors. This is achieved through the allocation of resources, assignment of responsibilities, and ongoing evaluation of practices, procedures, and processes. [International Organisation for Standardisation, 1996] EMSs have become a major focus for many industrial companies. These systems serve to ensure that companies take responsibility for their environment and endeavour to decrease harmful environmental impacts in a voluntary way.

The first EMS standard was developed by the British Standards Institution, and a number of companies have registered with this standard. The International Organisation for Standardisation (ISO) introduced a range of EMS standards called the ISO 14000 series. The series resulted from ISO's commitment to support the objective of sustainable development discussed at the United Nations Conference on Environment and Development in Rio de Janeiro, in 1992. The first ISO 14000 standards were published in 1996, and have grown to include more than twenty documents. In addition to ISO 14000, ISO also has a wide portfolio of standards that are specific to, for example, air, water, or soil pollution. ISO 14000 was developed with the aim of providing a framework for an overall, strategic approach to an organisation's environmental policy, plans and actions. It does not lay down levels of environmental performance, therefore the standards can be implemented by a wide variety of organisations, whatever their current level of environmental maturity. *However, a commitment to compliance with applicable environmental legislation and regulations is required, along with a commitment to continuous improvement* – for which the environmental management system provides the framework.

The underlying philosophy is that the requirements of an effective EMS are the same, whatever the type of business. [World Business Council for Sustainable Development, 1997]

A similar voluntary standard is the Eco-Management and Audit Scheme (EMAS) developed by the European Union. It differs from ISO 14000 in that it requires a regular public statement of performance after the company has been reviewed and audited by independent verifiers. EMAS requires an Environmental Policy to be in existence within the organisation, fully supported by senior management, and outlining the policies of the company, not only to the staff but to the general public and other stake holders. The policy needs to clarify compliance with Environmental Regulations that may affect the organisation, and must stress a commitment to continuous improvement. Emphasis has been placed on policy as this provides the direction for the remainder of the Management System. With EMAS, companies are expected to have audits carried out every three years. [Honkasalo, 1998]

EMSs, along with eco-labels and negotiated agreements are voluntary approaches that are now being favoured in international policy documents as an alternative to the traditional command and control approach.

2.3 ENVIRONMENTAL REGULATIONS

The concepts of cleaner production and waste minimisation have been gaining recognition over the years and are included in many countries' environmental policies. The policies and programmes present in South Africa and other countries are discussed in this section.

2.3.1 International Policies and Programmes

Cleaner production programs have been initiated by international organisations such as the United Nations Environmental Programme (UNEP), United Nations Industrial and Development Organisation (UNIDO), and the Organisation for Economic Co-operation and Development (OECD) to promote cleaner production in different countries. The policies adopted by the OECD and the United States of America (USA) are similar and combine regulation, incentives, and information transfer. [US EPA, 1995]

OECD countries have close working relationships with their governments, which sponsor research, develop waste management plans, implement waste collection, and help develop waste-specific reduction programmes. In the United States, it has been reported that environmental performance has a significant effect on the competitive dynamics within an industry. Since cleaner production is less prevalent in small and medium sized enterprises, the focus of cleaner production initiatives is on this sector of the industry. [US EPA, 1995]

2.3.2 The European Community

The European Community has adopted a directive that introduces a system of Integrated Pollution Prevention and Control (IPPC). The IPPC requires that operators of industrial installations with a high potential to cause pollution obtain a permit in order to operate. The directive covers the production and processing of metals, as well as installations using more than 200 kg/h of organic solvent. [US EPA, 1995]

2.3.3 The Nordic Council

The Nordic Council was formed to promote cooperation among the parliaments and governments of Denmark, Iceland, Norway, Sweden, and Finland. The Nordic Action Programme on Cleaner Technologies was developed in 1992. The programme is concerned with the reduction in energy consumption and the development of cleaner technologies. An industry network has been set up by the council for the dissemination of Nordic cleaner technologies. They have also hosted industry-specific seminars, established a Nordic newsletter, and coordinated with the UNEP cleaner production activities. [US EPA, 1995]

2.3.4 Canada

The Canadian Government released its "Green Plan" in 1990, which contains targets and schedules to drive environmental initiatives with the aim of reducing the amount of waste needing special treatment or disposal. The Canadian Environmental Protection Act (1998) is the key environmental legislation in Canada and sets environmental quality objectives, guidelines, and regulations to prevent the contamination of water, soil and air. [US EPA, 1995]

2.3.5 Denmark

Action for both cleaner technology and waste recycling are administered by the National Agency of Environmental Protection. The funding of individual projects, however, is the responsibility of the Danish Recycling and Cleaner Technology Council. This council comprises representatives from the Ministry of the Environment, industrial organisations, municipalities, countries, non-governmental organisations, and two experts on recycling and cleaner technology. [US EPA, 1995]

2.3.6 South Africa

The Constitution of South Africa (Act 108 of 1996), being the overarching law of the land places the responsibility of environmental management with the South African Government. In order to comply with the constitution, a number of policies and legislative developments containing sections on pollution prevention have been introduced in South Africa. The pollution liability of waste generating enterprises has increased considerably with increased fines, clean up orders, liability for environmental rehabilitation, and personal liability all being issues included in the new acts, bills and policies. Water pollution is one of the highest priorities. Developments in control of water pollution have been made with the passing of the Water Services Act (Act 108 of 1997) and the National Water Act (Act 36 of 1998). Owners and occupiers of land now have an obligation to prevent pollution as per the National Water Act.

The National Environmental Act (NEMA) (Act 107 of 1998) places a responsibility on every person who may cause pollution to take measures to prevent that pollution from occurring. Both the New Water Act and the NEMA attach liability to someone for a past activity that has led to pollution. This is important to the metal finishers who produce sludge containing hazardous persistent chemicals and metals that can lead to serious health and environmental problems downstream from their operations.

The other laws that are primarily aimed at pollution control and waste minimisation are the White Paper on Environmental Management Policy for South Africa (1998), and the Policy on Integrated Pollution Control and Waste Management for South Africa. These papers and laws detail the government's policy on pollution and waste management, which is to move away from the previous fragmented situation of uncoordinated waste management to a system of integrated waste management. The National Waste Management Strategy (1998) is a government strategy for integrated waste management in South Africa. The strategy is a long-term plan for addressing issues related to waste management. It puts into action the policy set out in the White Paper on Integrated Pollution Control and Waste Management. A key issue in this and other government policies is the adoption of the polluter pays principle. These legislative developments make it necessary for enterprises to examine their processes and endeavour to reduce their environmental impact.

The implementation of these legislative documents is the responsibility of the country's appropriate regulatory bodies. These bodies exist at national and local levels. At national level, the Department of Environmental Affairs and Tourism (DEAT) is the lead agent responsible for the overall protection of the national environment and deals with issues directly or indirectly concerned with waste disposal and pollution, including air pollution. The Department of Water Affairs and Forestry (DWAF) is the lead agent responsible for monitoring and controlling discharges into the natural water systems; i.e. rivers and seas, and solid waste disposal. Both operate to established standards and both are authorised to issue permits. Both the DEAT and the DWAF share a strong and natural commitment to the development of cleaner production initiatives and to all initiatives aimed at enhancing environmental protection. [Danced, 1999]

Responsibility for the environment at a provincial level has been delegated by the National Minister of Environmental Affairs and Tourism to the relevant provincial authority in each province of South Africa. In KwaZulu-Natal, this authority is the Department of Agriculture and Environmental Affairs. This department receives its mandate from the Environment Conservation Act (Act 73 of 1989) and NEMA and is responsible for drafting provincial policies on pollution and waste management.

At local level, the Municipal Authorities are responsible for regulating and monitoring waste disposal and the discharge of effluent into the sewerage systems. These authorities formulate local by-laws and have the authority to demand site access, take samples and enforce standards. Problems at municipal treatment plants and waste disposal sites have made the problem of upstream pollution more urgent. Therefore, the municipal authorities express commitment to cleaner production and prioritise that over *end of pipe solutions*, which would transfer the burden of responsibility onto the municipal waste management departments.

2.3.7 Impact of Policies

The policies implemented by governments can be grouped into voluntary and mandatory programmes. Voluntary programmes include those that rely on establishing waste reduction goals, information and technology transfer, grants, and achieved waste minimisation objectives. Mandatory policies include direct regulation (e.g. effluent limits or hazardous waste listings that create strong incentives for reduction), and the use of permitting authorities. Most governments attempt at promoting the advantages of prevention-oriented policies. Both governments and industry need to understand that waste minimisation policies are advantageous from a cost-benefit perspective when compared to traditional regulatory approaches. [US EPA, 1995]

2.4 WASTE MINIMISATION

The generation of waste is inevitable from the manufacture of a product or the application of a process. While the 'zero waste' concept has been mentioned as a goal at times, it often refers to zero waste disposed of to landfill. [Freeman, 1999] It is unlikely that a company will achieve complete elimination of waste. Reduction in the volume and toxicity of waste is possible through the implementation of waste minimisation, which is defined as *the continuous application of a systematic approach to reducing the generation of waste*. Waste minimisation entails reduction of waste at source and on-site recycling. Source reduction involves reducing the amount of waste at source, usually by changing or improving the existing processes and by introducing more efficient process control. Recycling involves the re-use or recycling of waste for the same process or another purpose. [Crittendon and Kolaczkowski]

Waste minimisation has become the preferred option when dealing with pollution control problems due to the many limitations with conventional pollution control measures. These measures result mainly in a change in the physical form of the pollutants i.e. the pollutants are not reduced or eliminated. They also assume that the environment has sufficient capacity to handle the pollution load, and they represent a major cost to companies. [US EPA, 1995]

Waste minimisation does not necessarily imply a cost for the company, as the majority of waste minimisation options require an improvement in basic housekeeping. This may involve simple tasks like repairing all leaks, ensuring that all taps are closed when not in use, and avoiding spillage. Some capital investment may be required if equipment modifications and technology changes are suggested. The techniques involved with waste minimisation are illustrated in Figure 2.2.

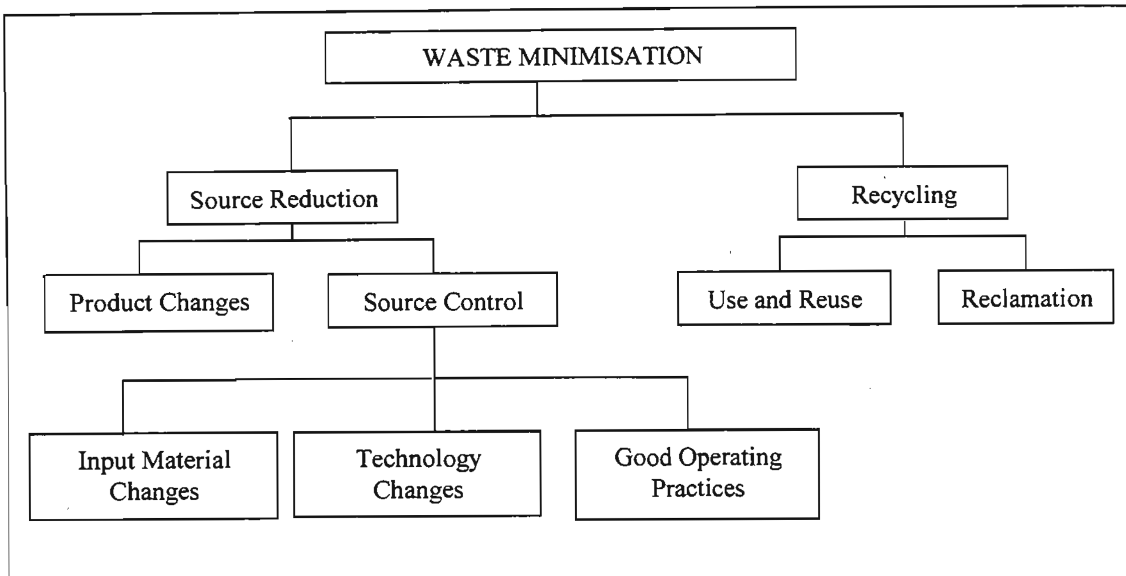

Figure 2.2 Waste Minimisation Techniques

It is necessary to take into account all pollutant emissions into air, water and land when implementing waste minimisation. It is also important to note that transferring the pollutants from one medium to another does not constitute waste minimisation. Generators of hazardous waste can benefit greatly from implementing a waste minimisation programme but need to acknowledge that it is an on-going process and therefore requires long term commitment. The primary goal of waste minimisation is the reduction of waste but it also may result in improved production efficiency. [US EPA, 1986]

A waste minimisation programme is an organised, comprehensive, and continual effort to systematically reduce waste generation. A successful programme requires [CEST, 1995]:

- commitment and support from management,
- clear objectives,
- accurate waste accounting ,
- accurate cost accounting,
- waste minimisation philosophy, and
- technology transfer.

Waste minimisation assessments are key components of a waste minimisation programme. A waste minimisation assessment is a systematic, planned procedure with the objective of identifying ways to reduce waste. [US EPA, 1995] During the assessment, the plant's process and waste streams are reviewed and assessed. Areas requiring specific attention are identified and the appropriate waste minimisation options are developed. The technical and economic feasibility of those options is evaluated. The most feasible options are then implemented.

2.4.1 Waste Minimisation Assessment Methodology

A number of manuals and guideline documents have been published to assist industries in running a waste minimisation programme. The US EPA guide, Waste Minimisation Opportunity Assessment Manual (1986) was one of the early publications and provides a detailed procedure on conducting assessments and compiling data. The manual contains a number of worksheets that can be followed to complete an audit. These worksheets however do need to be modified according the type of industry. Several other guides, based on this manual, have been published. The methodology outlined by the United Nations Environment Programme is different in that it is more descriptive of the procedural requirements. These guides require the user to possess some fundamental understanding of process chemistry and technology. Using both the EPA and UNEP approaches can be of great benefit to companies running waste minimisation programmes. The methodology used for this project was obtained from the US EPA guide.

The waste minimisation assessment procedure as outlined in the US EPA manual is illustrated in Figure 2.3 and the steps involved are discussed in detail thereafter.

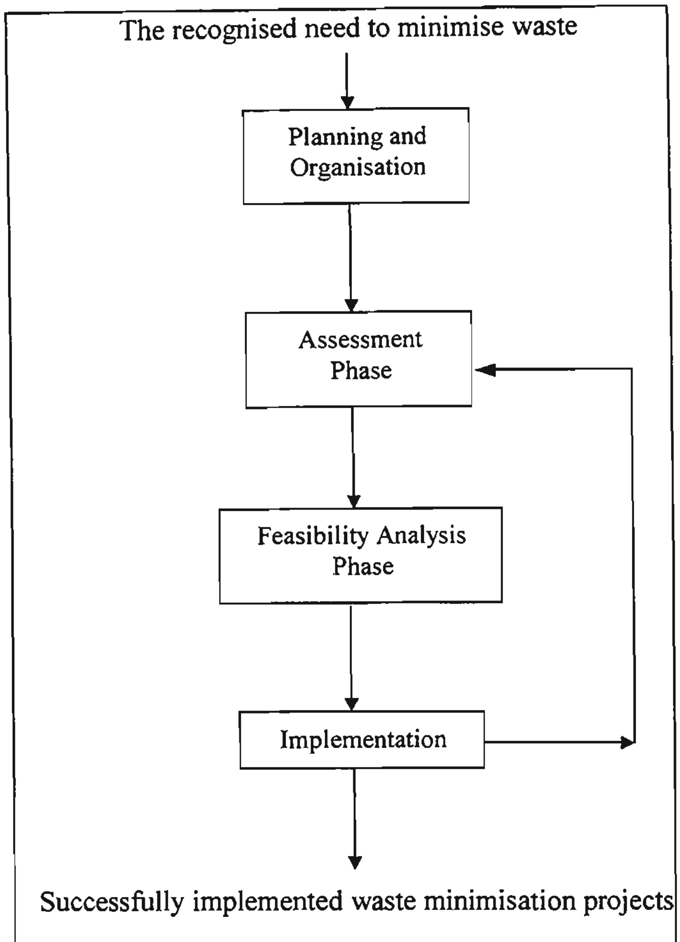

Figure 2.3: Waste Minimisation Assessment Procedure

Planning and Organisation

The first phase in setting up a waste minimisation programme focuses on obtaining management commitment, ensuring employee involvement, electing a project champion, defining the programme, and setting goals.

- Obtaining Management Commitment

  Management commitment is essential for the successful development and running of a waste minimisation programme. The management of a company will support a waste minimisation programme if they are convinced that the benefits of the programme will outweigh the costs. Once the programme has been developed, it requires support from management to endorse goals and implementation efforts. A formal policy statement of management directive is used to inform company employees of a waste minimisation programme.

- Employee Involvement

While commitment from management is essential for the success of a waste minimisation programme, co-operation throughout the organisation is also important in order to resolve conflict and to remove any barriers to waste minimisation. Bonuses, awards, and other forms of recognition are often used to provide motivation, and to boost employee co-operation and participation.

- Cause Champions
  A waste minimisation programme needs one or more people to champion the cause within an organisation. They are responsible for helping to overcome any opposition that arises when changes to an existing operation are proposed. The project champion also leads the waste minimisation programme and should be given enough authority to effectively carry out the programme.

- Organising the Waste Minimisation Programme
  Since a waste minimisation programme affects a number of groups within a company, a waste minimisation team should be assembled, comprised of members of all departments in the company that has an interest in the outcome of the programme. The members of a team are responsible for working with management to set goals, gathering and analysing information relevant to the programme, promoting waste minimisation within the company and educating employees on how they can participate, and monitoring and reporting progress to management. The size of the team depends on the size of the organisation. In small companies, one person may be responsible for waste minimisation activities. In larger companies, the team may consist of environmental managers, technical staff, maintenance staff, and accountants.

- Setting Goals
  The first priority of the waste minimisation programme task force is to establish goals that are consistent with the policy adopted by management. Waste minimisation goals, since they are qualitative, can be reviewed periodically and re-evaluated when changes occur. Typical goals identified include complying with effluent limits, improving efficiency, and reducing costs.

- Overcoming Barriers
  The programme task force should recognise potential barriers. There are a number of attitude-related barriers that can disrupt a waste minimisation programme. Most people are afraid of change and don't see the need to implement waste minimisation. A common feeling is also that waste minimisation just doesn't work. One way to avoid this is to use idea-generating sessions that involve all interested parties.

Assessment

The purpose of the assessment phase is to develop a comprehensive set of waste minimisation options, and to identify the options that deserve additional, more detailed analysis.

- Collecting and Compiling Data

This stage involves the identification of the types and volumes of waste streams generated from the plant, and from which processes these streams originate. The waste streams are then divided into the hazardous and non-hazardous streams. The types and quantities of input materials are also investigated. Collecting this information enables understanding of the plant's production and maintenance processes and will allow priorities to be determined.

- Flow Diagrams and Material Balances
  Flow diagrams provide the basic means for identifying and organising information that is useful for the assessment. Material balances are generated from flow diagrams and are important for many waste minimisation projects, since they provide a baseline for tracking progress of the waste minimisation efforts. The material balance is represented by the following basic mass conservation equation:

  $$\textit{mass in} = \textit{mass out} + \textit{mass accumulated}$$

  A material balance should be formulated individually for all components that enter and leave the process. Material balances are easier and more accurate when they are done for individual processes. An overall material balance can be constructed from the individual balances.

- Prioritising Waste Streams and/or Operations to Assess
  Ideally, all waste streams and plant operations should be assessed. Prioritising the waste streams and plant operations is necessary when available resources and or personnel are limited. Plants with only a few processes should assess their entire facility.

- Selecting the Assessment Teams
  Assessment teams should include people with direct responsibility and knowledge of a particular waste stream or area of the plants making the focus of each team very specific. In addition to internal staff, outside consultants should be brought in to assist with the assessment phase. An outsider can provide an objective viewpoint and generally sees things from a different perspective. Production operations and line employees must be considered as a source of waste minimisation suggestions, since they possess first hand knowledge and experience with the process.

- Site Inspection
  When performing the site inspection, the assessment team should follow the process from the point where raw materials enter the area to the point where the products and the wastes leave the area. This inspection often results in forming preliminary conclusions about the causes of waste generation. Confirmation of these conclusions may require additional data collection analysis, and or site visits.

- Generation of Waste Minimisation Options
  Once the origin and causes of waste generations are understood, a set of waste minimisation options needs to be generated. Identifying potential options relies both on the experience and creativity of the team members. The process for identifying options should follow a hierarchy

in which source reduction options are explored first, followed by recycling options. This stems from the desirability of source reduction as the preferred means of minimising waste. Treatment options should be considered only after acceptable waste minimisation techniques have been identified. Source reduction techniques are characterised as good operating practices, technology changes, material changes, or product changes. Recycling techniques are characterised as use/reuse techniques and resource recovery techniques.

Many waste minimisation options will be identified in a successful assessment. It is therefore necessary to identify those options that offer real potential to minimise waste and reduce costs. This screening procedure serves to eliminate suggested options that appear marginal, impractical, or inferior without a detailed and more costly feasibility study. The results of the screening activity are used to promote the successful options for technical and economic feasibility analysis. Some options may involve no capital costs and can be implemented quickly with little or no further evaluation.

Feasibility Analysis

A final set of potential waste minimisation options are sent for a feasibility analysis where technical and economical feasibility is investigated.

- Technical Evaluation

  The technical evaluation determines whether a proposed waste minimisation option will work in a specific application. Options that do not involve major equipment installation or modifications can be evaluated relatively quickly. For equipment related options or process changes, visits to see existing installations can be arranged. The technical evaluation of an option must also consider facility constraints and product requirements.

- Economic Evaluation

  The economic evaluation is carried out using standard measures of profitability, such as payback period, return on investment, and net present value. Various costs and savings are considered during the evaluation. Obvious waste minimisation options, such as installation of flow controls and good operating practices may be implemented with little or no economic evaluation. In these instances, no complicated analyses are necessary to demonstrate the advantages of adopting the selected waste minimisation options.

Implementing Waste Minimisation Options

The final phase in a waste minimisation programme involves the implementation of those options identified as being feasible. Funding needs to be obtained for options requiring capital investment.

- Obtaining Funding

  Some companies find it difficult to raise funds for options requiring capital investment. An organisation's capital resources are usually prioritised towards improving future revenues, rather than toward cutting current costs. In this situation companies can consider private sector financing and government assisted funding.

- Installation
  Waste minimisation options that involve operational, procedural, or materials changes should be implemented as soon as the potential cost savings have been determined. For options involving equipment modifications or new equipment, installation is similar to any other capital improvement project.

After the options have been implemented, it remains to be seen how effective the option is. Options that don't measure up to their original performance expectations may require modifications.

2.4.2 Drivers for, and Barriers to Implementing Waste Minimisation

There are a number of benefits of implementing waste minimisation. According the US EPA manual: International Waste Minimisation Approaches and Policies to Metal Plating (1995) the most significant benefits include,

- savings in raw materials, manufacturing costs, landfill disposal costs and treatment costs,
- helping the waste generator to comply with the legal limits,
- reducing the liability for environmental problems and worker safety,
- an improved public image, and
- improved process efficiency.

These benefits are the main drivers for companies interested in adopting waste minimisation practices.

Despite the benefits mentioned above, a number of barriers to waste minimisation still exist. The basis of these barriers lies in the attitude of the people involved. Some of the major barriers are:

- lack of awareness and technical knowledge,
- lack of management commitment,
- lack of resources, and
- fear of change.

A number of barriers to waste minimisation were discussed in Danced Draft Proposal Document for a Cleaner Production Project in South Africa (1999). These barriers can be divided into four categories, which are described below.

Awareness and Attitude Barriers

Generally, reducing environmental impact is considered by industry to imply improving effluent treatment. Industry, especially the small business sector, does not appreciate the potential of cleaner production nor do they believe its benefits. Companies are reluctant to try new practices and adopt new technologies. A lack of communication and information dissemination within industry leads to cleaner production success stories being untold.

Practical Operational Barriers at Factory Level

The adoption and implementation of waste minimisation sometimes requires changes or additions to a process that may require more space, equipment, or labour. Constraints with respect to these issues contribute to the pollution problem and prevent the adoption of waste minimisation. In addition, outdated equipment and poor maintenance leads to increased utility consumption, and the generation of unnecessary waste. The lack of motivation of shop floor employees to improve working practices can lead to an apathetic approach to operating methods.

Regulatory Barriers

The majority of metal finishing companies in South Africa discharge their effluent to sewer. This implies that the effluent must comply with effluent bylaws set by local authorities, who in turn must comply with the regulations set by the DWAF. To facilitate effluent analysis, the standards are based in concentrations. This however encourages compliance by dilution. This practice does not reduce the total load, and actually worsens the environmental impact due to increased water use.

Financial Barriers

The economic environment, especially for small and medium sized enterprises, is not favourable in the metal finishing industry. Many companies are fighting against closure. They are unable to raise capital and invest in solutions with payback periods longer than six months.

While most organisations recognise the benefits of implementing waste minimisation, they must work towards overcoming the barriers to waste minimisation in order to run an effective waste minimisation programme and thus realise the resultant benefits.

2.5 WASTE MINIMISATION CLUBS

Waste minimisation clubs (WMCs) are formed to promote waste minimisation within industry and to facilitate the exchange of information and experience among geographically close companies. The members of a club represent companies that are committed to the reduction of waste generated. The clubs may be formed by sector-specific as well cross-sector industries.

2.5.1 History of Waste Minimisation Clubs

The WMC for the metal finishing industry is a first for South African industry. A number of clubs have however been successfully established and managed in other countries. Well known examples include the PRISMA study (The Netherlands), the Aire and Calder Project (Yorkshire, United Kingdom), and Project Catalyst (Merseyside, United Kingdom). Similar concepts are also being run in India and New Zealand. These clubs are briefly described in this section.

- The Prisma Project

  The project involved ten companies from two districts, Rotterdam and Amsterdam. They represented five different industrial sectors, namely: food, chemical, metal processing, electroplating and public transport. The main aims of the project were to show that pollution prevention could be successfully implemented, and to use the results obtained to develop a pollution prevention policy. [CEST, 1995]

- The Aire and Calder Project
  The Aire and Calder project was initiated following the success of the Prisma Project. Its club members consisted of representatives from different industries including the chemical, beverage, and printing industries. The project concentrated on one river basin and aimed to reduce the volume or strength of wastewater. Site reviews were carried out by consultants who identified a number of waste minimisation options resulting in an improvement in the state of the environment and significant financial savings for the club members. A total of 3.3 million pounds was saved per annum. [CEST, 1995]

- Project Catalyst
  The Mersey River basin was the site of this project, which involved a number of manufacturers covering a range of operations. An outcome of the project was the generation of 399 waste minimisation options. The majority of these options had little or no costs associated with them. [CEST, 1995]

- India
  In India, waste minimisation circles are established. These differ from the clubs in that membership is limited to five SMEs in the same area that follow similar manufacturing processes. During the first two years of this project, 263 waste minimisation options were identified. [National Productivity Council, 1993]

The success experienced in these countries serves as a valuable lesson for South African industries that are experiencing increasing regulatory pressure with regard to their environmental impact.

While a number of clubs had been formed internationally, there was an apparent lack of published material on the methodology of managing a club. It was therefore not possible to include a theoretical methodology for the management of clubs. The development of such methodology would be useful for the further establishment of waste minimisation clubs.

2.6 MONITORING AND TARGETING

Monitoring and targeting is a management process that involves the measurement of a plant's utility and resource consumption and the generation of targets for this consumption based on the production output of the company. The process results in the reduction of utility and resource consumption and hence financial savings for the company. Plant efficiency is also greatly improved through monitoring and targeting. [Enviros March, 1999]

Montage, the software developed by the United Kingdom (UK) consulting company, Enviros March, is a management tool used to control utility and material consumption in commercial and industrial sites.

If sufficient historical data has been entered, then performance targets for utilities can be set. This is done by regression analysis on the data. A best-fit line is drawn for the utility consumption versus production output. Montage then identifies those parts of the site that are performing better than expected, and those that are underperforming. This eliminates poor procedure within a factory. Reports and graphs enable identification and analysis of the underlying causes of good and bad performance. [Enviros March, 1999] The use of a monitoring and targeting programme could thus form an integral part of a waste minimisation programme.

2.7 SMALL AND MEDIUM SIZED ENTERPRISES

In South Africa, there is a national strategy to promote and assist Small and Medium Sized Enterprises (SMEs). This strategy is contained in the White Paper on National Strategy for the Development and Promotion of Small Business in South Africa (Notice 213 of 1995).

SMEs have been defined in the National Small Business Act (No. 102 of 1996), where a small business is a term used to describe a diverse range of activities, differing in terms of size and sector. It is a distinct entity that cannot form part of a group of companies. According to the act, a small business is one employing less than 50 people, while a medium sized enterprise in the manufacturing sector has a maximum of 200 employees. This definition has been used to characterise companies involved in this project.

SMEs are acknowledged as an important part of South African economy as they provide and create jobs. There are therefore many organisations supporting these enterprises, such as the Ntsika Enterprise Promotion Agency, and the National Small Business Council. Despite their valuable contribution to a country's economy, SMEs also account for their share of pollution, waste, and other unsustainable practices. [Hillary, 2000]

According to Hillary (2000), SMEs are more likely to fail or experience stunted growth than large firms, and suffer more financial problems. Smaller businesses usually lack the human and financial resources to handle new pressures such as environmental regulations. Many smaller firms, especially in developing countries, are characterised by their use of older technologies, their lack of awareness of legislation and their own environmental impacts, and their less structured management of such issues. There are therefore potential opportunities to be derived from engaging SMEs in the drive towards sustainable development

2.8 THE METAL FINISHING INDUSTRY

Metal finishing operations are employed at some point during the manufacture of nearly all metal products. The most common of these include fabricated metal products, common machinery, electronic machinery, and household appliances.

Metal finishing companies are either captive shops or job shops. Captive shops perform finishing activities on the parts they manufacture, while job shops are a service industry that provides metal finishing for manufacturers. [US EPA, 1995] Captive shops are usually larger than job shops, and are prevalent in the automotive components industry.

2.8.1 METAL FINISHING PROCESSES

Metal Finishing comprises a broad range of processes and is performed on manufactured parts after they have been shaped, formed, forged, etc. The metal surfaces are prepared for finishing by cleaning, pickling, and dipping. A finish is any final operation applied to the metal object to alter its surface. This is done to increase corrosion or abrasion resistance, alter appearance, add hardness, or improve solderability. These characteristics can be significant for a product and could determine its quality and usefulness. Plating operations are typically carried out in batches. Processes used involve the cleaning, hardening or softening, smoothing, and conversion of the object's surface using chemicals. The metal objects are dipped into and removed from baths containing the plating solutions. In general, the metal surface treatment and plating operations can be divided into three stages, namely surface preparation, surface treatment, and post treatment. During surface preparation, the object is cleaned using solvents, detergents, and caustic solutions. Surface treatment entails the actual plating, coating, or polishing of the object, while post treatment refers to further finishing such as colouring. The processes can be either manual or automated. The level of automation will depend directly on the availability of appropriate technology and capital.

The Canning Handbook on Electroplating is a valuable source of information on metal finishing processes. The book contains detailed descriptions of all types of electroplating and other metal finishing operations. It is a useful reference for researchers as well as electroplaters. Other sources such as A Cleaner Production Manual for the Metal Finishing Industry (UNEPWG, 1998) and the US EPA (1996) guide on International Waste Minimisation Approaches and Policies to Metal Plating, also provide good descriptions of major metal finishing processes. Details of the various steps employed in a typical metal finishing operation has been included in **Appendix 6** along with descriptions of the electroplating, powder coating, anodising, and galvanising processes.

2.8.2 ENVIRONMENTAL ISSUES RELATED TO THE METAL FINISHING INDUSTRY

Metal finishing operations are a significant source of pollution. The consumption of water and chemicals by this industry is extremely high. Due to the toxic nature of the chemicals involved in treatment and the metals being coated, releasing them into the environment results in serious environmental degradation. [UNEPIE, 1996] Some of the effects are immediate whilst others are cumulative in nature and may take many years to manifest themselves. The effects include the destruction of aquatic life, the accumulation of heavy metals in the food chain and the pollution of drinking water. [UNEP, 1989] The industry is a major source of heavy metals in the wastewater, which presents a problem at the treatment works. [WRC, 1994]

A number of different stages are involved in a metal finishing operation including cleaning and pre-treatment of the metal prior to coating. There are thus a number of different chemicals involved and a number of potential hazards. Spills and careless dumping of waste or spent chemicals result in the contamination of the soil around the premises of a metal finishing concern. This leads to the contamination of ground and surface water. Waste carried in the discarded wastewater may pollute streams. The improper storage and transportation of residue containing toxic chemicals present a potential hazard to humans and the environment. The unsafe handling of process chemicals may result in workplace accidents and illness. Worker education and training is important to prevent the above problems from arising. [UNEPIE, 1996]

In the past industries have been primarily concerned with water pollution from untreated wastewater, but it has become more important to consider air emissions and soil and groundwater pollution. The disposal of treatment sludge and solid wastes is a high priority in society today. Metal finishers are finding it increasingly difficult to dispose of their sludge due to its high metal content.

2.8.3 WASTE GENERATED FROM THE INDUSTRY

The MFI generates waste that has the potential to harm humans and the environment. The most common waste streams generated by this industry and their sources are depicted in the diagram below (Figure 2.4) and discussed in detail.

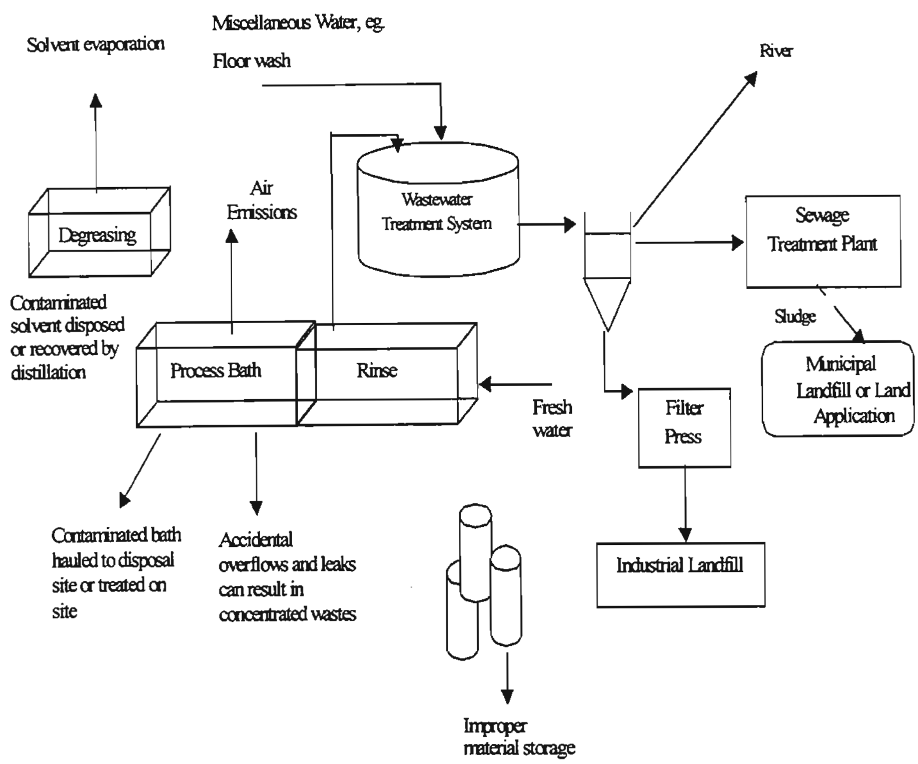

Figure 2.4: Waste Generated from a Metal Finishing Enterprise [UNEP WG, 1998]

Air Emissions

Air emissions result mainly from volatile organic compounds, which contribute to overall air pollution, and dust mists containing cyanide, acid, and ammonia. These emissions have a serious negative effect on the air quality. Emissions can be controlled by the use of wet scrubbers and carbon adsorption treatment systems. [US EPA, 1996]

Wastewater Discharged to Sewer

The primary use of water in a metal finishing shop is rinsing to dilute and wash away the chemical film of drag-out found on part and racks after processing in a chemical bath. This represents approximately 80 % of the wastewater generated by a metal finishing enterprise. Other sources include scrubber blowdown, cooling water, floorwash water, and spent baths. [US EPA, 1996]

A great deal of the chemicals used in the plating industry end up as waste due to inefficient rinsing. Wastewater discharged by the industry is highly toxic due to the high presence of cyanide and heavy metals such as copper, nickel, silver, cadmium and chromium. Heavy metals cause problems downstream at treatment plant since they are not easily removed from wastewater. They inhibit the biological treatment processes at treatment plants, thereby reducing the efficiency of the plant, and tend to accumulate in sewage sludge.

Hazardous Liquid Wastes

Acid or alkali wastes, soluble heavy metal wastes, soluble oils, and cyanide wastes are hazardous because they are either toxic or they accumulate in the environment and do not readily biodegrade. This type of waste usually requires special treatment prior to disposal.

Treatment of Wastewater

Typically, wastewater streams from metal finishing companies are segregated into cyanide bearing, chromium bearing, and acid/alkali streams. Conventional treatment systems consist of preliminary treatment of cyanide and chromium containing wastewater followed by chemical precipitation, clarification and filtration, and solids dewatering. Cyanide is most often treated using alkaline chlorinating treatment. During chromium reduction, hexavalent chromium is reduced to trivalent chromium. This is done since the hexavalent species cannot be precipitated from wastewater, while the trivalent species are readily removed. The most common method of chromium reduction is the addition of sodium metabisulphite. The wastewaters are combined and treated for metals removal, which is usually achieved by hydroxide precipitation. Once the acceptable discharge limits are reached, the wastewater can be discharged to sewer. Treatment leads to the generation of hazardous sludge, which must be disposed of in an approved landfill.

The removal of heavy metals from industrial wastewater is important since they cause problems downstream at sewage treatment plants. Heavy metals are not easily removed from effluent streams and will therefore be present in the effluent discharged to waterways leading to possible negative effects on aquatic life. [UNEP WG, 1998]

Solid Waste

Solid waste in the MFI is mainly formed from the hydroxide precipitation treatment process of wastewater. This is achieved by adjusting the pH of wastewater to reduce the solubility of the dissolved metals. The resultant metal hydroxides are then settled and removed. Mechanical or thermal methods are used to dewater the sludge thus reducing its volume. The sludge is then generally disposed of in suitable landfills.

Hazards to Human Health and the Environment

Many of the chemical substances and metals used in the MFI are hazardous. Metals are toxic to the environment if they are present in large quantities. Being metals, they cannot be metabolised, and if they enter rivers they accumulate to levels that are toxic to aquatic life. As a result, very strict standards are placed on the maximum levels of metals permitted to be discharged, and substances of particular concern are chromium and cadmium. Restrictions are placed on the cyanide content of electroplating wastewater as cyanide is considered one of the most hazardous chemicals used in electroplating.

Chromium
All forms of chromium can be toxic at high levels, but hexavalent chrome is the most toxic. Inhaling high levels of hexavalent chrome leads to damage to the nose, lungs, stomach, and intestines. Skin contact with liquids or solids containing the compound cause skin ulcers.

Hexavalent chrome is widely used in the electroplating industry because of its finishing qualities, Trivalent chromium compounds are less toxic and considered more environmentally friendly. Electroplaters are therefore encouraged to use the trivalent compounds.

Cadmium
Airborne cadmium particles can travel long distances before settling. Cadmium enters water and soil from waste disposal and spills or leaks. It binds strongly to soil particles with some dissolving in water. Breathing high levels of cadmium contaminated air leads to severe lung damage. Cadmium does not break down in the environment, but can change forms and accumulates in aquatic and terrestrial life. For humans, long term exposure to cadmium by eating contaminated food or drinking contaminated water, leads to stomach ailments. Cadmium has been known to cause nerve damage in animals.

Cyanide
There are many hazards related to cyanide and its compounds. If sodium cyanide, for example, is swallowed, inhaled or absorbed through the skin, the results could be fatal. Contact of the compound with acids liberates a poisonous gas which leads to burning of the skin, eyes, and respiratory tract. Sodium cyanide is also flammable, and is toxic to aquatic and terrestrial life. [ATSDR, 1995]

The free cyanide found in electroplating wastewater is one of the most toxic contaminants in the industry. Exposure to large amounts of all forms of cyanide can harm the brain, lungs and heart, and cause death. Consequently, there is a trend away from the use of cyanide. Much research has been undertaken into the development of a non-cyanide process.

2.9 WASTE MINIMISATION IN THE METAL FINISHING INDUSTRY

The concept of waste minimisation, and the methodology of waste minimisation assessments was discussed in section 2.4, while aspects of the metal finishing industry were covered in section 2.8. Since the predominant environmental problems associated with the metal finishing industry has been explained, and the benefits of implementing waste minimisation stated, the potential for implementing waste minimisation in the industry is evident. A number of manuals have been specifically produced to assist the metal finishing industry in identifying suitable waste minimisation options. The UNEPIE Guide, Environmental Aspects of the Metal Finishing Industry: A Technical Guide, the US EPA Waste Minimisation Opportunity Assessment Manual (1986) and the UNEP's Working Group's, A Cleaner Production Manual for the Metal Finishing Industry

(1998), present a comprehensive set of options available to the metal finishing industry to aid in reducing waste. The possible solutions for reducing wastes from this industry are described in this section.

For a metal finishing enterprise the following considerations are important in pollution control [UNEPIE,1996]:

- the use of low and non -waste production technology,
- proper treatment of waste,
- competent operation and maintenance of the above, and
- the education and training of workers.

General waste minimisation in the metal finishing industry involves developing options to reduce rinse water consumption, recycling of rinse waters, extending the life of solutions and plating baths, and avoiding spills and overflows. The economic gains achieved are accompanied by environmental gains. The reduction of harmful effluents can be achieved by reducing effluent volume or its strength or both. By producing less effluent, it implies lower treatment costs.

In order for metal finishers to reduce the concentration of pollutant in their effluent, they may consider the following options [UNEPIE, 1996]:

- recycling spent solutions to reduce loss of chemicals,
- improving maintenance of baths to increase their service life,
- avoiding the use of toxic chemicals,
- adopting alternative processes that require lower concentrations of chemicals,
- preventing spills,
- reducing dragout into rinse tanks, and
- preventing contamination of the bath.

Some waste minimisation options will require an initial investment, but the environmental and economic benefits usually justify this investment. The situation at a metal finishing enterprise needs to be evaluated before waste minimisation measures can be selected. The evaluation covers the consumption of process chemicals water and energy; assessment of the production methods and wastewater treatment and disposal.

The various waste minimisation techniques that may be employed at a metal finishing enterprise are described in detail below.

2.9.1 Product and Input Material Changes

Metal finishers have numerous opportunities for source reduction including design of new products, product changes, and input material changes.

Product Changes

Product changes (changes in the composition or use of the intermediate or end products) can be implemented to reduce the use of hazardous materials during finishing. The manufacturer is usually responsible for product changes because they have control over the design and specifications of the product. Some job shops do provide customer education for part modification and design. [UNEP WG, 1998]

Input Material Changes

The most important changes made regarding input materials focus on chlorinated solvents, cyanide, and cadmium.

Alternative cleaners containing non-chlorinated materials are preferred in metal finishing operations. New cleaners are available which allow light oils to float, enabling its removal from the cleaner's surface, thus extending the life of the cleaner.

Cyanide-containing plating baths pose a problem in terms of pollution control. There is thus an effort to implement cyanide-free plating processes. Zinc cyanide plating has been successfully replaced with zinc chloride and zinc alkaline plating. The elimination of cyanide also eliminates the need to chlorinate the cyanide during treatment, thus improving treatment efficiency.

The most successful alternative to cadmium plating has been zinc-nickel plating, which offers sufficient corrosion resistance as determined by cadmium plating. [USEPA, 1986]

2.9.2 General Waste Reduction Techniques

General waste reduction techniques lead to an overall improvement in the operating conditions of a metal finishing enterprise.

General Housekeeping

Improved housekeeping is the simplest way to reduce pollution and is usually achieved without the purchase of additional equipment. Operating costs are also reduced through improved housekeeping.

- Workshop Tidiness

  Keeping the workplace clean and free of clutter reduces the risk of accidents and damage to stock or equipment. It ensures smooth workflow thereby improving efficiency.

- Preventative Maintenance

  Leaks in pipes and equipment results in losses of resources. Preventative maintenance minimises leaks and spills, and should be supplemented on a regular basis.

- Spill Prevention and Control

The best way to prevent spills is to train staff about the proper handling of materials, and provide clear procedures for mixing chemicals. Drain boards or splash guards should be used on tanks to direct drainage back into process baths.

Production Planning

Process layouts can have a significant effect on waste generation. Streamlining a process by placing baths as close to each other as possible, reduces processing time and dripping onto the floors. The installation of overhead racks enables control over drain times and rinse cycles, often reducing the amount of drag-out.

Cleaning and Pre-treatment

The cleaning of objects in electroplating process is carried out in caustic or acidic solutions. These solutions have a limited life and are usually dumped after a certain time. As a result, acid and alkali wastes account for a large volume of liquid waste generated from the MFI. It is therefore worthwhile to investigate ways to extend the life of these cleaning solutions.

- Extending the Life of Cleaning Solutions

  The cleaning process produces a sludge, which collects in the cleaning tank. This sludge builds up until it renders the cleaning solution ineffective. The bath is then dumped and replaced. Filtering the solutions to remove the sludge and then adding fresh solution to the tank can increase the life of the bath.

- Ultrasonic Cleaning

  Ultrasonic cleaning can achieve high levels of cleanliness for metal surfaces, and has the ability to remove extremely small particles. It does have the disadvantage of being very expensive and therefore not a feasible economic option for most electroplaters.

Control of Bath Conditions

Bath conditions can be maintained at optimum levels by proper maintenance and control. This will improve efficiency and reduce wastage. Process control can be achieved by using sensors to control process temperature, pH, flow rates, and contamination levels.

- Concentration of Chemicals

  Most retail plates tend to overdose plating baths. This leads to increased wastage of chemicals, as well as effluent problems. Baths should be maintained at the minimum chemical concentration to achieve necessary product quality. Chemical suppliers should not be relied on for bath monitoring as companies should undertake this on their own.

- Reduce Heat and Vapour Loss

  The loss of heat and vapour from tanks can be reduced by insulating heated tanks to minimise heat loss, using floating balls to reduce heat loss from solution surfaces, and using chemical mist suppressants to prevent vapour loss.

- Preventing Contamination of Plating Solutions

  The build up of contaminants in plating baths reduces the efficiency of the bath solutions. Contaminants can be effectively removed by filtration and electrowinning. The use of deionised water reduces the build-up of contaminants since it does not contain ions of calcium, iron, magnesium and manganese, which are present in tap water. [UNEP WG, 1998]

Improved Operating Procedures

- Employee education

  Employee awareness and education is an essential part of any company's overall environmental programme. Waste minimisation at source, routine process chemistry additions and sample-taking, and handling of spills and leaks should be included in employee training.

- Chemical Tracking

  A record should be kept of chemical purchases, inventory, bath analyses, chemical additions, and water usage. This data can be used to determine areas of losses and serves as an indication of the success of a waste minimisation programme. Controlling the purchasing and handling of materials can significantly reduce waste generation. Materials should be stored in a locked space with limited employee access. Standard mixing procedures for chemicals should be developed to reduce spills, provide correctly mixed baths, and ensure that baths are operated at the lowest possible concentration to minimise dragout losses.

[US EPA, 1986]

2.9.3 Reducing Dragout

Drag-out of process fluid into rinse water is a major source of pollution. Reduction of dragout not only reduces the mass of pollutants reaching the wastewater stream but also reduces the amount of chemical loss suffered by the process. Most of the reduction techniques require only operator training or small process changes, therefore the cost savings are realised quickly. These techniques are described below. [UNEP WG, 1998]

- Plating solution control

  Reducing the viscosity of plating solutions decreases the drag-out between baths. This is achieved by operating either at the lowest possible concentration, or the highest possible temperature.

- Positioning parts on racks

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

  Proper positioning of parts can be important for dragout reduction. The best position is determined by experimentation.

- Drain Boards
  Drain boards suspended between process tanks are widely used to capture plating solutions and allow them to drain back into their processing tanks.

- Wetting Agents
  Surfactants and other wetting agents can help reduce dragout by as much as 50 %, by reducing surface tension of the solution.

- Withdrawal rates and drainage
  The speed with which the object is withdrawn from the plating bath is a critical factor in determining the quantity of drag-out. The faster an item is removed from the bath, the thicker is the film on the work piece and the greater the dragout volume. Maximising drip time and using drip shields to capture and return dragout are successful methods of reducing dragout.

2.9.4 Optimising Rinsing

Reducing water usage offers several benefits including reduced water costs, higher waste treatment efficiency, and reduction in the use of treatment chemicals. The best system is achieved by obtaining a compromise between obtaining acceptable rinse efficiency, and using the minimum amount of water. The most effective rinse water reduction techniques are discussed below.

- Tank design
  Tanks should be sized to accommodate rinsing of the largest objects. Inlet and outlet points should be at opposite sides of the tank. Water consumption can also be improved by optimising the rinsing quality of the baths. Agitation of the rinse water or agitation of work pieces during rinsing can achieve this.

- Flow Controls
  Flow through the rinse tanks should be closely monitored and/or controlled. The simplest way to achieve this is to turn off the water to rinse tanks when they are not in use. However, this is usually not feasible. It is relatively easy to install flow restrictors to regulate flow. Variable flows are controlled by automated metering systems that operate either based on preset flows, or are controlled by conductivity sensors. These sensors measure the concentration of contaminants in the rinse water, and adjust the flow accordingly. Flow restrictors can be installed to regulate flow. A conductivity controller can be installed to regulate flow based on rinse water conductivity.

- Rinsing Configuration
  Counterflowing rinse series are more efficient than a simple overflow rinse, and consists of a series of tanks where fresh water enters the tank furthest from the process tank and overflows to the next tank in the opposite direction to the workflow. A multistage counter-current rinse system uses up to 90 % less water than a conventional single-stage rinse system.

- Spray Rinsing and Fog Sprays

  Spray nozzles are used to spray rinse water onto work pieces as it drains above the process tank. Fog sprays are a variation of spray rinsing, and combines the water spray with air pressure to produce a fine water mist. The fog captures the chemicals and returns it to the process bath.

- Static and Running Rinses

  In smaller electroplating plants, static rinses are adequate in order to achieve effective rinsing. Plants with higher production throughput usually use overflowing rinses, where a constant feed of water is supplied to the tank to keep the contaminant concentration low. [UNEP WG, 1998]

2.9.5 Techniques for Rinse Water Reuse and Metal Recovery

Treated effluent water can be recycled to non-critical processes such as rinsing, cleaning or floor cleaning. Treating and recycling wastes to reclaim water or recover metals usually requires capital investment in treatment systems. [UNEP WG, 1998]

- Reverse Osmosis

  In this process, a high pressure is used to force liquid through a membrane that is impermeable to most dissolved salts. A purified waste stream is produced, suitable for reuse.

- Ion Exchange

  Positive and negative charged metal and chemical ions are removed from solution by passing the rinse water through resin beds. Once the bed reaches its capacity, the metals are recovered in concentrated solution and the resin is regenerated for reuse.

2.9.6 Alternative Processes

Metal finishing companies are encouraged to use alternative, less harmful processes. Alternatives for the most widely used processes are described below.

- Non-Cyanide plating systems

  Cyanide is widely used in the plating industry, but due to its high toxicity effluent containing cyanide requires additional chemical treatment prior to discharge. The replacement of the cyanide process has been most successful in zinc plating, where there has been the introduction of zinc chloride and zinc alkaline systems. Non-cyanide substitutes are also available for cadmium, silver and gold, but produces significantly inferior deposits. By eliminating the cyanide, the need to chlorinate it as treatment is also eliminated.

- Replacing Hexavalent Chromium with Trivalent Chromium

  Using hexavalent chrome instead of trivalent chrome has a number of advantages. It firstly eliminates the health risk brought about by exposure. Less sludge is created when using trivalent chrome and drag-out volumes are reduced due to the solutions being less viscous.

- Replacing Cadmium

  Common alternatives to cadmium plating include zinc-plating, tin or tin alloy plating, cobalt-zinc plating, zinc-nickel plating, and zinc-iron plating. The most successful of these has been zinc-nickel plating. In order for alternatives to be successful, they must provide sufficient corrosion resistance, and meet the desired characteristics expected from consumers. [UNEP WG, 1998]

CHAPTER 3 – THE METAL FINISHING WASTE MINIMISATION CLUB

As regulations become tighter, and the costs of waste treatment and disposal increase, business will have much to gain from adopting cleaner production practices – UNEP WG, 1999

Durban is a city situated on the east coast of Africa as indicated in Figure 3.1. Durban is a major gateway to Africa and is also the largest and busiest port city on the continent. The Durban Metropolitan Area (DMA) is the largest urban area in the province of KwaZulu-Natal and extends from Tongaat (North) to Amanzimtoti (South) to Cato Ridge (West). [Hindson et al, 1996]

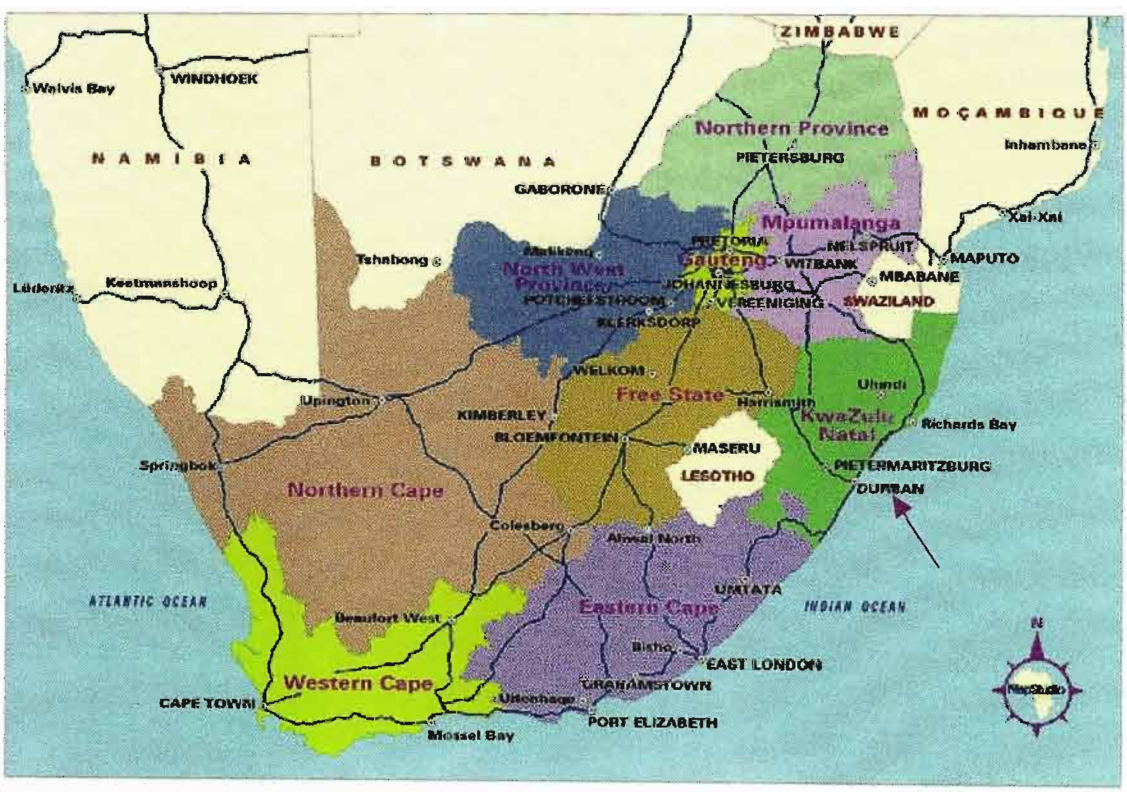

Figure 3.1 Map of South Africa

The DMA has a large and diversified economy with strong manufacturing, tourism, transportation, finance and government sectors. The DMA also has a dynamic and growing small and micro business sector. In the past, industrial growth has occurred with few environmental controls, creating a legacy of degraded living environments particularly in the industrial heartland of the Durban South Basin. Economic activity has had significant negative impacts on the DMA's natural environment resulting in air, soil and water pollution, high noise levels and loss of biodiversity and cultural resources. [Hindson et al, 1996]

It is therefore important to recognise the importance of managing the environmental impacts of economic activity so that it has minimal negative impact on the environment and aquatic and terrestrial life.

3.1 THE SOUTH AFRICAN METAL FINISHING INDUSTRY

The metal finishing industry in South Africa is widespread and diverse. It includes galvanising, electroplating, painting, and a wide range of machining processes. [Danced, 1999] Due to a lack of quantitative data on the industry in South Africa, Naumann (2000) conducted an economic analysis of the industry. He found that the majority of metal finishers in SA are located in the Gauteng area, followed by Cape Town and Durban. It is estimated that there are more than 500 electroplaters and approximately thirty galvanisers in the country. The industry has a low skill requirement for its workers, and is therefore a medium/low wage employer. However, the directly employed workforce has been declining significantly, implying that the metal finishing industry has not been creating jobs.

The University of Cape Town as part of their Industrial Symbiosis project also conducted a survey of the South African metal finishing industry. The survey resulted in the compilation of a database of South African metal finishing companies, containing information on location, size, products, and processes. The database contains the names of 316 metal finishing companies in South Africa. Of these, 217 were surveyed. The results of the survey showed that 88 % of the companies were small and medium sized enterprises (SMEs) made up of job (48 %) and captive (40 %) shops. Electroplaters represent the largest proportion of the industry with 42 % of the industry being electroplaters. Within electroplating companies, the most common types of plating were zinc, nickel, and copper [Janisch, 2000].

Most enterprises within the metal finishing industry are SMEs, and therefore are generally not as technologically advanced or environmentally conscious as the larger companies. The difficulties experienced by the SMEs contributes strongly to the decline in output from the metal finishing industry that has been occurring [Naumann, 2000]. Often in small job shops, the owner is responsible for a multitude of administrative and production tasks. There is little time for training the workforce. Often the managers themselves are not sufficiently knowledgeable to provide skilled supervision, and a number of companies rely on chemical suppliers for technical knowledge and expertise. [Danced, 1999]. The industry is regulated by the Departments of Environmental

Affairs and Tourism and Water Affairs and Forestry at national level, the Department of Agriculture and Environmental Affairs at provincial level, and municipal authorities at a local level.

3.2 CHALLENGES FACING THE METAL FINISHING INDUSTRY

Metal finishing enterprises in South Africa are exposed to world prices and international currency fluctuations, especially in terms of imported chemicals and metals that are linked to the world price. The cost of water and electricity to the industry is relatively low at present, but water prices are expected to rise due to the country's impending water shortage.

The Metal Finishing Industry has been determined to be the fourth most polluting industry in South Africa, and is a major industrial source of heavy metals in wastewater. The waste generated from the industry has been found to be hazardous to the environment and humans. This emanates from the fact that the raw materials used are usually highly toxic, flammable, and the acid and alkali solutions used in the processes are both corrosive and reactive [Nauman, 2000].

The diverse and intermittent discharges of heavy metals from SME metal finishing operations have a potentially detrimental effect on the operation of sewage treatment works and impact negatively on down stream water users [WRC, 1994]. Thus, the metal finishing industry has been targeted by regulators and is therefore faced with stringent environmental legislation. The new Water Act (Act 36 of 1998) and the Water Services Act (Act 108 of 1997) place industry under obligation to prevent water pollution from occurring. Local authorities are responsible for regulating and monitoring waste disposal and the discharge of effluent into the sewerage systems. The metal content of metal finishing effluent and sludge is of particular concern, and has led to local authorities searching for methods of alleviating the problem. Durban's metal finishers are now being regulated by stricter effluent bylaws and are required to reduce effluent heavy metal content to 20 mg/L. Table 3.1 shows the heavy metal limits for the DMA, published in February 1999.

Table 3.1: General Quality Limits for Heavy Metals in the DMA

Heavy Metal		Concentration (mg/L) Large Works (>25 ML/d)	Small Works (<25 ML/d)
Copper	(Cu)	50	5
Nickel	(Ni)	50	5
Zinc	(Zn)	50	5
Iron	(Fe)	50	5
Boron	(B)	50	5
Selenium	(Se)	50	5
Manganese	(Mn)	50	5
Lead	(Pb)	50	5
Cadmium	(Cd)	20	5
Mercury	(Hg)	20	5
Total Chrome	(Cr)	1	1
Arsenic	(As)	20	5
Titanium	(Ti)	20	5
Cobalt	(Co)	20	5
Total Metals		**100**	**20**

Source: Durban Sewage Disposal Bylaws, Dept of Wastewater Management [February 1999]

The industry in the DMA faced a problem with sludge disposal, as there was no suitable hazardous waste disposal site in the province of KwaZulu-Natal for metal finishing waste. The DMA has six operational landfill sites of which four are general waste sites and two are low hazard co-disposal sites. At the time of this study (1999), metal finishing sludge could not be disposed of at low hazard waste disposal sites. Companies were forced to transport their sludge to disposal sites in Gauteng and Port Elizabeth. This practice was extremely costly, and risky, as the companies were still responsible for their waste while it was being transported. The companies who couldnot afford to transport their sludge stored it on their premises.

Poor disposal of waste in some areas of the DMA has had significant negative impacts on many aspects of the natural environment, as well as negatively impacting on the health of some communities and tourism. The Durban Metropolitan Council (Metro) is therefore actively involved in promoting integrated waste management for the metropolitan area. This includes promoting recycling and waste minimisation where feasible, identifying safe sites for future land disposal and improving management of existing landfill sites. The new Durban Metropolitan Environmental Policy (1998) set out a range of objectives to address the metropolitan area's waste management issues in the future. This is supported by new national and provincial policy in promoting an integrated approach to waste management. [Hindson et al, 1996]

Due to the high volumes of water consumed by the metal finishing industry (mainly for rinsing purposes) there is a corresponding high effluent production. Costs of treating and disposing of this effluent are high.

These issues emphasise the need for the metal finishing industry to adopt waste minimisation as a technique to reduce environmental impact, comply with regulations, and reduce costs. However due to a lack of awareness on the subject, it was not considered by the industry. Based on the above problems, it was evident that the metal finishing industry was an ideal candidate for the establishment of a club. The Pollution Research Group based at the University of Natal in Durban thus submitted a proposal for the investigation of the feasibility of establishing waste minimisation clubs in South Africa, and thus initiated this project to investigate the establishment of a waste minimisation club in the metal finishing area. The DMA was considered the most suitable area to initiate such a project due to its location and inherent environmental problems.

3.3 ESTABLISHMENT OF THE METAL FINISHING WASTE MINIMISATION CLUB

The Metal Finishing Waste Minimisation Club (WMC) was established in the DMA in June 1998 as a result of a meeting between the local government authority and 81 representatives of the local metal finishing industry. The meeting was held to introduce new municipal bylaws for the DMA. The opportunity was taken at this meeting for the purpose of introducing the concept of waste minimisation to the metal finishing industry, and proposing the establishment of a club for this industry. The lack of awareness on the topic was evident during the meeting. Companies were very sceptical about the potential benefits of waste minimisation, and were concerned with the announcement of the new bylaws. Forms were handed out to companies to determine their interest in forming a club. The response was poor, but interested companies were invited to a further meeting where the definition and benefits of a waste minimisation club were discussed, and the method of management developed. This meeting was attended by twenty-nine companies, the local authorities, and service providers such as chemical suppliers, who were considered interested parties. It was agreed that waste minimisation club activities would be coordinated and managed by the project leader, who would also be responsible for education and training as well as the initial waste audits.

3.4 PROFILE OF CLUB MEMBERS

Twenty-nine companies subsequently formed the waste minimisation club for the metal finishing industry with the main objectives of implementing waste minimisation programmes and reducing waste at source. The greatest concentration of members was in the Pinetown area, which is in the Inner West Region of the DMA (see Figure 3.2). Of the twenty-nine companies, twenty-one were electroplaters, five powdercoaters, and two hot dip galvanisers.

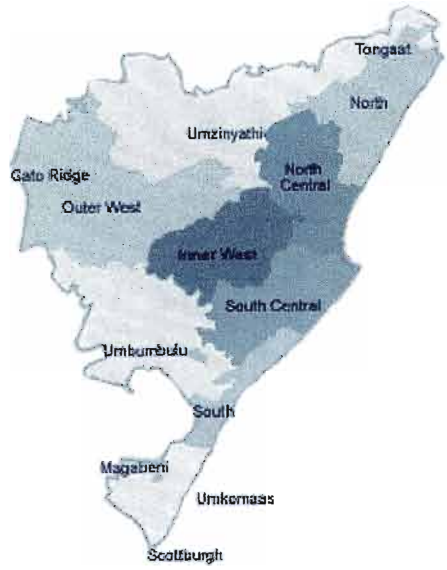

Figure 3.2: Map of the Durban Metropolitan Area

The companies were classified according to number of employees, and it was found that 90 % of the club members were SMEs (having less than 200 employees) and over 50 % had less than 50 employees. These statistics are presented in Table 3.2.

Table 3.2: Employee Statistics of Club Members

Number of Employees	Number of Companies	
	Number	%
<10	4	14
10 to 20	8	28
20 to 50	5	17
50 to 200	9	31
>200	3	10

The majority of the companies (60 %) were job shops, implying that metal finishing is their primary concern and they provide a service to manufacturers of fabricated metal objects and the public. The remaining companies conduct metal finishing operations on site as part of their manufacturing process. To these companies, the metal finishing process is not of primary concern.

3.5 INITIAL ASSESSMENTS

Following the successful establishment of the club, the next step was to introduce waste minimisation assessments to the club members and conduct initial assessments. Due to the large number of companies, it was not possible to personally conduct each assessment. Therefore 22 senior engineering students (chemical and electrical) were recruited in July 1998 to undertake initial waste minimisation audits in each factory. Each company that agreed to be assessed at the time was assigned a student who was expected to conduct their assessments during normal factory hours. Thus students initially assessed twenty-two companies.

Prior to entering the factories, the students were given training I n waste minimisation and procedures of conducting waste minimisation audits. Specific waste minimisation techniques applicable to the metal finishing industry were discussed in detail. Students were supplied with the EPA and UNEP waste minimisation guides, and were expected to follow use EPA self-assessment worksheets as a guide for their assessments.

The club members were also invited to attend these lectures. Four members attended. Two club members also lectured the students on metal finishing operations, and provided valuable practical insight to the processes. These talks gave the students an idea of what to expect in a typical metal finishing factory.

Most of the students spent between four to six weeks at the companies observing processes, collecting data, conducting measurements, and identifying areas where waste was being generated. The assessment methodology contained in the EPA waste minimisation manual was followed closely during the investigations. This guide along with the UNEP guide provided the students with a number of possible waste minimisation suggestions for common waste problems in the metal finishing industry. Basic information required by students included:

- a factory floor plan,
- process flow diagrams,
- data on chemical and utility consumption,
- information on effluent treatment, and
- cost and method of waste disposal.

Weekly meetings were held with students to discuss progress at factories and any problems experienced. Common areas of concern were raised, and attempts were made to find solutions.

Waste minimisation assessment reports were prepared for twenty-two companies (companies E to Z) by the students, where areas of waste were identified and quantified. Waste minimisation options were suggested, and the possible savings resulting from the implementation of these suggestions, quantified. A compilation of the students' reports for companies E to Z is presented in **Appendix 1**. Companies A to D have been investigated in detail and are presented as case studies (see section 3.14). Thus twenty-six club members were assessed during the project. The remaining three companies did have the time to facilitate a waste minimisation assessment at their establishments. Due to the requirement for confidentiality, the company names have not been used.

Student involvement ended in August 1998. Companies then formed waste minimisation teams headed by a project champion from the company and continued with waste minimisation programme activities. Regular feedback was obtained during club meetings. In addition, contact was maintained with all participating companies in between meetings, and assistance was provided when requested.

3.6 CLUB MEETINGS AND TRAINING

An important aspect of managing a waste minimisation club is to hold regular club meetings. Initially metal finishing club meetings were held every three months, but at the request of club members this was increased to bimonthly. The meetings were attended by each company's project champion/s. Regular meetings allowed the club's facilitators to update the members on important waste minimisation issues and developments, and to obtain feedback from members. Members were required to report back on waste minimisation activities and progress made within their companies. The quantification of any savings resulting from the implementation of waste minimisation options was encouraged. Meetings also served as a forum for members to discuss problems being experienced by the companies. A collective solution was sometimes found to common problems.

Guest speakers were also invited to meetings to give presentations on important issues for the industry. Presentations on waste classification, filtration, pollution liability, worker training, government funding initiatives, benchmarking studies, and health and safety aspects related to waste minimisation were presented. Additional meetings and site visits were arranged whenever necessary. Since the establishment of the club, site visits to landfill sites and a club member's factory site were undertaken. Waste minimisation training modules were presented to the club members by a consultant from Enviros March on a regular basis. These modules covered the basics of waste minimisation, as well as the more detailed aspects of maintaining a waste minimisation programme, thus enabling club members to continue with waste minimisation activities at their sites. Most sessions were interactive, where companies would either form groups or work individually to solve typical problems related to waste generation. This consultant had also visited selected member factory sites to conduct energy audits. Energy consumption was not high in this industry and there was not great potential for energy savings. Therefore these audits were not carried out in detail.

During meetings, members were also made aware of additional sources of information on waste minimisation such as pamphlets, guidelines, manuals, and videos. These sources were usually made available to members at the cost of copying.

3.7 CLUB CONSTITUTION

As discussed in **Chapter 2** section 2.4, the first step in setting up a waste minimisation programme at a company is to obtain commitment to waste minimisation from management. This step is essential, as management approval will be required for any time or money spent on waste minimisation activities. All members were therefore required to sign a declaration of commitment that contains the goals of the club. The main goal of the declaration was a commitment by members to implementing a waste minimisation programme.

The declaration of commitment requires that the member company shows commitment to:

- implementing a programme of waste minimisation,
- reducing all sources of waste (liquid, solid, energy, gaseous),
- continual improvement,
- establishing a monitoring programme,
- reducing environmental impact,
- sharing information with other club members, and
- regular attendance at club meetings.

It was also considered beneficial for the club to have a constitution. A constitution adds value to a club, constitutes it as an organisation, and gives it a legal standing and a more powerful voice. Therefore a draft constitution was prepared for the club based on the declaration of commitment. The draft was distributed to all members for comments and suggestions. Club members reviewed the draft and decided to have it formalised as their constitution. However due to the pending formation of an association for metal finishers (discussed in detail in **Chapter 5**, section 5.11), and the dissolution of the club, club members opted to rather adopt the constitution for the association since the club's lifespan was limited and waste minimisation would be continued as part of the activities of the association.

3.8 FOLLOW-UP SITE VISITS

In addition to the site visits conducted while conducting the waste minimisation assessments, follow-up site visits were conducted during the course of 1999 and 2000 at member companies. The purpose of these visits was to acquire first hand knowledge on each company, get an idea of the extent to which the company had adopted waste minimisation, and to provide further assistance. Brief site inspections were conducted to become familiar with processes and operating practices. The inspections were carried out in conjunction with the company's project champion. Thus it was possible to immediately point out areas of concern and suggest further options for improvements. Discussions with the owner/manager on the company's progress with waste minimisation (or lack thereof) also took place. Information on options implemented and savings achieved were recorded during these visits. The observations and results are given in **Chapter 5**, section 5.2.

3.9 DATABASE

A database for the metal finishing waste minimisation club was created. This database contained company information, such as location, age, size, type of operation, number of employees, major processes carried out, major metals plated, utility consumption and costs, as well as any waste minimisation options implemented and savings achieved. Information from assessment reports, minutes of meetings, site visits, and surveys were used to create the database, which was updated whenever new information became available.

3.10 IDENTIFICATION OF BARRIERS AND DRIVERS

An important by-product of establishing the waste minimisation club was the identification of barriers to and drivers for the implementation of waste minimisation within the metal finishing industry. Based on a survey conducted of the members of three waste minimisation clubs in the United Kingdom, certain barriers and drivers to implementing waste minimisation were identified. At the recruitment meeting, these barriers and drivers were listed for the companies present and placed on sheets of paper and stuck on the walls in the hall. Attendees were then asked to identify barriers and drivers. This was done in the form of votes, where each person was given three stickers to place on those barriers / drivers that they felt were of the greatest importance. Industries, regulators (e.g. Durban Metro), service providers (e.g. chemical suppliers) and others (e.g. University) were given different colours in order that their views could be differentiated. The results are given in **Appendix 2** and discussed in **Chapter 5**, section 5.4. During follow-up site visits and interviews with club members, the barriers and drivers for club members since the establishment of the club were also determined.

3.11 SURVEYS

In March 1999, a questionnaire was compiled to gauge the views of the club members on the waste minimisation club, waste minimisation in general, and their reasons for joining the club. Sixteen companies were interviewed. These companies covered the active club members and those who were less involved in club activities. The interviews were conducted telephonically, and the results are given in **Chapter 5**, section 5.5. A copy of the questionnaire along with member's responses is included in **Appendix 4**.

A second survey was conducted between February and June 2000. The second questionnaire was prepared to ascertain the level of knowledge possessed by club members on waste minimisation, their opinions on the club and its management, and their idea of what was beneficial to them. This survey was conducted personally by interviewing each company's project champion during site visits. The questionnaire included aspects such as the relationship between members and between members and the local authority, member views on the club, and their motives for joining the club. Copies of these questionnaires are included in **Appendix 4**.

3.12 NEWSLETTER

In order, to disseminate information among club members and to inform other interested parties (other metal finishers, authorities, and research institutions) of the success of the metal finishing club, it was decided to compile a club newsletter. The newsletter helps to create awareness on environmental issues, and promotes waste minimisation as an effective tool for sustainable business. The first edition of the newsletter was released in February 2000, and contained articles on the establishment of the club, the people involved, and the progress made. Club members were contacted to provide comments and suggestions, and two members (a chemical supplier and an electroplater) contributed articles regarding their views on the club and its success. Two further editions of the newsletter were released. These contained the latest issues of interest to metal finishers as well as a case study of the successful adoption of waste minimisation at a club members company.

3.13 MONITORING AND TARGETING

The concept of monitoring and targeting was introduced and explained in **Chapter 2**, section 2.6. The monitoring and targeting software, Montage was used to set up two company's sites for a monitoring and targeting programme. The sites' details were entered into the program, and the departments for which data were available were set up. The companies were requested to provide weekly water and chemical consumption data for each department, and the corresponding weekly production data. The results of this effort are discussed in **Chapter** 5 section 5.10.

3.14 CASE STUDIES

Since it was not possible to pay detailed attention to all twenty-nine club members, it was decided to concentrate on four companies (A to D) and produce them as case studies. The companies were chosen to represent the different types of metal finishing club members, and to show the level of commitment by different sizes of companies. There were different levels of involvement with each of the companies based on the advancement of their waste minimisation programmes.

The procedure followed in conducting assessments at these companies was adapted from the US EPA waste minimisation guide and is described in **Chapter 4** along with a presentation of the case studies.

3.15 EXTERNAL ASSISTANCE

The project was funded by the Water Research Commission (WRC) of South Africa, and co-funded by the European Union Directorate General XVII for Energy (Thermie). In addition, South Africa has been fortunate to receive external assistance in terms of finance and expertise from Denmark for projects concerned with pollution prevention. The Danish Cooperation for Environmental Development (Danced) has funded cleaner production projects in the fishing and textile industries, and has had some involvement with the metal finishers club. The assistance obtained will be discussed in this section.

3.15.1 Danced Technical Study Tour

In September 1998, a study tour to Denmark was sponsored by Danced, with the objective of transferring Danish knowledge on waste minimisation. Members of the tour included the head of the Pollution Research Group, a metal finishing club member, and a WRC research manager involved in this project. Visits to metal finishing and textile factories were arranged.

The metal finisher gave a presentation regarding the tour, to the club members upon his return. This was an informative and detailed account of his experiences and observations regarding the metal finishing companies that he visited. He mentioned that his attitude towards waste minimisation changed during his trip when he noticed that the Danish Metal Finishers achieved vast savings by running their processes more efficiently. The benefits of using drag-out tanks and counter-flow rinsing were explained to the club members. By implementing simple waste minimisation techniques he has reduced his water consumption by 75 %. He presented a similar talk to the Metal Finishers in the Pietermaritzburg area. His enthusiasm was instrumental in getting the other club members to change their way of thinking and to begin implementing waste minimisation options.

3.15.2 Students

Two students from the Danish Technical University became involved in the project during 1999. They were initially based at a member's factory where they assisted with the waste minimisation programme.

3.15.3 European Union

The European Union through its Directorate XVII for Energy (Thermie), has supported the waste minimisation club project in terms of funding and expertise in the form of consultants. Thermie's involvement enabled the input of Enviros March Consultants, who conducted waste minimisation assessment training sessions and energy audits. The monitoring and targeting software Montage was also made available to the project by Enviros March.

3.16 SUMMARY

The metal finishing industry in the DMA contributes substantially to the pollution load and was under pressure to reduce this load and improve environmental performance. This sector was chosen to be part of the pilot project run by the Pollution Research Group to establish waste minimisation clubs. A waste minimisation club was formed consisting of twenty-nine metal finishing companies. Waste minimisation audits were conducted at twenty-six member companies, and waste minimisation options were identified. The club ran from June 1998 to November 2000. Four companies were investigated in detail with regard to waste minimisation programmes. These results are presented in **Chapter 4** and the overall project results in **Chapter 5**.

CHAPTER 4 – CASE STUDIES

Small and medium sized enterprises appear to be less involved in cleaner production than large enterprises, and are targeted by cleaner production programmes – Aquatech, 1997

As discussed in **Chapter 3** section 3.14, four companies were investigated in detail and form the case studies that are presented in this chapter. This was done to demonstrate the benefits of waste minimisation and compare the results achieved in different companies with different structures and processes.

Brief descriptions of each company are given, followed by the results achieved from implementing waste minimisation programmes. The results discussed are from the period June 1998 to November 2000. Detailed reports on each company can be found in **Appendix 3**.

4.1 METHODOLOGY

The methodology followed in conducting assessments at these companies was adapted from the US EPA Waste Minimisation Guide [1995] and is described below.

4.1.1 Obtaining Management Commitment

As mentioned in **Chapter 2**, the commitment of senior management to waste minimisation is essential for the successful running of a waste minimisation programme. As such a declaration of commitment was signed by the management of each of the four companies.

4.1.2 Electing the Project Champion

The project champion is responsible for promoting waste minimisation within the company, and co-ordinating waste minimisation activities. This person must possess a good understanding of the processes occurring in the company, and must have sufficient authority to delegate responsibility. The project champions of the four companies were nominated when the club was initiated.

4.1.3. Assessment

A preliminary assessment was completed at each company. The purpose of the assessment was to conduct site visits, collect and compile data, and identify the origin and causes of wastes. Data collection formed the major task of this phase. Information on utility consumption, types and quantities of raw materials, and waste streams, were compiled.

Water and chemical consumption and effluent generation were targeted as the main areas to be investigated in detail. Other aspects concentrated on included rinsing configurations, process layout, and health and safety issues. The steps followed and the areas investigated are discussed in more detail below.

Water Consumption

The main water meter for the factory was located and if the company did not already monitor its water consumption, the practice was initiated. Water meter readings were taken to ensure that the company was being charged for the correct amount consumed, and to monitor consumption so that changes in consumption patterns could be noticed immediately. Records of the company's water bills were obtained to determine the average monthly consumption and cost.

Taps, pipes and rinse tanks were checked for leaks during the site inspection. Since water is used mainly for rinsing purposes, methods of rinsing and the arrangements of rinse tanks were given specific attention.

Rinsing

Metal finishing operations require efficient rinsing of jobs to ensure effective plating. This generally leads to excessive volumes of water being used in rinsing tanks. Rinsing operations were investigated with respect to type of rinse (static, overflowing, or spray), rinsing configuration (single, counterflow, or cascade), and the use if any of dragout tanks. The flowrates of overflowing rinses were determined using a container of known volume and a stopwatch.

Chemical Consumption

The types, quantities, and costs of chemicals associated with the process were determined. Average monthly costs and consumption of chemicals were obtained and the addition of chemicals to process baths observed. The storage and handling of chemicals was also investigated. Since the predominant loss of chemicals is through dragout from process tanks, spills, and draining workpieces onto the floor, these issues were made a priority and attempts were made to quantify the resultant losses.

Process

The layout of the process was observed to determine if optimum use of space was used and if the arrangement of tanks was best suited to prevent excessive losses of process solution by spills. Drainage systems of the companies were also inspected.

Effluent

Information on the types, and origins of waste streams was collected. The quantity of effluent produced along with the type of treatment (if any) and associated costs were determined.

Following the investigation into the above areas, a number of waste minimisation options were developed for each company.

4.1.4 Feasibility Analysis

The identification of options was a continuous process at each company. These options were presented to the companies' project champions who would determine if they were technically and economically feasible. Most of the options identified involved simple housekeeping improvements, or improved process control and could therefore be implemented immediately at minimal or no cost.

4.1.5 Implementation of Waste Minimisation Options

The implementation of waste minimisation options was generally the responsibility of the project champions. Where capital investment was required, it was necessary to obtain funding first. This was not always possible since capital resources, especially in small companies, are usually restricted.

4.2 COMPANY A

The company involved is a manufacturing concern situated in Jacobs, Durban, South Africa. The company is concerned primarily with the production of a variety of domestic appliances including stoves, washing machines, tumble dryers, air conditioners, and microwave ovens. These products are sold within South Africa and stoves are exported to other African countries. The company is approximately 50 years old, and employs 864 production workers. Production occurs 24 hours a day, and 6 days a week. The company is a 'captive shop' implying that metal finishing is only one part of the entire operation and facilitates pre-treatment and protection of the different appliance parts before assembly. The main processes carried out on site include pressing, fabrication, plating, assembly and ballast weight preparation.

4.2.1 Process Description

The metal finishing processes occur before assembly of products and consist of:

- a metal pre-treatment (MPT) enamel line,
- a zinc phosphate paint metal pre-treatment line, and
- a nickel/chrome plating line.

The process flow of the above lines is illustrated in Figures 4.1, 4.2, and 4.3.

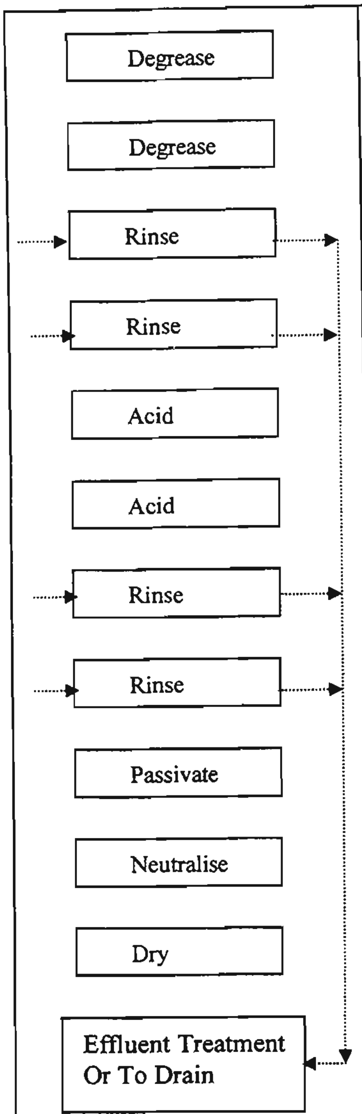

Figure 4.1: Diagram of Enamel MPT line

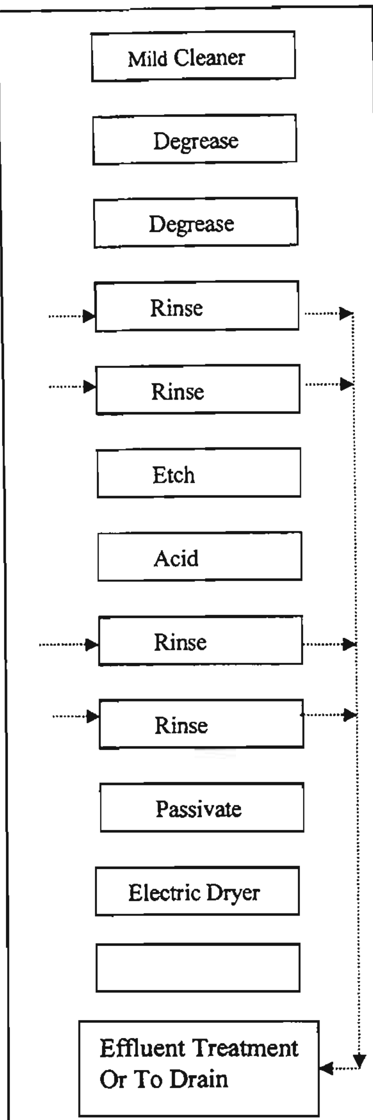

Figure 4.2: Diagram of Paint MPT line

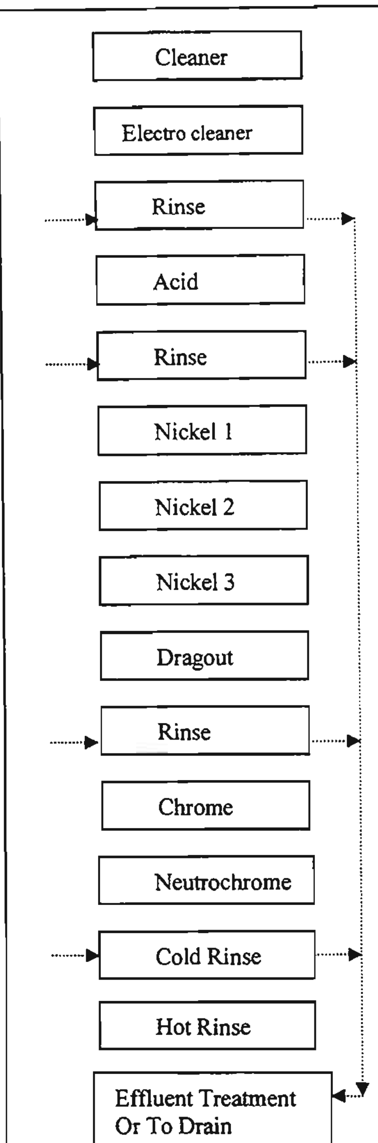

Figure 4.3: Diagram of Nickel/Chrome plating line

All lines are automatic but manual dosing of chemicals took place. In the above diagrams, process flow is from top to bottom, while the dashed lines indicate the flow of water. The enamel MPT line serves to prepare the objects being treated for enamel coating. The jobs (appliance panels) are loaded into baskets, which are attached to flight bars that move over the tanks. A similar system is used in the paint MPT line that provides a zinc phosphate coating onto metal surfaces to improve adhesion of subsequent coatings, and impart corrosion resistance to the overall substrate. The objects treated are various sizes and designs of washing machine components. Sludge is produced in the phosphate tank. This sludge is removed to pits and the water recycled to the process.

The nickel/chrome plating line was a jig operated line. The jobs (oven racks) were hung from jigs, which were attached to automated flight bars. All rinse tanks are overflowing except for the nickel dragout and hot rinse. The reduction of hexavalent chrome to trivalent chrome was achieved in the line in the neutrochrome tank.

The above processes consumed large quantities of water, energy, and chemicals, and contributed approximately 90 % of the company's waste. Therefore management at this company had made a commitment to waste minimisation, and as a result, their metal finishing processes were investigated.

4.2.2 Water Consumption

The company's water supply comes from the municipality. Water was used mainly for rinsing purposes and the testing of washing machines. The monthly water consumption and corresponding costs are given in Table 4.1.

Table 4.1: Monthly Water Consumption

Line	Consumption (kL/mth)	Cost (R/mth)	Monthly Effluent Cost (R/mth)	Total Monthly Cost (R/mth)
Enamel MPT	1 240	3 137	655	3 692
Paint MPT	2 520	6 376	1 127	7 503
Plating line	3 000	7 590	1 342	8 931
Total	**6 760**	**17 103**	**3 124**	**20 126**

4.2.3 Chemical Consumption

The company used a number of proprietary chemicals, as well as sulphuric acid, metal salts, chromic acid, and phosphoric acid. A breakdown of the chemicals used in each line is provided in **Appendix 3.**

4.2.4 Energy Consumption

The main uses of energy were in the heated process baths, the dryers in the enamel and paint lines, the drying ovens, and the compressors.

4.2.5 Wastes Generated

Air Emissions

The application of chrome plating resulted in the formation of a chromic mist above the bath. This emission was reduced by a proprietary additive that formed a foam blanket on the solution surface and prevented the toxic mist from escaping.

Effluent
Most of the effluent generated by the company originated from the metal finishing processes on site. The remainder of daily effluent was produced by the washing machine test bays, the mill room and the ballast weight department.

The company installed an effluent treatment plant in 2000. Prior to this, the paint and enamel MPT effluent were piped into a make-shift holding tank and neutralized with soda ash, whereas the plating effluent (which has a pH of approximately 9) was piped directly to the drain. Since installing the treatment plant, all effluent is first pumped to the plant, treated with the appropriate chemicals, and then discharged to sewer.

Solid Waste
The resultant sludge from effluent treatment was hauled to a landfill site by a certified waste disposal company.

4.2.6 Waste Minimisation Programme
The company was a member of the waste minimisation club since its inception, and its management had signed a declaration of commitment to waste minimisation. Senior management showed a keen interest in the progress made with waste minimisation at the factory. The company had two project champions (the plating manager and a maintenance officer), who worked together to co-ordinate waste minimisation activities. The company was represented at all club meetings.

Problems Identified
During the assessment the areas chosen for investigation included:

- water consumption,
- chemical consumption,
- metals lost to drain,
- energy consumption, and
- effluent treatment and control.

Water, chemical, and energy consumption and effluent control was of major concern to the company. Excessive volumes of water were used in rinsing to maintain a neutral pH in the rinse tanks. Water was always well metered at the factory. Records were kept of water consumption throughout the factory, but no steps were taken to counteract high water consumption prior to the implementation of a waste minimisation programme.

The generation of sludge in the paint line was found to be high due to poor control over chemical use. Losses in water, chemicals, and metals were occurring on all three lines due to dragout and insufficient drip times.

Losses in energy were encountered in the enamel line where the gas dryer was operating continuously even when not in use. The use of compressed air for agitation of rinse water wastes energy, as compressed air is expensive to generate.

Waste Minimsation Options

These problems lead to a number of waste minimisation options being generated for the company. Most options were identified during site visits and the detailed assessment, but many were identified by the project champions during their ongoing waste minimisation programme. Thus a total of fifty-four options were identified for the company, and eight were implemented as at November 2000. The options implemented are discussed below.

- *Water Consumption:*
  The company had nine water meters, which following the implementation of waste minimisation options, were being regularly read thus enabling the monitoring of water consumption. Measures were being taken to measure the rinsewater flowrates in all rinse tanks and adjust them to the minimum required for adequate rinsing. Options for the reuse of water were also investigated. This resulted in a decrease in water use in each line. The rinsing configurations on all three lines were changed with cascade rinsing being introduced in the plating line and cascade and counterflow rinsing in the enamel and paint lines. In addition orifice plates were installed to restrict rinsewater flowrates. These measures resulted in savings of 29 kL/d in the plating line, 12 kL/d in the enamel line, and 23 kL/d in the paint line.

- *Chemicals and Metals*
  The high consumption of process chemicals and the loss of metal to drain were of particular concern to the company. Not only did it lead to higher costs, but also presented a problem with effluent treatment and compliance with legal limits. Loss of chemicals and metals occurred mainly as a result of dragout and insufficient drainage. Therefore the drip times were increased on two of the three lines thus decreasing the dragout. Drip times could not be increased on the paint pre-treatment line due to streaking occurring on the products. Jigs were modified on the plating line to allow jobs to drain at an angle thus decreasing the carry over of solution. The dumping of cleaners and process baths was rescheduled to take place less often. Cleaners were reused where possible, and the dumping of baths was controlled since operators had to seek permission prior to dumping. These measures resulted in a decrease in the use of chemicals and metals, but this was not quantified as at November 2000. The company was also investigating the use of ultrafiltration to extend the lifetime of the degreasing baths.

- *Energy Consumption*
  A power factor correction led to an annual saving of R 110 000 for the company. A small blower was installed on the plating line to agitate the baths in place of compressed air. A new compressor was installed resulting in more efficient air generation. The installation of heat exchangers on the paint and enamel pretreatment lines was being investigated.

- *Effluent Treatment and Control*

By preventing baths from being dumped at the discretion of the operator, there was no longer shock loading of the effluent treatment plant. This resulted in more efficient treatment of effluent. Sludge from the various lines was segregated, enabling easier disposal. Due to the reductions in water consumption and chemicals and metals sent to drain, the volume and toxicity of effluent requiring treatment was reduced, resulting in further savings to the company.

- *Solid Waste Disposal*
  A waste skip was used by the company for the disposal of metal containing sludge. It was discovered that other types of solid waste were being discarded into this drum causing it to be collected at least four times a month for disposal. By placing the bin in a controlled area such that only sludge could be placed in it, resulted in the bin being collected just once a month.

4.2.7 ECONOMIC BENEFITS

The implementation of the above options resulted in substantial savings for the company. These savings are tabulated below.

Table 4.2: Savings Achieved

Item	Annual Saving (R/y)	Pay-back
Water	33 000	2 weeks
Chemicals and Metals	Not quantified	
Electricity	110 000	Immediate
Total	**143 000**	

The costs incurred in implementing options were for the installation of additional piping and pumps for the changes in rinse water configurations.

4.2.8 Environmental Benefits

The company's environmental impact has been reduced by the implementation of waste minimisation. Savings to the environment include:

- a reduction in water consumption by 14 ML/y,
- a reduction in metals to drain, and
- a reduction in volume of effluent discharged.

4.3 COMPANY B

The company is a job shop situated in Jacobs, Durban, South Africa. At the time of the study, the company was 15 years old and had 10 employees. Galvanising and powder coating of metal objects was provided as a service for various customers. The objects to be plated were mainly burglar guards and large gates

4.3.1 Process Description

The main processes employed at the company were zinc plating and powder coating. White, black, and brown powder coating was carried out with approximately 90 % of the white powder being recovered and reused.

The investigation focused on the main zinc line since its consumption of water and chemicals and the generation of effluent were of concern to the company. The process flow diagram is illustrated in Figure 4.4. Overflow rinses are indicated by the dashed lines.

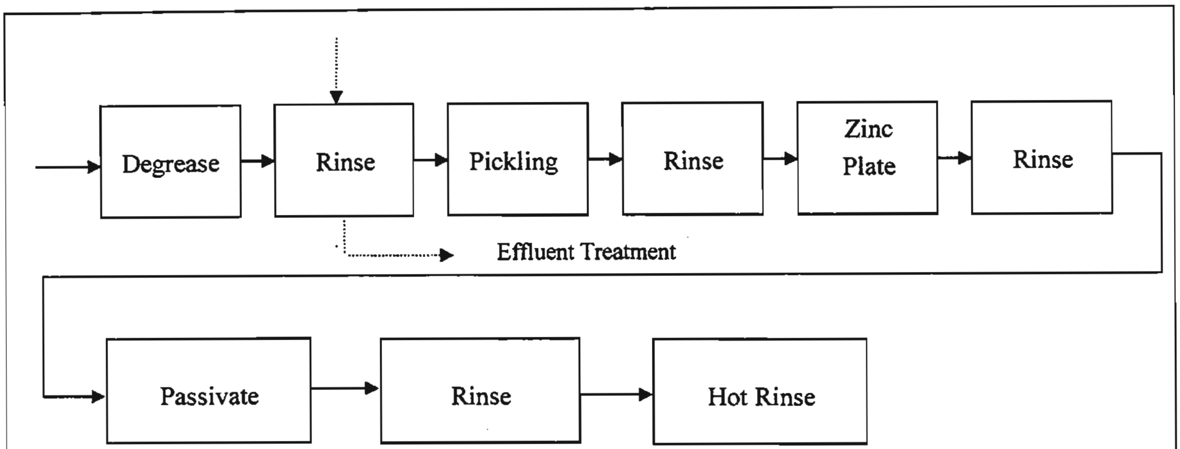

Figure 4.4: Process diagram of zinc plating process

The plating process was completely manual. Rinsing of small jobs was carried out in static rinses, while the larger articles were rinsed off with a hosepipe. Some barrel plating took place, but the larger jobs (burglar guards and gates) were immersed into the baths by workers.

4.3.2 Water Consumption

The company used municipal water. Water was used mainly for rinsing purposes. The company had one water meter, which was read daily. Records of water consumption were kept, but the company was charged for its water use by the landlord and thus did not receive a separate water bill.

4.3.3 Chemical Consumption

The jobs were degreased in a caustic cleaning solution, while hydrochloric acid was used for pickling. Other major chemicals used include sodium cyanide, sodium hydroxide and passivates. The company was not able to provide details of chemical use.

4.3.4 Energy Consumption

Energy was used mainly for the drying ovens following the powder coating process and the heating of process baths.

4.3.5 Wastes Generated

The main areas investigated were air emissions and effluent.

Air Emissions

The cyanide zinc process was the main source of air pollution. Some evaporation occurred from the degrease and acid tanks.

Effluent

Rinsing operations contributed the largest proportion of the effluent stream. Spills and floorwash drained into the effluent holding tanks. Regular dumping of the acid and alkali baths took place. Effluent treatment was carried out in three tanks installed in the ground. Cyanide was treated by the addition of sodium hypochlorite, and the pH was controlled with soda ash.

4.3.6 Waste Minimisation Programme

The company was a member of the waste minimisation club since its inception, and its management signed a declaration of commitment to waste minimisation. Complying with new regulations and learning more about waste minimisation were the primary reasons for the company joining the club. The company had two project champions, the owner and the manager. They were responsible for co-ordinating waste minimisation activities at the factory, and ensured that the workers were aware of the efforts being made and the importance of these efforts.

Problems Identified

During the assessment the areas chosen for investigation were:

- water consumption,
- chemical consumption,
- metals lost to drain, and
- effluent treatment and control.

While the company kept records of its water consumption, this was not used to monitor its use or to compare it with the amount for which the company is charged. No control was being exercised over the amount of water used for rinsing jobs by hosepipe. Odd shaped containers were used as static rinse baths for small jobs. The process baths were not arranged for the optimisation of the process with respect to space and time. As a result, workers had to carry jobs around leading to drainage over the floor. This resulted in a loss in water, chemicals, and metals. Further losses were incurred by insufficient drainage of jobs and dragout. The company did not have a proper effluent treatment plant.

Waste Minimsation Options

The investigation lead to a total of 19 waste minimisation options being identified for the site. The company was very keen to implement the options and improve conditions on site, and had implemented eight options by November 2000. Savings in water and chemicals were realised.

- *Water Consumption:*

  The company began monitoring water consumption so that discrepancies could be identified. A reduction of water use was achieved through the fixing of leaks in pipes and tanks. A maintenance programme made possible the quick detection and repairing of further leaks. Efforts were made to train shop floor employees on the importance of saving water. These measures led to a saving in water of 220 kL/year.

- *Chemicals and Metals*

  Drip trays were installed to collect spills and reduce dragout. The solution collected was used to top up process baths. An overhead drainage bar was installed for the zinc tank to increase the drainage time of larger jobs. More control was exercised over the use of chemicals, and the company undertook to conduct its own analyses of process baths to prevent excess addition of chemicals. These changes resulted in savings in process chemicals, zinc metal, and treatment chemicals. Cyanide consumption in particular has been decreased by 40 kg/month.

- *Effluent Treatment and Control*

  The reduction in water use and chemicals and metals lost to drain resulted in a lower volume of effluent requiring treatment and therefore lower treatment costs. The company was also building an effluent treatment plant to enable compliance with bylaws.

4.3.7 Economic Benefits

The company benefited from savings in water and chemicals. The savings achieved as at November 2000 are shown in table 4.3.

Table 4.3: Savings Achieved

Item	Annual Saving (R/yr)	Pay-back
Water	636	Not quantified
Chemicals and Metals	13 200	Immediate
Total	**13 836**	

4.3.8 Environmental Benefits

The company's environmental impact was reduced by the implementation of waste minimisation. Savings to the environment as at November 2000 include:

- a reduction in water consumption by 220kL/year,
- a reduction in cyanide use by 4 800 kg/year,
- a reduction in metals to drain, and
- a reduction in volume of effluent discharged.

4.4 COMPANY C

Company C was a plating job shop situated in Chatsworth, Durban, South Africa. It was established in 1982 and had 10 employees. Various objects of different shapes and sizes were plated at the company, which is ISO 9000 accredited, and is audited every six months. Zinc plating was the major process employed with some tin and cadmium plating taking place.

4.4.1 Process Description

Zinc plating was the primary process carried out in the company. Facilities were available for cadmium, nickel, and tin plating, but these lines were seldom used as the majority of work received was for zinc plating. There was a barrel and a jig-operated line. These lines followed the same process as illustrated in Figure 4.5.

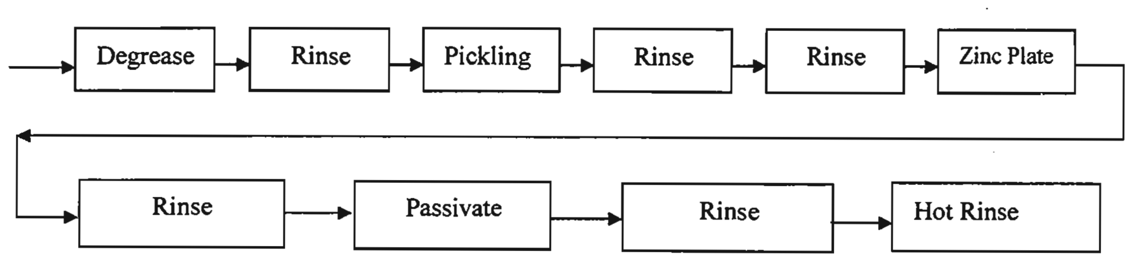

Figure 4.5: Process diagram of zinc plating process

All rinse tanks were overflowing except the hot rinse. Due to the variety of shapes and sizes of objects received for plating, the existing rinse tanks were sometimes too small for rinsing. In these cases, jobs were manually rinsed by workers using hosepipes.

4.4.2 Water Consumption

Municipal and borehole water was used in the factory. Water was used mainly for rinsing purposes. The company had two water meters but did not monitor the water use. On average the company used 104 kL of water every month at a cost of R 300 per month.

4.4.3 Chemical Consumption

Proprietary cleaners, hydrochloric acid, passivates, and zinc metal were the major chemicals used. The company did not provide details of chemical consumption.

4.4.4 Energy Consumption

Energy was used mainly for the heating of process baths and hot rinse baths, and the spin drying of barrel plated objects.

4.4.5 Effluent

Rinsing and the dumping of cleaners and acids led to the majority of effluent generated. The volume of effluent was increased by the washing of floors to get rid of spills and drainage from large jobs. An effluent treatment plant was being built on site to comply with new regulations. Sludge was stored on site due to it not being accepted at local waste disposal sites. Between two to three tons of sludge per month was produced by the factory.

4.4.6 Waste Minimisation Programme

The company's owner was the waste minimisation project champion. This was beneficial in the sense that the incentive to reduce waste and costs was strong and suggestions for improvement did not have to be taken to higher management.

Problems Identified

During the assessment the areas targeted for improvement were:

- water consumption,
- chemical consumption,
- metals lost to drain, and
- effluent treatment and control.

No effort was made to monitor water use even though the company had two water meters. Therefore the company could not be certain if there were underground leaks or if they were being correctly charged for water use. The drainage from floors was observed to be ineffective. Some rinsing was done directly onto floors leading to stagnant pools of water around process tanks. There was limited control over the use of water especially for manual rinsing operations. A loss of chemicals and metals was incurred by insufficient drip times being allowed for jobs. This resulted in excessive dragout, which in turn led to a higher consumption of water required for effective rinsing. Solution from jobs also dripped onto the floor while the large jobs were carried to the drying area.

Waste Minimsation Options

The investigation led to a total of 17 waste minimisation options being identified for the site (see **Appendix 3**). The implementation of seven of these options lead to savings in chemicals, water, and energy.

- *Water Consumption*

  Replacing overflow rinses with static rinses significantly reduced water consumption. Dragout tanks were installed and the solution was used to top up process baths, thus saving water and chemicals. Leaks in pipes, taps, and tanks were identified and repaired. The company began investigating the reuse of treated water for cleaning purposes. These improvements resulted in a reduction in water use of 200 L/month.

- *Chemicals and Metals*

  The installation of dragout tanks reduced the amount of chemicals and metals lost to drain. By conducting tests on the process solutions, the company discovered that lower additions than that recommended by chemical suppliers were needed for effective operation. Thus by monitoring chemical consumption and optimising the chemical concentrations in process baths, the company was able to reduce its chemical costs by 50 %. Further savings were achieved on the barrel plating line where the barrels were rotated as they were removed from solution to increase drainage.

- *Energy Use*

  By monitoring the electricity consumption on a monthly basis and reporting their readings to the municipality, the company realised a saving of approximately R 8 000/month in electricity costs.

4.4.7 Economic Benefits

The company benefited from savings in water, energy and chemicals. The savings achieved as at November 2000 is shown in Table 4.4.

Table 4.4: Savings Achieved

Item	Annual Saving (R/y)	Pay-back
Water	5 500	Immediate
Chemicals and Metals	110 000	Immediate
Energy	88 000	Immediate
Total	**203 500**	

4.4.8 Environmental Benefits

The company's environmental impact was reduced by the implementation of waste minimisation. Savings to the environment included:

- a reduction in water consumption by 2 200 kL/y,

- a reduction in chemicals and metals to drain,
- a reduction in volume of effluent discharged, and
- a reduction in energy use.

4.5 COMPANY D

Company D was a small electroplating job shop situated in Seaview, Durban, South Africa. The company was approximately 20 years old and had 50 employees at the time of the study. Plating was performed on steel, copper, brass, die cast and aluminium, and typical objects plated included screwdrivers, fences, stove parts, electrical components, and jewellery.

4.5.1 Process Description

A number of different processes were carried out on site including zinc galvanising, chrome plating copper plating, cadmium plating, silver plating, gold plating, iridising, anodising, tin plating, and brass plating. The factory was divided into different sections, namely the Zinc Plant, the Screwdriver Plating Plant, General Plating, and the Reutech Defense Industry (RDI) Plant.

The departments concentrated on during the assessment were the Zinc Plant and the Screwdriver plating plant.

Zinc: Galvanising Plant

This plant consisted of four lines. The main line (zinc followed by silver or gold plating) is illustrated in Figure 4.6. This line consisted of eleven tanks, which allowed for cleaning, pickling, rinsing, and plating of the metal objects. Zinc plating was followed by silver or gold plating, depending on the customer's preference. The main chemicals used in this line include sodium hyroxide, sulphuric acid, and sodium cyanide. There were five overflowing rinse tanks in this line. Other lines followed the same process with minor differences.

Screwdriver Plating Plant

The plating of screwdrivers is a long process and is illustrated in Figure 4.7. The workflow is from top to bottom. Plating baths (nickel and chrome) were run at a temperature of 50 ^{0}C. The reduction of the toxic hexavalent chrome to trivalent chrome took place in the line. Some recovery of plating solutions was achieved by the use of dragout tanks. All rinses except the hot rinse were overflowing. The main chemicals used include hydrochloric acid, sulphuric acid, nickel sulphate, nickel chloride, and chromic acid.

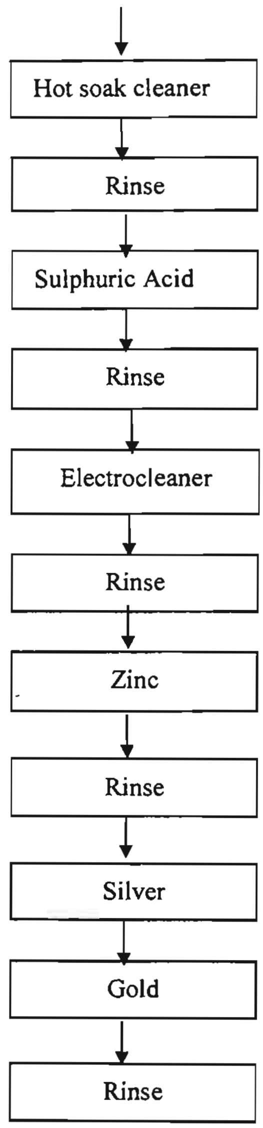

Figure 4.6: Flow diagram of main zinc line

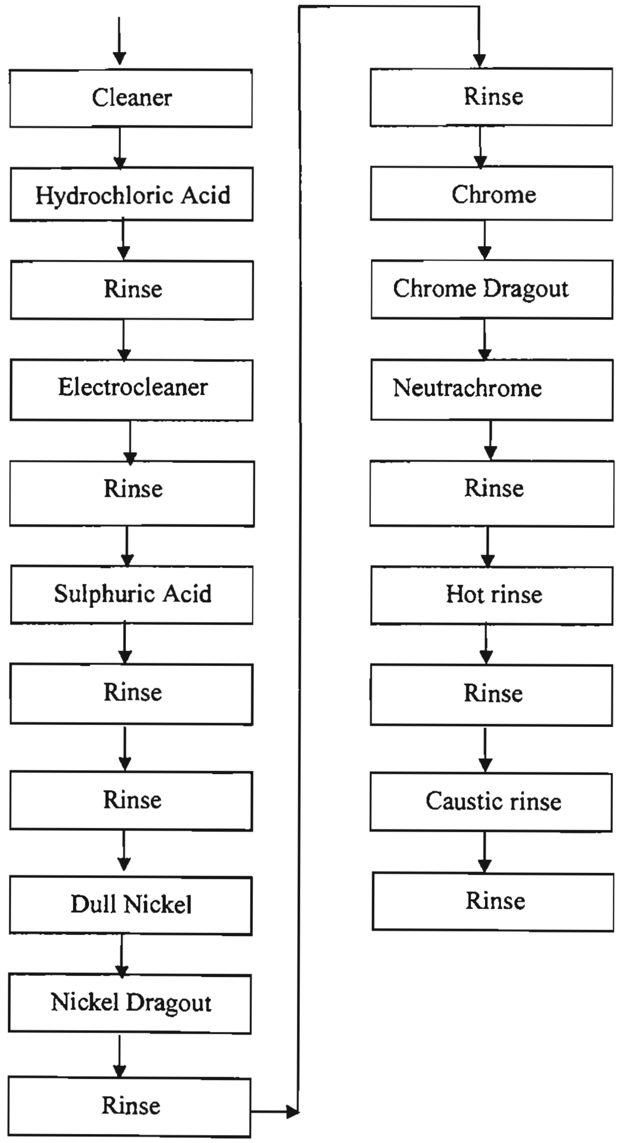

Figure 4.7: Flow diagram of screwdriver plating process

4.5.2 Water Consumption

The factory had two sources of water, namely the municipality and the Umhlatuzana River, which runs behind the factory. The water from the municipality was used at the Chrome and RDI plants. The water from the river was filtered and then pumped to the Zinc, Screwdriver and General Plating sections. Water was used mainly for rinsing purposes. Initially the company had one water meter, but water consumption was not monitored. The advantage of using the water from the river was that the company did not pay for the supply of this water, but was charged for it on discharge to sewer.

Prior to the implementation of waste minimisation the company consumed an average of 2 100 kL/month of water at a cost of approximately R 5 200 per month.

4.5.3 Chemical Consumption

The company used a variety of chemicals for its processes (see **Appendix 3**). A number of the chemicals have proprietary names, therefore the constituents are unknown. The company did not disclose the cost of their purchased chemicals.

4.5.4 Energy Consumption

The company was not a large consumer of energy. In the plating departments, energy was used mainly by a drying oven (for the drying of plated articles), and heated tanks. The rectifiers on site drew electricity constantly.

4.5.5 Wastes Generated

Air Emissions

Cyanide and acid containing dust mists are the primary sources of air pollution.

Effluent

Rinsewater formed the largest proportion of the daily effluent generated by the company. Since rinsing serves to remove and dilute the dragout of chemicals and metals from baths, the effluent stream therefore became concentrated with these components. Copper, nickel, cadmium, silver and zinc were the metals that were expected in this stream. The effluent was treated with sodium metabisulphite ($Na_2S_2O_3$ or MBS) for the reduction of hexavalent chrome to trivalent chrome, and sodium hypochlorite (NaOCl) to eliminate cyanide. Caustic soda or soda ash (Na_2CO_3) was added to adjust the pH.

The quantity of effluent produced and the associated cost prior to implementing waste minimisation is shown in Table 4.5.

Table 4.5: Effluent Quantity and Costs

Cost of effluent	**(R/kL)**	0.50
Quantity	**(kL/month)**	6 692
Monitoring Charge	**(R/month)**	431
Total cost	**(R/month)**	3 923

Effluent tariffs subsequently increased thus making the need for reducing the amount of effluent generated more urgent.

4.5.6 Waste Minimisation Programme

The company's waste minimisation programme began when it joined the club in June 1998. A commitment to implementing waste minimisation was made by the owner of the company, who was also the project champion. The company's main reasons for joining the club were to comply with new regulations, learn about waste minimisation, and achieve savings. However, the owner was initially sceptical of the benefits of waste minimisation and was therefore not very enthusiastic at the beginning. His views subsequently changed following the study tour to Denmark (discussed in **Chapter 3**, section 3.14). It was after this that serious effort was put into the waste minimisation programme.

Problems Identified

During the initial assessment, the following areas were chosen for investigation:

- Water consumption,
- Chemical consumption,
- Reducing metal concentrations to drain,
- Energy use, and
- Effluent control.

Water consumption was high throughout the factory. The company had one meter, which was not monitored regularly. There were no restrictions on the flowrate of water used for rinsing. Dosing of process tanks with chemicals took place manually. There was limited control over the use of chemicals, and as a result an excess of chemicals was being added to the tanks. This not only represented a waste in chemicals leading to higher consumptions than necessary, but also to increased metal concentrations in the effluent. Improved effluent control was important for the company to comply with new regulations. The company also spent between R 12 000 and R 15 000/mth on cleaning agents, which also led to effluent problems. While electricity consumption was not high at the company, it was wasted by the rectifiers on site, which drew electricity continuously even when not in use.

Waste Minimisation Options

Based on the problems identified, a total of twenty-five waste minimisation options were generated during the waste minimisation audit and by the owner of the company. As at November 2000, the following improvements were made by the company:

- ***Water Consumption:***

  The company installed a further seven water meters, and began monitoring water consumption daily. This enabled any problems to be identified immediately. Rinsewater flowrates were adjusted to the minimum rate required for adequate rinsing. Additional dragout tanks were installed in process lines. Counterflow rinsing was introduced to processes thus reducing the water requirements of the factory.

- ***Chemicals and Metals:***

  A storeman was employed to control the quantities of chemicals being added to baths. This resulted in a saving of 10 to 15 % in chemical costs. An automatic crane was installed over the chrome bath thus allowing the jobs to be lifted out of the bath and drained at a slower rate. Process chemicals that were previously being carried over to the rinse water were being returned to the process bath. This resulted in a saving of 25 kg/month of Chrome. This in turn reduced the quantity of sodium metabisulphite required to treat the chrome in the effluent. The company managed to double the life of its cleaning solutions. Old cleaning solutions were being emptied into another tank, and new solutions were prepared. The jobs being processed were first dipped into the old cleaners and then the new ones. Increasing the drip times over process baths decreased losses of chemicals and metals through dragout on all lines. In addition, the orientation of jobs on jigs was improved to allow for maximum drainage of jobs, thus further reducing dragout, and saving chemicals.

  The cyanide zinc plating process was replaced with the alkaline zinc process. This process costs the same to operate and eliminates cyanide from the effluent. The reduction of chemical consumption led directly to a reduction of metals going to drain, and the amount of chemicals required for effluent treatment.

- ***Energy Use:***

  Rescheduling of the oven used for drying of jobs resulted in a reduction in use from eight to three hours per day. The installation of thermostats on hot baths facilitated the monitoring of energy use and ensured that the baths operate at the minimum temperature required. Further reductions in energy use were achieved by switching off the rectifiers when not in use.

- *Effluent Treatment*

  An effluent treatment plant was built on site to comply with legal discharge limits. Flocculants were added to aid in the settling of precipitated solids. Solids were effectively removed by filtration. Samples of effluent were taken by the local authority for compliance tests and the effluent was either passed for discharge to sewer or not. Due to the reductions in water and chemical consumption, and chemical loss to drain, a smaller effluent plant was required to treat the factory's effluent.

4.4.7 Savings Achieved

The savings achieved from the implementation of the above options as at November 2000 is given in Table 4.6

Table 4.6: Savings Achieved

Item	Annual Saving (R/y)	Pay-back
Water	59 400	Immediate
Chemicals and Metals	68 400	Immediate
Energy	33 000	Immediate
Effluent charges	36 500	Immediate
Total	**197 300**	

4.5.8 Environmental Benefits

Accompanying the substantial financial benefits to the company were also significant benefits to the environment. These were:

- a reduction in water consumption by 3 900 kL/mth,
- a reduction of 275 kg/y of chrome discharged to drain,
- a reduction in zinc metal to drain from 50 to 60 ppm to less than 25 ppm,
- the elimination of cyanide use,
- a reduction in the use of cadmium,
- a reduction in the volume of waste discharged, and
- a reduction in the use of electricity.

4.6 DISCUSSION

The running of waste minimisation programmes at these companies has been successful. However, the same level of cooperation was not obtained from each company. This was mainly due to the lack of time by project champions who had other responsibilities within their companies. The lack of reliable records was a particular problem in the smaller companies especially with regard to chemical consumption. Despite making a commitment to implementing waste minimisation it was not a high priority for companies, and production issues were understandably of more concern. Once the companies realised some benefits of implementing changes, they were more eager to contribute time and resources to waste minimisation programmes. A detailed analysis of results from these case studies is given in **Chapter 5**, section 5.4.

CHAPTER 5 - PROJECT RESULTS

The increasing cost of waste disposal – driven mainly by tougher laws - has underlined the financial benefits of waste reduction…- World Business Council on Sustainable Development, 1997

The Metal Finishing waste minimisation club was the first waste minimisation club for South African industry. There was consequently no published methodology for establishing and running such a club. The club was therefore an experiment, the outcome of which could not be predicted. However, the success achieved in other countries with clubs of this nature, and the established benefits of applying waste minimisation, made it reasonable to expect good results from the metal finishing industry.

After a few months of involvement, some companies began to realise the benefits of waste minimisation and reported their savings to the club. Their success served as an incentive for others to increase their efforts with waste minimisation programmes. As a result, more companies began achieving savings. In this chapter, the results obtained from conducting assessments, and creating waste minimisation awareness within companies is discussed. The social aspects of the club are discussed along with the problems experienced and lessons learnt.

5.1 INITIAL ASSESSMENTS

While the main purpose of a waste minimisation assessment is to produce a set of waste minimisation options, in this project it also served to create awareness within companies and help owners, managers, and employees of companies become familiar with the concepts of pollution prevention and waste minimisation.

5.1.1 Hypothesis

As discussed in **Chapter 3**, section 3.5, twenty-two engineering students were recruited to conduct waste minimsation assessments at companies. It was hypothesised that students of an engineering background would be useful in conducting initial waste minimisation assessments effectively.

5.1.2 Observations and Suggestions from Initial Audits

Initial waste minimisation assessments were carried out by students for twenty-two companies, and reports were prepared for each company. The main outcome of the student reports was the identification of areas of excessive waste generation and the suggestion of waste minimisation options. Since all students were given the same information to guide them with their investigation, most of the suggestions made were common to all companies. There were a number of similar problems experienced in each company. Common environmental and process problems associated with companies following the same processes were evident. The lack of environmental awareness and technical knowledge in terms of waste minimisation, and in some cases metal finishing processes, especially within the smaller companies was obvious from the reports.

The most common areas of wastage identified by the students were excessive water consumption and loss of chemicals due to dragout and spillage. These problems proved to be mainly a result of poor housekeeping practices. Several suggestions for improvement were made for each company. The most frequently suggested options for the targeted areas are described below.

Water Consumption

Metal finishing processes are water intensive, with rinsing being the predominant use of water. Rinsing systems were observed to be inefficient as a number of companies used excessive quantities of water to achieve good rinsing. Suggestions for reducing water consumption included:

- the fixing of leaks (taps, pipes, tanks),
- preventing spills,
- the replacement of static and overflow rinses with counterflow and cascade rinses,
- the use of flow restrictors (eg. orifice plates) to regulate flow in rinse tanks,
- increasing drip times, and
- the installation of drag-out tanks.

These options are common in waste minimisation guides including those surveyed in **Chapter 2**.

Chemical Consumption

Various types of chemicals are used in metal finishing operations from the surface preparation steps to the metal treatment and post treatment processes and finally in the effluent treatment process. The loss of chemicals and metals during the surface and treatment phases lead to more chemicals being required for effluent treatment. Chemical and metal losses were observed to occur mainly as a result of dragout and spills. A number of suggestions for reducing these losses were made including:

- increasing the drainage time of work pieces over the electroplating baths,
- using drainage boards between tanks to transfer solution back to tanks,
- installing overhead drip bars,
- preventing spills by worker education,
- using dragout tanks,
- controlling access to chemicals,
- education of workers on waste minimisation,
- eliminating the use of cyanide,
- the separation of hazardous and non-hazardous wastes to reduce effluent treatment costs, and
- monitoring chemical addition and not adding an excess of what is required.

Energy Consumption

The main focus of the student assessments was the use and pollution of water. Minimal emphasis was placed on energy consumption. This did not present a problem, as most of the companies were not big consumers of energy. Energy was used mainly for heating of process baths. The main suggestion for preventing energy losses was to insulate process tanks.

5.1.3 Discussion

As the students possessed basic and advanced knowledge of engineering principles and processes, they were able to grasp the fundamental processes associated with metal finishing and the nature of the chemicals and other materials utilised. In addition, the students were given three days of theoretical training in waste minimisation procedures and common metal finishing problems. This enabled them to approach the companies with some knowledge of the possible issues that would be dealt with.

Overall, it was found that employing students to undertake these waste audits had both advantages and disadvantages.

The advantages were that:

- due to time constraints, it would not have been possible to visit each site individually and personally conduct each audit,
- the students were able to liaise with the project champions every day and point out findings immediately, thus allowing the companies to make informed decisions,
- it assisted companies to begin investigating waste minimisation themselves, and
- it enabled identification of those companies who were genuinely interested in implementing waste minimisation, and those who joined merely to comply with Durban Metropolitan Council's(Metro) wishes.

The disadvantages were that:

- it was difficult to control the number of students,
- not all students delivered the same quality of work,
- some companies felt they were doing the students a favour and were therefore not cooperative,
- the inexperience was a drawback at times, and
- it was difficult to be certain of the situation at each company.

The above is evident from the differences in report writing from the students. A compilation of student reports has been included in **Appendix 1.**

5.2 SITE VISITS

When conducting a waste minimisation audit, one of the main steps is to conduct a site visit to the company in order to study the processes and identify areas where improvements can be made. As discussed in **Chapter 3**, section 3.5, the students conducted initial site visits to companies while carrying out the audits.

5.2.1 Hypothesis

Based on the nature of problems experienced with the initial assessments, and the number of club members, it was hypothesised that follow-up site visits would be essential to gain hands on knowledge of each company's situation.

5.2.2 Observations from Site Visits

As discussed in **Chapter 3**, Section 3.8, follow up site visits were conducted at each factory. During site visits, the company's processes and practices were observed. The attitude of different levels of employees was observed and it was evident that the shop floor employees were not educated on waste minimisation, and did not consider it an obligation to save water and chemicals. There was little dissemination of information down to the shop floor level especially in larger companies. In many of the smaller companies, the concentration was on production and profit issues rather than waste and pollution. This is understandable and expected, but the goal was to impress upon the owner of these companies that adopting waste minimisation practices can improve production and led to cost savings. The visits aided in creating awareness of waste minimisation within companies and lead to further options for improvement being suggested.

One of the main problems identified during site visits was the lack of proper waste management, particularly by the smaller companies. While applying waste minimisation practices results in the reduction in quantities and concentrations of waste, the generation of waste still occurs, and needs to be properly managed to reduce negative effects on the environment. The larger companies were found to follow acceptable disposal procedures, that is effluent treatment to comply with legal limits and sludge disposal via waste disposal companies. Some smaller companies did not conduct effluent treatment and disposed of effluent with heavy metal concentrations in excess of the acceptable limits. Those that do treat their waste are then faced with the problem of sludge disposal. The lack of a disposal site for hazardous wastes in KwaZulu-Natal led to the illegal storage of waste or its costly transport to disposal sites in Gauteng. A number of possible solutions to this problem were investigated and are discussed in section 5.10.

5.2.3 Discussion

The site visits led to additional insight of company operating procedures and attitudes towards waste minimisation. It enabled a better understanding of the capacity of each company to implement a waste minimisation programme. This proved very useful when feedback was received from each company at club meetings, as it was then possible to understand what the project champion was presenting.

5.3 MEETINGS

Since its inception, there have been twelve club meetings and three special meetings.

5.3.1 Hypothesis

Due to the size of the companies (90 % were small and medium sized), it was hypothesised that club members would not have time to regularly attend meetings.

5.3.2 Observations from Club Meetings

Details of each meeting (dates, agendas, guests, and attendance) are given in **Appendix 5**. All club members did not regularly attend meetings. It was noted that the companies making the most effort with waste minimisation programmes attended meetings more regularly. A number of project champions for the smaller companies were also responsible for production and other departments within their companies. This meant that attendance at the club meetings was not a priority especially since it was during working hours.

During the first six months of running the club (from June 1998), it was found that companies were wary of each other and the club's facilitator. They were therefore reluctant to discuss problems or reveal details on their processes. This gradually changed and during 1999 and 2000, club members have been more willing to share their experiences and discuss problems openly. There was a growing sense of unity among members who often grouped together to solve common problems. In some cases, companies would receive advice and assistance from other members on a specific problem.

5.3.3 Discussion

It was clear that time was a major barrier to attending meetings. The smaller companies especially, were absent at meetings due to more urgent requirements at work. Despite sending out invitations to meetings two weeks before, and telephonically reminding members of meetings, some club members could not confirm their attendance in advance.

5.4 BARRIERS AND DRIVERS

In **Chapter 3** section 3.2, the identification of barriers and drivers, affecting the implementation of waste minimisation, during the club's inaugural meeting, were discussed.

5.4.1 Hypothesis

As it was established that the metal finishing sector faced serious problems with respect to their pollution load and contribution to environmental degradation, it was hypothesised that the main reason for companies joining the waste minimisation club would be to reduce their environmental impact. Similarly, it was hypothesised that companies would be committed to implementing waste minimisation.

5.4.2 Results from Identification of Barriers and Drivers in 1998 and 2000

The results of the process of identifying barriers and drivers is given in **Appendix 2** and discussed in this section.

At the inaugural meeting in June 1998, it was found that the greatest barriers to implementing waste minimisation for the companies present were a lack of technical knowledge, information, and finance; unclear legislation and operational constraints.

The main drivers identified by the companies were the savings that could be made, an improved environmental performance and more stringent legislation. The ISO 14000 environmental management requirements also received a fairly high vote.

During interviews in March 1999 and March 2000, club members were again asked to identify the most important barriers to waste minimisation. Views were different in March 1999, where the lack of time, resources, and commitment were the top barriers. In March 2000 companies identified a lack of finance as the main barrier to implementing waste minimisation. This was at a time when each company had sets of waste minimisation options to consider, and had already implemented those requiring little or no capital investment. A comparison of the barriers identified in each year is given in Table 5.1. These results are taken from interviews with the club members during 1999 and 2000 (**Appendix 4**).

The number of companies taking part differs on each occasion, but those interviewed in 1999 and 2000 are considered to be representative of the active club members. Of the seventeen companies interviewed in 2000, four were actively implementing waste minimsation measures and therefore did not answer this question.

Table 5.1: Summary of top barriers to implementing waste minimisation as identified by the club members

Priority	June 1998	March 1999	March 2000
1	Lack of finance	Lack of time	Lack of finance
2	Lack of information	Lack of resources	Lack of time
3	Operational constraints	Lack of commitment	Lack of commitment
4	Unclear legislation		

5.4.3 Discussion

It is understandable that initially the companies were not well versed on the concept of waste minimisation. As the club progressed, it became evident that the lack of information or knowledge was not a major barrier to implementing waste minimisation. This indicates that significant capacity building had taken place within the club. Once club members understood the concepts and benefits of waste minimisation, a lack of finances became a barrier when certain waste minimisation options that required capital expenditure were proposed. It was noted that while the industry as a whole did not feel that they were resistant to change, the regulators saw this as the main reason for waste minimisation not being implemented. In addition, lack of time was not considered a barrier, although later it became evident that this is one of the greatest problems facing companies in implementing a waste minimisation programme.

5.5 SURVEYS

This section presents the results obtained from interviews conducted in March 1999 and between February and June 2000.

5.5.1 Hypotheses

Conducting surveys tested three hypotheses. It was hypothesised that:

- club members would want the club to continue in the future,
- companies would not fully grasp the concept of waste minimisation, and
- companies' relationship with the local authorities would improve through their participation in the waste minimisation club.

5.5.2 Results of Survey Conducted in March 1999

As discussed in **Chapter 3**, section 3.11 telephonic interviews were conducted with sixteen club members. Initial results of the survey indicate that the majority of member companies were small, employing less than 50 people. All respondents joined the club when it was first started in June 1998.

Club's Potential

There was general agreement amongst respondents that the potential for the continuing existence of the metal finishing club was very good. Few respondents felt that there were constraints to the continuation of the club. Those constraints that were mentioned included possible financial constraints once external funds were withdrawn, the possible dropping off of attendance as companies solve their waste problems, and time constraints for company representatives, which prevents attendance at meetings.

Suggestions for Improvement

Some members suggested that some changes need to be made in the functioning of the club, such as:

- the establishment of a more relevant agenda, focussing on issues specifically relevant to the metal finishing industry rather than general waste management, and
- the addressing of specific problems and needs of the smaller companies (those with less than ten employees). These companies claimed that at times they felt overwhelmed by the needs and demands of the larger companies.

Benefits of the Club

There was widespread agreement that the open discussion, knowledge sharing, informality and positive atmosphere within the club served as an encouragement to minimise waste rather than other possible mechanisms such as legislation, which would not be well received. Further general agreement centred on the issue of the role of waste minimisation clubs within the arena of environmental management. Members agree that the waste minimisation clubs can be effective in the broader project of improving the condition of the environment.

Complete responses to of these interviews are included in **Appendix 4**.

5.5.3 Results of Survey Conducted in March 2000

The results of this survey, together with the questionnaire are given in **Appendix 4** and are summarised below.

Understanding of Waste Minimisation

In order to ascertain the level of understanding that club members attained on waste minimisation, they were required to identify what they perceived to be waste minimisation options from five possible techniques that could be applied to a metal finishing enterprise. All the companies interviewed agreed that the reuse of dragouts, the modification of jigs and the monitoring and recording of water use constitute waste minimisation. However, a high proportion (73 %) agreed that dilution of effluent was a waste minimisation technique, and only 18 % thought that the installation of an effluent treatment plant was an end-of-pipe solution and not waste minimisation. Upon further questioning, it was determined that the industry considered waste minimisation to be any action that reduced the waste (effluent) discharged from their premises.

Benefits of the Club

Companies were questioned on the benefits of being club members, and considered the biggest benefits to be a greater understanding of waste minimisation, a better understanding of the environmental impacts of their factories, interacting with the other metal finishers, and the savings achieved. More than 50 % of those interviewed liked to see the club continue and were willing to contribute towards an outside organisation managing the meetings. Other benefits include improved relationship with both their employees and the Metro.

Barriers to attending meetings

Poor attendance at meetings was a significant problem experienced while running the club. Members were therefore asked as to reasons for not attending. For those companies with poor attendance, the main reason given was a factory emergency, followed by a lack of time. All agreed that there was good notice of meetings and it was not due to a lack of interest.

Reasons for joining the club

Table 5.2 compares the top four drivers behind the companies joining the club, taken from the interviews conducted in 1999 and 2000. They are listed in descending order of magnitude of votes.

Table 5.2: Top drivers for joining the waste minimisation club

Priority	March 1999	March 2000
1	Legal compliance	Save money
2	Increase knowledge	Reduce pollution
3	Improve operation	Learn about waste minimisation
4	Improve environment	Proposed new limits

The number of companies interviewed in each case was different, but represent the members who were most involved in club activities. Initially companies were sceptical of the benefits of waste minimisation and therefore did not expect to achieve savings, but after realising some savings, quoted this as a driver for joining.

Relations within the club and between club member and authorities and suppliers

Participation in the club not only affected companies' technical processes, but also their relations with each other, with their chemical suppliers, and with the Metro. This section briefly discusses members' views on these relationships.

- *Interaction between club members*

  The majority of members interviewed stated that while they were aware of the other metal finishers in operation, there was no interaction with them. Joining the club therefore improved their relations, and has led to many companies assisting each other with various problems.

- *Relationship with Durban Metropolitan Council*

  The industry's relationship with the Metro was of considerable interest, and it was felt to be an important issue for discussion during interviews.

  While 80 % of the respondents felt that the relationship improved since the establishment of the club, there was still a feeling of an 'us and them' situation. Companies agreed that it is important to have regulations for the industry, but expressed that it was unfair to impose different standards in different regions.

- *Relationship to Chemical Supplier*

  A representative of a chemical supplier was elected a member of the club due to the assistance and support shown to the companies involved. The supplier assisted club members with implementing waste minimisation, and all companies interviewed agreed that the technical information given by the supplier was very important to them. It was interesting to note that only one in ten respondents stated their supplier was responsible for the maintenance of process baths.

5.5.4 Discussion

Based on these results, it is not clear whether all club members had fully grasped the concepts of waste minimisation. Although it seemed as if the concepts of source reduction and monitoring had been accepted by the club members, there was still the view that effluent treatment is part of the process. It is evident that the club has been of benefit to the companies, although some were sceptical at the beginning. The willingness of club members to contribute financially to the future running of the club indicates the level to which the importance of waste minimisation has been understood, and the effectiveness of using the club approach.

5.6 CASE STUDIES

An analysis of results from the case study companies is included in this section. **Chapter 4** contains summary reports on each of these companies.

5.6.1 Hypothesis

It was proposed that the differences in size of a company, the type of operation carried out, and the level of the project champion within the company would have significant effects on the progress of waste minimisation programmes within the companies.

5.6.2 Summary of Results from Case Studies

A description of the companies in terms of employees, type of enterprise, and main processes is given in Table 5.3. Correspondence with each company and co-ordination of waste minimisation activities took place mainly via the project champions. Table 5.4 gives a description of the project champions.

Table 5.3: Case Study Company Characteristics

Company	Number of Employees	Type of Operation	Main Metal Finishing Processes
A	800	Manufacturing	Enamel metal pre-treatment line Paint metal pre-treatment Nickel/Chrome plating
B	14	Job	Zinc Plating Powder Coating
C	10	Job	Zinc Plating Tin plating
D	50	Job	Galvanising Nickel, chrome, copper, and brass plating

Table 5.4: Description of Project Champions

Company	No. of Project Champions	Position in Company
A	2	Safety Officer Plant Engineer
B	2	Manager Owner
C	1	Owner
D	1	Owner

Each company has benefited from savings resulting from the implementation of waste minimisation options. This is represented below in Table 5.5.

Table 5.5: Options and Savings

Company	Number of Options Identified	Number of Options Implemented	Total Annual Savings (R/y)
A	54	8	143 000
B	19	8	13 800
C	17	7	203 500
D	25	23	197 320

5.6.3 Discussion

The case studies showed that it was not necessary to be a large company with high financial resources in order to realise financial benefits from implementing waste minimisation. It depended rather on commitment, time available by project champions, the availability of accurate and sufficient records, and the level of the problems to begin with. Company C (the smallest) managed to achieve the highest saving while implementing a minimum number of options. Company D was able to implement almost all of the options that were identified at the time of the study. This was mainly due to the fact that the project champion was also the owner of the company, and highly committed to implementing waste minimisation. While the project champion of Company C was also the company owner, the same level of commitment was not noted. It was found to be more difficult to obtain information and liase with this company compared to the other three. Company A, despite being the largest achieved the third highest financial saving, and only implemented 9 % of the options identified. While the project champions at Company A were enthusiastic, and willing to dedicate time and effort to waste minimisation, it was more difficult for them to seek approval for the implementation of all the options. Although senior management signed a commitment to waste minimisation, it was still difficult to make effective progress. Conducting the waste minimisation audit at Company A was however made easier due to the excellent records kept of production, utility consumption and costs, and chemical consumption and costs. This was relatively difficult at the smaller job shops due to the different objects being plated. This slowed down the progress of the waste minimisation programme and made monitoring and targeting difficult.

5.7 WASTE MINIMISATION OPTIONS FOR THE ENTIRE CLUB

This sections analyses the waste minimisation options identified and implemented by each company.

5.7.1 Hypothesis

From the literature, it was determined that significant reduction in waste from the metal finishing industry could be achieved by implementing simple low cost waste minimisation options. It was therefore proposed that the majority of the options implemented by the club members would be housekeeping improvements.

5.7.2 Options Identified and Implemented by Club Members

The number of options identified and implemented for each company has been included in Table 5.6. A total of **391** options were identified for twenty-six companies by November 2000, and **147** of those options were implemented. (See **Appendix 8**)

Table 5.6: Options Identified and Implemented as at November 2000

Company	Number of Options Identified	Number of Options Implemented
A	54	8
B	19	8
C	17	7
D	25	23
E	25	10
F	11	6
G	18	7
H	33	15
I	25	10
J	23	14
K	10	5
L	10	7
M	8	1
N	17	4
O	11	5
P	12	10
Q	10	3
R	6	1
S	5	3
T	14	Not known
U	4	Not known
V	4	Not known
W	4	Not known
X	11	Not known
Y	13	Not known
Z	2	Not known
Total	**391**	**147**

For companies T to Z, it was not known whether the waste minimisation options identified were implemented as at November 2000.

The options that were identified can be divided into five main categories, namely:

- improved housekeeping,
- technology changes,

- raw material changes,
- product changes, and
- on-site recycling.

Options for improvement were identified for twenty-six companies (A-Z). However only nineteen companies (A-S) have reported the implementation of options. The options identified for the nineteen companies discussed in this section were divided into the abovementioned categories, and the result is graphically represented in Figure 5.1 as proportions of total options. Options that were implemented by the nineteen companies are represented in Figure 5.2. A spreadsheet of the options identified in each category is included in **Appendix 7**. The number of options identified and implemented in each category is given in **Appendix 8**.

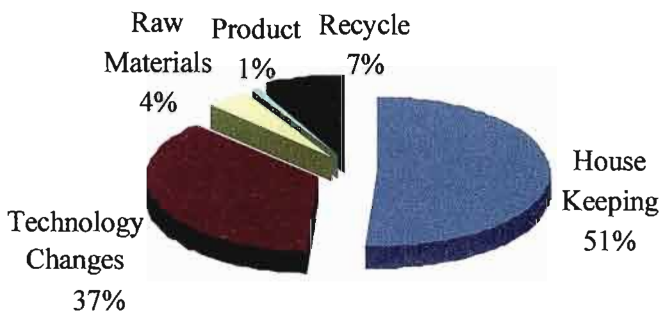

Figure 5.1: Options Identified for 25 Metal Finishing Club Members by November 2000

Housekeeping

Housekeeping improvements represent the highest proportion of options identified and implemented, followed by technology changes. The housekeeping options were the easiest to implement due to minimal cost associated with it.

Common options falling into this category include:

- improved monitoring of utility and chemical consumption,
- installing water meters,
- improved control of processes,
- improved bath control, and
- insulating baths to prevent evaporation.

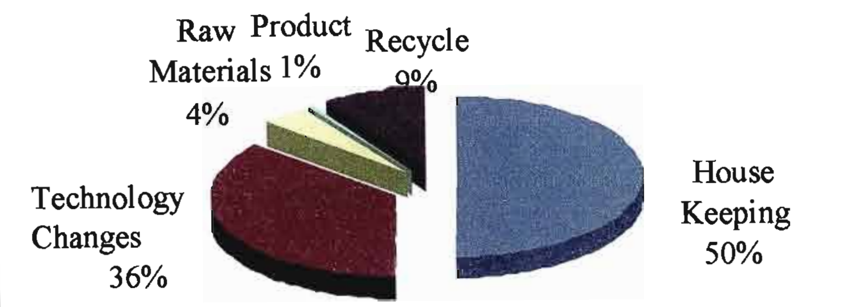

Figure 5.2: Options Implemented by Metal Finishing Club Members by November 2000.

Technology Changes

Technology changes range from simple low cost options to capital intensive ones. Common options in this category include:

- increasing drip times,
- altering jig orientation,
- insulating baths,
- installing new equipment,
- installing dragout tanks, and
- rescheduling of jobs.

The most common options implemented from this category were increasing drip times, and installing dragout tanks.

Raw Material

Raw material changes include:

- altering suppliers, and
- substitution of chemicals

For the metal finishing industry, raw material changes refer mainly to the chemicals used. Companies were encouraged to employ alternative solutions to cyanide metal plating and cadmium plating. These were the areas where the most raw material changes were made.

Product Changes

Those options considered to be product changes include:

- altering the design of products, and
- convincing customers to change their requirements.

Such changes lead to a lower raw material and utilities requirement.

On-site Recycling
Only on-site recycling is considered a waste minimisation option. This can include:
- reuse of baths, and
- reuse of water in either the same process or another process/activity.

The options implemented by each company are given in **Appendix 9**. While only 9 % of the options successfully implemented involved on-site recycling, a number of companies have investigated the reuse of water from effluent treatment. However, companies are encouraged to use less water rather than recycle it. In this way, the demand for water would be reduced. The number of options identified and implemented varied for each company, based on individual situations. Options were implemented based on their technical and economic feasibility. Therefore the least complicated options with minimal associated costs were implemented first. Companies with more resources (time, capital, human) were better equipped to consider more expensive options. A comparison between the number of options identified and implemented by the nineteen companies is graphically represented in Figure 5.3.

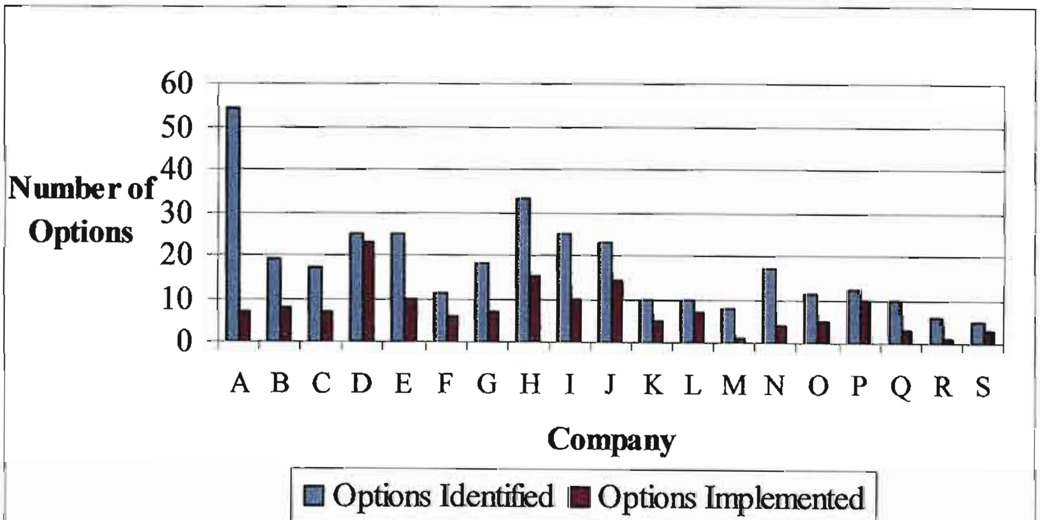

Figure 5.3: Comparison of number of options identified and number of options implemented by 19 Metal Finishing Companies as at November 2000

5.7.3 Discussion

Less than 50 % of the total options identified were implemented. The highest proportion of options identified and implemented was from the housekeeping category. This implies that companies were previously not paying attention to housekeeping, and had become accustomed to their methods of handling processes. Conducting the waste minimisation audits at these companies helped to make them aware of the realities in their establishments.

5.8 FINANCIAL BENEFITS

One of the primary drivers for companies implementing waste minimisation options was the incentive of achieving savings. Implementing waste minimisation options led to improved process efficiency for the companies as well as reductions in costs.

5.8.1 Hypothesis

It was proposed that the size of a company would not be the most important factor determining the amount of savings achieved by individual companies.

5.8.2 Savings Achieved

The most common areas of wastage identified during waste minimisation assessments and site visits were excessive water consumption and loss of chemicals due to dragout and spills. These problems were mainly a result of poor housekeeping practices. This was found to be related to worker education. The implementation of options has resulted in significant financial savings for companies. Club members who have implemented options were requested to report back on any resultant savings achieved, at each club meeting. Nineteen companies have reported the implementation of options, but only sixteen have quantified the resultant savings. Lists of options implemented by each company are provided in **Appendix 9**.

The characteristics of the nineteen companies are presented in Table 5.7.

Table 5.7: Company Characteristics

Company	Description	Number of Employees
A	Manufacturer	800
B	Job Shop	14
C	Job Shop	10
D	Job Shop	50
E	Job Shop	10
F	Manufacturer	80
G	Manufacturer	26
H	Manufacturer	190
I	Manufacturer	350
J	Job Shop	30
K	Job Shop	7
L	Job Shop	9
M	Job Shop	37
N	Manufacturer	300
O	Job Shop	6
P	Job Shop	18
Q	Manufacturer	24
R	Job Shop	80
S	Job Shop	10

The annual savings achieved in water, chemicals, effluent disposal, energy, and waste disposal costs by sixteen companies are presented in Table 5.8. These figures were obtained from feedback during meetings, site visits, and surveys. A dash indicates that the savings in that category were not reported or not quantified.

Table 5.8: Annual Savings Reported by 16 Companies as at November 2000

Company	Water (R/y)	Chemicals (R/y)	Metals (R/y)	Effluent (R/y)	Energy (R/y)	Waste Disposal (R/y)	Total (R/y)
A	33 000	-	-	-	110000	-	143 000
B	600	13 200	-	-	-	-	13 800
C	5 500	110 000	-	-	88000	-	203 500
D	59 400	68 400	-	36 520	33000	-	197 320
E	7 500	-	-	-	5060	-	12 560
F	8 000	24 750	-	-	5500	-	38 250
G	11 000	55 000	-	-	-	-	66 000
H	-	#777 601	168 630	99 880	78870	30 910	1 155 891
I	8 668	10 263	-	33 600	-	-	52 531
J	17 300	30 800	12 100	33 000	-	16 864	1 10 064
K	330	-	-	-	-	-	330
L	550	220	-	-	-	-	770
M	4 770	-	-	-	-	-	4 770
N	40	970	-	-	-	-	1 010
O	-	550	-	-	-	-	550
P	1 000	88 000	-	-	-	-	89 000
TOTAL	**161 548.5**	**1 108 934**	**1 80 730**	**1 77 507**	**287 430**	**30 910**	**2 089 346**

#The chemical savings reported for this company include the savings achieved by changing the type of oil used in the manufacturing process, and therefore does not imply that the company was consuming excessive amounts of chemicals.

As can be seen from Table 5.8, an emphasis was placed on the reduction of water and chemical consumption. While this leads to reductions in effluent concentrations and volumes, a number of companies have not quantified that resultant saving. The reported savings are graphically represented in Figure 5.4. These savings are representative of the club's efforts but do not reflect the total cost savings achieved as a number of companies have not quantified all resultant savings.

The highest combined financial saving was achieved in chemical costs as illustrated in Figure 5.4. As mentioned in **Chapter 3**, section 3.2, the South African metal finishing industry is exposed to world prices when it comes to chemicals and metals. Therefore costs of chemicals are high. Thus there are considerable savings to be made by reducing chemical consumption. Savings in energy are the next highest followed by water and effluent. While significant reductions in water consumption have been made, water is relatively inexpensive in South Africa. Therefore great quantities must be saved to achieve a substantial financial saving.

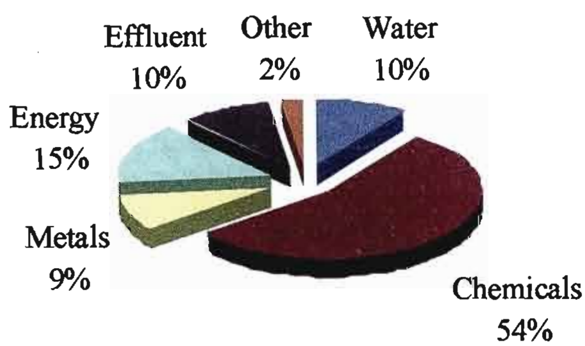

Figure 5.4: Breakdown of Financial Savings Achieved by 16 Metal Finishing Club Members by November 2000

Water

The savings in water costs were mainly achieved through better process control and improved housekeeping. Regulating flowrates in rinse tanks and monitoring water use resulted in substantial reductions in water costs. For some companies, it was possible to alter rinsing configurations so that less water was used. The most favoured option for achieving this was introducing counterflow and cascade rinsing to replace single overflow rinses.

Chemicals

Due to a lack of understanding of the chemistry of process baths, and insufficient monitoring of chemical additions, most companies used far more chemicals than was required by their processes. Companies relied on chemical suppliers for dosing instructions and usually followed this closely. The typical compositions for each type of process bath were available in manuals and handbooks. Therefore by simply, calculating the correct amount needed, and ensuring that this was used, significant savings in chemical costs were achieved. The reduction of dragout, prevention of spills, and the increase of drainage times contributed considerably to most companies' chemical savings. This in turn reduced effluent treatment and disposal costs. Reducing the amount of proprietary chemicals lost to effluent reduced the quantity of treatment chemicals required, which lead to further savings in chemical consumption.

Effluent

Reduced water consumption resulted in a reduction in effluent volumes. The reduction of chemical consumption and chemical loss due to dragout resulted in reduced toxicity of effluent and subsequently considerable effluent treatment savings.

Energy

Energy consumption has not been of as much concern to club members as water and chemicals have been. Metal finishers are generally not big consumers of energy. Energy is used mainly for heating process baths, and in drying ovens. However, a number of companies have reduced their energy consumption by improved process control and monitoring. Two companies (A and H) achieved substantial energy savings from power factor corrections.

Total Annual Savings

The combined reported annual club savings were in excess of **R 2 million** by November 2000. The highest reported saving had been achieved by company H due to the reduction in chemical costs. An attempt was made to obtain some comparison amongst the companies in terms of the savings achieved. This would ideally have been done with respect to annual turnover of each company, but this information was not made available during investigations. Therefore a simple comparison has been performed based on the size of each company in terms of number of employees. The results are listed in Table 5.9. The third column in the table ranks the companies in descending order in terms of the savings per employee.

Table 5.9: Savings Achieved per Company Employee by November 2000

Company	Number of Employees	Savings per employee (R/employee)	Rank
C	10	20 350	1
H	190	6 084	2
P	18	4 889	3
D	50	3 946	4
J	30	3 669	5
G	26	2 539	6
E	10	1 256	7
B	14	986	8
F	80	478	9
A	800	179	10
I	350	150	11
M	37	129	12
O	6	92	13
L	9	86	14
K	7	47	15
N	300	3	16

5.8.3 Discussion

Of the sixteen companies that reported savings, twelve were SMEs. The highest saving per employee was achieved by a company with 10 employees. These results show that there has been great potential for reducing waste at SMEs. Housekeeping practices at the larger companies were observed to be generally satisfactory. This was generally not true of the SMEs. As a result, most of the options identified involved improved housekeeping usually at minimal or no cost to the company making it easier for smaller companies to make improvements.

5.9 ENVIRONMENTAL BENEFITS

One of the primary objectives of this project was to reduce the environmental impact of the metal finishing industry.

5.9.1 Hypothesis

Based on the initial response from the metal finishing industry on the drivers for implementing waste minimisation (see section 5.5.2), it was hypothesised that companies would be interested in the environmental benefits that would result from following a waste minimisation programme.

5.9.2 Overall Environmental Benefits Resulting from the Metal Finishing Club

Reductions in costs have been of particular interest to the companies themselves, but the adoption of waste minimisation by the club's members has lead to significant environmental benefits.

Reductions have been achieved in:

- water consumption,
- metals discharged to drain,
- chemicals discharged to drain,
- volumes of effluent discharged to sewer,
- volumes of sludge disposed of to landfill,
- cyanide use,
- solvent emissions,
- cadmium use, and
- energy consumption.

The decrease in chemical use includes reductions in the use of detergents and other cleaners. Reducing this has resulted in a lower effluent Chemical Oxygen Demand (COD) value. The reduction in COD indicates that the effluent is 'cleaner', more biodegradable and therefore poses less of a problem downstream at wastewater treatment works.

Reductions in heavy metal (zinc, chromium, cadmium) consumption has reduced harmful impacts on the environment. The accumulation of these elements in the environment is dangerous due to their adverse effects on biosystems. The reduction of these metals also alleviated the problem at wastewater treatment plants where heavy metals inhibit the actions of micro-organisms used in effluent treatment. The dangers of cyanide and heavy metals to the environment have been discussed in **Chapter 2**, Section 2.7. Reducing the quantities used thus reduces the occurrence and severity of any harmful effects.

It was difficult to quantify these environmental savings due to a lack of records by companies. The successful implementation of options and the corresponding financial savings proves that reductions in have been made. The quantity of water saved has been calculated based on the cost savings given in Table 5.4. The cost of water has changed since the establishment of the club, therefore an average value was taken. Thus the total financial savings were divided by the average cost of water during the research period, R 2.70/kl. The results are given in Table 5.10. The savings in water have been rounded to the nearest 50 kL.

Table 5.10: Water and Chemical Savings

Company	Water Saved (R/y)	Water Saved (kL/y)	Chemicals Saved (R/y)
A	33 000	1 200	-
B	600	220	13 200
C	5 500	2 050	110 000
D	59 400	22 000	68 400
E	7 500	2 800	-
F	8 000	3 000	24 750
G	11 000	4 100	55 000
H	-	-	777 601
I	8 668	3 200	10 263
J	17 300	6 400	30 800
K	330	120	
L	550	200	220
M	4 770	1 800	-
N	40	15	970
O	-	-	550
P	1 000	370	88 000
Total	**161 549**	**58 000**	**1 108 934**

The total savings in water (almost 60 ML/y) also indicate the reduction in volume of effluent discharged to sewer.

5.9.2 Discussion

The lack of emphasis on environmental benefits was evident from the feedback received from companies. It is clear that less effort was put into quantifying any savings to the environment than with financial savings.

5.10 MONITORING AND TARGETING

The concept of monitoring and targeting was introduced in **Chapter 2**, Section 2.6. As mentioned in **Chapter 3**, Section 3.10, use of the monitoring and targeting software Montage was offered to some members of the metal finishing club as a bureau service.

5.10.1 Hypothesis

Based on the requirements of a monitoring and targeting programme, which are good records specifically of production, utility and raw material consumption and costs, it was proposed that SMEs would not be successful in running a monitoring and targeting programmes.

5.10.2 Results from Initiating Monitoring and Targeting at Selected Companies

A monitoring and targeting programme was initiated at two of the club member's sites. The sites were set up in Montage according to the relevant departments and meters. Unfortunately, there was much progress with this aspect due to a lack of data. A significant problem was the lack of production data. This was essential for the optimal use of Montage as it enables a direct comparison to be made between consumption and the corresponding production for a period of time. In job shops it was difficult to keep records of production as the type and quantity of object plated varied on a weekly and sometimes on a daily basis. A lack of recording of water and energy consumption also posed a problem. The smaller companies generally did not dedicate any time or personnel to take meter readings, as this was not considered important. When data were made available, it was not in the required format or it was not supplied at regular intervals to make meaningful use of it.

As a result, as at November 2000, the club members had yet to realise the benefits of monitoring and targeting.

5.10.3 Discussion

Small sized companies especially were not eager to commit time and effort to a process where the results would only be realised months later. Companies were of the belief that participation in the club and implementing some waste minimisation options was more than sufficient and were not convinced that monitoring and targeting could add value to their processes.

5.11 ADDITIONAL OUTCOMES FROM CLUB ACTIVITIES

Due to the improved relations resulting from interaction among club members, between club members and the authorities, between members and other stakeholders, there was increased opportunity for working together to find solutions to problems facing the metal finishing industry.

5.11.1 Club Members

According to club members, interaction with each other prior to the establishment of the club had been minimal. Club activities resulted in greater interaction. The sharing of ideas and information, and assisting each other in implementing changes resulted in improved relations among companies. Members have collaborated to work on common issues of concern such as sludge disposal. Working together has also lead to the formation of an association for the metal finishing industry in the Durban Metropolitan Area (DMA).

Sludge Disposal

It has already been mentioned that at the time of this study, metal finishers in the DMA could not dispose of their sludge to the landfills in KwaZulu-Natal. This was because the sludge contained hazardous metals and chemicals and the province does not have a high hazard landfill site. Companies then either transported sludge to suitable sites in Gauteng (a practice that is both costly and risky), or stored it on site. A suggestion was made during a meeting of the Bylaw Working Group to investigate stabilising the industry's sludge thus enabling disposal to a local landfill. A proposal was then made by a local waste disposal company to undertake the investigation. The company was willing to fund the study and establish a treatment facility at their site if they received a commitment from the industry to dispose of their sludge at this site. This proposal was put to the industry in August 1999, and by February 2000, 22 companies signed a commitment. The disposal company then decided it needed to establish if the project would be profitable, and therefore requested information on volumes and characteristics of each metal finishing company's sludge. A student was then hired to collect this information. Club members expected to receive further feedback on the progress of the study, but the solution that they were assured of by June 2000 was not received. This led to alternative methods of sludge stabilisation being sought, such as the formation of bricks.

In June 2000, a manufacturing company made a second proposal to club members. The company proposed mixing metal hydroxide sludge with zeolite and clay to fire it in a rotary kiln furnace at 1000 ^{0}C. The final product would have been environmentally safe and could be disposed of easily at a landfill site. A trial run was conducted with waste from two club members' companies. The procedure reduces waste metal content down to 0.1 ppm and the product would be suitable for the manufacture of bricks and tiles. While the local authorities were enthusiastic about the project, the company was required to perform an Environmental Impact Assessment at its site before the project could be permitted. In September 2000, the club was informed that a scoping audit at a cost of R 25 000 would have to be carried out at the company to determine if the project could be allowed. While companies awaited the results, many continued to store their sludge while some found ways to use it in cement and bricks. The situation had not been resolved as at November 2000.

The Metal Finishing Association

The club led to the formation of the Metal Finishing Association (MFA), which was initiated by a group of club members. The first official meeting of the MFA was held on 10 July 2000. The members adopted a constitution, and elected a committee. Three club members were elected to the committee. The association has eighty-nine members consisting of electroplaters, powder coaters, and hot dip galvanisers. The purpose of the association was to deal with issues of mutual concern to the metal finishers like waste minimisation and waste treatment. The constitution emphasises environmental issues, and the association planned to establish new waste minimisation clubs. A metal finisher's club was formed in Pietermaritzburg (Pmb) consisting of eight members. A general club was also established in the Pmb region by Umgeni Water. New clubs were planned for the Durban/Pinetown area in 2001.

The MFA was included in the planning discussions of a hazardous waste disposal site in Durban. A club member was chosen to represent the MFA on the committee.

5.11.2 Chemical Supplier

Chemical suppliers are important to the metal finishing industry. Many companies relied on their chemical supplier for bath maintenance. The supplier common to most club members made an effort to assist companies in reducing waste generation and improving their operation. Consequently, a representative of this company, who was an interested party in the club since its formation, was elected a club member by the companies. The companies valued the information and technical expertise given to them by this supplier.

5.11.3 Local Authority

When the club was formed, the metal finishing industry was facing the introduction of new bylaws by the Metro. As a result there was tension between the two parties. The relationship between club members and the Durban Metro improved since the club's formation. The Bylaws Working Group was instrumental in bringing about this improvement. The attitude of the Durban Metro towards club members also changed once they became aware of the efforts made by companies to reduce metal concentrations and overall environmental impact.

Bylaws Working Group

One of the reasons for targeting the metal finishing industry in Durban for promoting waste minimisation was the impending introduction of new effluent bylaws. These bylaws were met with objections from the industry. As a result, the Bylaw Working Group was established in December 1998. The purpose of the group was to discuss the objections and develop bylaws that were acceptable to all stakeholders. The metal finishing industry was represented by three club members. Other members were from the Durban Metro Waste Water Department, a chemical supplier, the Durban Chamber of Commerce, and the Department of Water Affairs and Forestry. The efforts of the working group resulted in the effluent metal limits for industry discharging to the Umbilo Sewage Works being relaxed to the original limits. This followed a study that was conducted by a club member (also part of the working group) into the effluent generated by metal finishing companies in the area. The study showed that metal finishing companies were not responsible for the high concentrations of metals present at the treatment works.

5.12 PROMOTING WASTE MINIMISATION AND WASTE MINIMISATION CLUBS

At the beginning of this project, there was no known case of a waste minimisation club in existence in South Africa. The concept of waste minimisation was foreign to most SMEs and concern for the environment was not a top priority for these enterprises. However since the formation of the club in 1998, not only did the club members become familiar with waste minimisation and its benefits, but so did the rest of the industry and other industries in different provinces. The club's newsletter was distributed to various interested parties including those within government departments.

5.13 ANALYSIS OF CLUB APPROACH

The results achieved by club members indicate successful implementation of waste minimisation programmes. While the successes were significant, there were many drawbacks to the running of the club. The lessons learnt are valuable for the future management of similar clubs.

5.13.1 Success Factors

The key success factors that were a direct result of the activities of club members are discussed below.

Awareness and Capacity Building

Prior to joining the waste minimisation club, the companies had little or no knowledge on waste minimisation and its benefits. The formation of the club had a ripple effect in that the dissemination of knowledge was not only within the club, but within the metal finishing industry, other industries, in KwaZulu-Natal, other provinces and academic institutions and many interested parties. Aside from building capacity on waste minimisation, the club served to enlighten industry on the environment in general. Companies not only became aware of the wastes and the impacts thereof that they were generating, but also learnt from the mistakes of their fellow club members through the information sharing that took place.

Environmental Impact and Profitability

From the results, it is evident that adopting waste minimisation practice led to increased profitability for the companies involved as well as significant benefits to the environment. The low cost associated with the common improvement options makes waste minimisation an excellent business tool.

Social Interactions

As mentioned earlier, the club served not only to improve relations among members of the industry, but also between members and the local authority. This contributed to achieving the goals of waste minimisation due to the openness and willingness to assist each other. Members assisted each other in finding solutions to specific site problems and were encouraged by each other's success. The improved relationship with the local authority created the opportunity for constructive discussions between members of the club and the authorities.

5.13.2 Lessons Learnt

The club was formed quickly due to pressure from the local authority. There was therefore insufficient time to plan the club's management. Valuable experience was gained while facilitating the club, which should be taken into consideration for the future establishment of clubs. The most important lessons are described below.

Meetings

Due to the large size of the club, regular club meetings were important to provide information to members and to obtain feedback from companies so that results could be updated. It was thus a drawback when meetings were poorly attended.

Club members were notified of meetings two weeks prior to the date of the meeting, and were reminded the day before the meeting. Meetings were generally attended by a core group of sixteen members. It was thus difficult to obtain information on the progress made at all companies, or the problems experienced. A number of members requested to be kept informed of the meetings and the discussions that took place despite being unable to attend.

The time and duration of meetings were often said to be inconvenient for most members. Many project champions felt they were needed more on site than at a meeting. Despite the discussion sessions of meetings being held informally, it was observed that many companies did not participate due to feeling overwhelmed by those club members who had made significant progress. Some companies were not comfortable with speaking in front of others.

Training sessions were also poorly attended despite being held after normal factory hours. A combination of meetings and training sessions is thought to be more successful in the future.

Motivation and Commitment

Initially it was difficult to convince companies of the benefits of waste minimisation to their businesses. The lack of awareness and understanding of the subject was an obstacle to realising the benefits that were described in the literature reviewed. The lack of interest by the metal finishing industry was first evident at the inaugural meeting in June 1998, where out of eighty companies, only twenty-nine joined the waste minimisation club. In addition, only sixteen companies were actively involved in the club. As discussed in sections 5.5.1 and 5.5.2, the main reasons for the companies joining the club were given as legal compliance and cost savings. However, from discussions and observations, it was clear that a number of companies did not believe they would achieve any financial savings. This was especially true of smaller companies who were sceptical of investing time, effort, and money in something new. It was important to provide them with real cases of waste minimisation success stories in order to motivate them. Success by a single company within the club proved to be very instrumental in jumpstarting other companies' waste minimisation programmes.

Some companies were complacent and were prepared to be part of the club in the hope that this would be well favoured by the local authority. It also took a while for companies to trust the facilitator and each other. Members were not enthusiastic about divulging information on their companies, especially since some were in competition with each other.

Most project champions were responsible for more than one task at their companies such as process control and production, and therefore could not devote significant proportions of their time to waste minimisation programmes. This prevented regular attendance at meetings and training sessions. It was also difficult to arrange meetings and site visits with companies, and often months would go by before a site visit could be set up.

Waste Minimisation Programmes

Insufficient emphasis was placed on the importance of waste minimisation project teams and champions to run waste minimisation programmes. The tasks of the team should have been clearer, and each company needed to set definite goals for minimising waste. While companies made commitments to running waste minimisation programmes, these did not always prove to be well thought out. This was especially true when the required additional information necessary to implement changes, such as data on consumption of raw materials and costs was not readily available. Thus a major difficulty experienced during the running of the club was the collection of data during waste minimisation assessments. This was particularly difficult with the smaller companies where records were not easily attainable. A number of the smaller companies did not keep records of production data or utility consumption, and raw material consumption and costs. In many instances when information was required, it was necessary to visit the company personally to retrieve the data. In the case of water consumption, water meter readings had to be taken personally. In some cases required information would be received months after it was requested. The club members involved attributed this to busy schedules and production issues. This severely slowed the progress with waste minimisation programmes.

Club Size

Generally, a waste minimisation club consists of between ten and fifteen members as was the case in most successful clubs formed in the UK. The Metal Finishing Club however consisted of twenty-nine companies. This resulted in some difficulties being experienced in managing it. The large number of members made it necessary to recruit students to assist with the initial assessments at the companies. These results were discussed in section 5.1.2. While the club was sector specific (consisted of metal finishers), due to its size it was not always possible to focus meetings on an issue that was of equal importance to all members. This created a feeling of being overlooked by some members. In addition the size meant it was more difficult to provide individual assistance to each company on a regular basis. It was difficult to co-ordinate meetings based on each project champion's availability. However, as discussed in section 5.3, as the club progressed, the companies making the most progress attended meetings regularly. This was generally sixteen members, which would have been a more appropriate size for the club.

Project Champions

As mentioned in **Chapter 2**, section 2.5, the roles of the project champion is to co-ordinate and facilitate waste minimisation within the company. It follows that this person should be enthusiastic about the process, be able to organise the project, communicate the requirements and results, and have the ability to gain support from co-workers. It was also mentioned that in order for waste minimisation to be successful, the support and commitment from senior management is essential. The project champions from the metal finishing club were mainly the owners or managers of their respective companies. This was helpful in that they were able to see first hand what the benefits of waste minimisation were, and were able to implement changes without having to first seek approval from management. The drawback to owners and managers being project champions was seen in a few cases where due to having a number of other responsibilities, these project champions did not have the time to attend meetings regularly.

The attitude of project champions was a key factor in determining whether progress was made with waste minimisation. Those project champions who were enthusiastic and willing to make an effort managed to achieve the objectives of waste minimisation. A number of project champions remained sceptical about the benefits of waste minimisation despite hearing about the successes of other members.

5.14 SUMMARY

Due to the large number of club members, it was necessary to hire students to carry out the initial waste minimisation audits at companies. This initiated waste minimisation programmes at each company, which were co-ordinated by a project champion from within the company. The project champion was expected to attend regular club meetings where waste management and other issues of relevance to the metal finishing industry were discussed, and feedback was obtained from companies on their progress with waste minimisation. Assistance was provided to project champions whenever possible.

During the course of running the club, it was determined that the main barriers to companies implementing waste minimisation were a lack of time, a lack of resources, and a lack of commitment.

As at November 2000, more than 300 waste minimisation options were identified for the companies. Less than 50 % of the options were implemented. Companies did however achieve significant savings with the options that were implemented. More than R 2 million per year was saved from reductions in water, chemicals, energy and metal consumption, and waste treatment and disposal costs. It was found that the size of a company was not critical to the success of waste minimisation, as one of the smaller companies achieved the highest saving as at November 2000.

The club led to significant improvements in relations among club members, between club members and the local authorities, and between club members and chemical suppliers. The club helped to build capacity on waste minimisation within the metal finishing industry and other organisations. As the club was a pilot study, there were some problems experienced managing the club especially due to its size, and a lack of commitment and motivation by some members.

CHAPTER 6 – CONCLUSIONS

Water conservation is no longer an option in SA-it is an absolute necessity. We cannot afford to squander this lifeblood of our people, our economy, our environment.

Prof Kader Asmal

Minister of Water Affairs and Forestry (1994 – 1999)

This project investigated the use of a waste minimisation club to promote waste minimisation within industry. The metal finishing industry in the Durban Metropolitan Area was chosen as the focus of the study due to the environmental problems faced by the industry and its proximity to the Pollution Research Group.

This chapter summarises the main findings of the project and provides recommendations developed from these findings. The aim of the recommendations is to provide guidelines for the future management of similar clubs.

As mentioned in **Chapter 1**, section 1. 6, the main aim of this project was to promote waste minimisation within industry by establishing and sustaining a waste minimisation club.

Secondary aims of the project were to:

- reduce the demand for water by the metal finishing industry,
- improve water quality through pollution prevention,
- assist companies in complying with bylaws,
- demonstrate the benefits of waste minimisation to industry,
- develop the concept of waste minimisation clubs for South Africa, and
- analyse the results to improve running of future clubs.

6.1 SUMMARY OF FINDINGS

The waste minimisation club for the metal finishing industry was successfully run for two and a half years.

During this period, the following results were obtained:

- A total of 391 waste minimisation options was identified for 26 club members as at November 2000, and 19 companies reported an implementation of a total of 147 of these options;
- The highest proportion of options identified and implemented was from the housekeeping category;
- Fourteen companies saved a total of 120 ML of water over the duration of the project;

- Twelve companies reported a total financial saving (from June 1998 to November 2000) in chemicals of more than R 2 million but did not report actual quantities saved. Similarly for metals where approximately R 360 000 was saved, and effluent energy and waste disposal where total savings of R 360 000, R 560 000, and R 62 000 were saved respectively;
- A total saving (over the entire research period) of R 4.2 million was made by 16 companies;
- Capacity was built within the club on waste minimisation, and successful dissemination of information was achieved through the distribution of the club's newsletter;
- It was difficult to be certain that members fully grasped the meaning of waste minimisation as some members believed that installing an effluent treatment plant constituted waste minimisation;
- The main barriers to implementing waste minimisation were identified as a lack of time, resources, and commitment;
- The main drivers were identified as cost savings, attaining legal compliance, and reducing environmental burden;
- The club improved relations within the metal finishing industry, between members and the local authority, and between members and chemical suppliers; and
- Analysis of the results indicated that the club's size and lack of motivation by club members were at times a drawback to the management of the club.

The results show that a commitment to waste minimisation and a well managed waste minimisation programme results in significant financial savings as well a lower environmental impact. Positive feedback was received from club members, who believed that the club had been of great benefit to them. To most members, waste minimisation was a simple way to improve efficiency at their factories, achieve cost savings and meet regulatory requirements.

It has been found however that some companies lack the commitment to continue with waste minimisation programmes. This is largely a result of the lack of time available for waste minimisation activities, especially in the smaller enterprises. The success achieved by the proactive companies who benefit the most from waste minimisation served as an incentive for other companies to become more active and commit time to a waste minimisation programme.

6.2 REALISATION OF OBJECTIVES

Based on the results of the project, it is evident that the objectives have been achieved. The club has successfully promoted and increased awareness on waste minimisation in the metal finishing industry. Significant savings in water, chemicals, and energy were made by club members. The negative environmental impact of the companies was reduced due to reductions in the use of harmful chemicals. A number of companies were able to comply with local discharge limits for metals due to reducing the amount of metals sent to drain. The metal finishing club led to further clubs being established in South Africa.

6.3 RECOMMENDATIONS

While a number of successes were achieved with the club, the following recommendations may assist to improve the future management of other waste minimisation clubs:

- The waste minimisation champion, management of the companies, and shop floor employees should receive training in the implementation of waste minimisation;
- Companies should report on options implemented and savings achieved on a more regular basis, and in writing;
- The results reported by companies should be verified by an independent person;
- Greater emphasis should be placed on the concept and importance of monitoring and targeting;
- Club membership should be limited to between 10 to 15 companies to facilitate improved management;
- Training should be conducted in conjunction with regular club meetings, and should start with the first meeting.

As clubs are a voluntary organisation, it would be useful to have the support of all spheres of government to make the waste minimisation club concept more attractive to industry. In this way the major polluting industries would not only be able to reduce their environmental impacts but also improve relations with relevant government departments. If further clubs were to be established for small and medium sized industries, it would be beneficial for government to subsidise these clubs or provide an incentive for companies to participate in a waste minimisation club.

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APPENDIX 1: INITIAL WASTE MINIMISATION ASSESSMENT REPORTS FOR COMPANIES E TO Z

COMPANY E

Background
The company is a small electroplating shop situated in Jacobs, Durban, South Africa. The company has been in operation for 8 years and employs 10 people. A number of different components are plated including nuts, bolts, burglar guards, gates, and screws. Objects plated are usually constructed of iron or steel. Being a job shop, the company has a number of different customers, who bring jobs in to be zinc or cadmium plated.

Process Description
The company performs zinc and cadmium plating. The main unit operations involved in the processes include degreasing, acid pickling, plating, washing, and passivating. The zinc barrel plating procedure is described below.

Zinc Barrel Plating
The tanks that make up this line and the procedure followed is described in detail in this section.

- Degreaser
  The function of this bath is the removal of heavy grease, soil and oil from components to be electroplated. Polycans are cut and holes are made on the bottom for drainage [from now on these polycans are going to be referred to as baskets. Components to be electroplated are placed in the baskets and then these baskets are placed into the bath. They are kept in the bath for sufficient amount of time for the removal of the grime and then are manually removed with the help of an overhead crane. The excess solution is drained out.

- Water Rinse
  Rinsing serves to remove excess soap solution from the components to be electroplated.
  The baskets are placed into the bath using the overhead crane and manually. They are kept in the bath for sufficient amount of time and then are manually removed with the help of an overhead crane. The excess solution is drained out.

- Pickling
  Cold dilute hydrochloric acid is preferred by some operators for pickling iron or steel parts that only have a thin film of oxide on them as it leaves a somewhat cleaner surface than sulphuric acid on mild steel. It is generally recommended for removal of heavy scale. Hot acid presents a problem since the fumes are rather objectionable and the selection of hooks, baskets, and heating coils, which will withstand this action, presents a problem. Therefore hot acid is not used.
  The baskets are placed into the bath using the overhead crane and manually. They are kept in the bath for sufficient amount of time and then are manually removed with the help of an overhead crane. The excess solution is drained out.

- Rinse
  The purpose of this step is to rinse off excess acid solution from the components to be electroplated.

The baskets are placed into the bath using the overhead crain and manually. They are kept in the bath for sufficient amount of time and then are manually removed with the help of an overhead crain. The excess solution is drained out.

- Zinc Plate
  Three zinc plating tanks are present. The electrodeposition of zinc onto the metal objects takes place here.

- Rinse
  This step removes excess plating solution from the components to be electroplated.
  The baskets are placed into the bath using the overhead crain and manually. They are kept in the bath for sufficient amount of time and then are manually removed with the help of an overhead crain. The excess solution is drained out.

- Blue Chromate Passivation
  The purpose of passivation processes is to protect zinc from corrosion, so that their main task of sacrificial protection to steel is not reduced. Passivation coatings also form a perfect bonding layer for subsequently applied paint schemes. Blue passivation processes are employed on bright zinc where increased resistance to corrosion and finger marking is required whilst still retaining a bright decorative appearance.
  The baskets are placed into the bath using the overhead crain and manually. They are kept in the bath for sufficient amount of time and then are manually removed with the help of an overhead crain. The excess solution is drained out.

- Yellow Chromate Passivation
  Function and process similar to blue passivation

- Rinse

Effluent Treatment
Process Steps :
- Neutralisation
- Precipitation
- Solids settling
- Effluent discharge to council sewer
- Settling tank desludged annually

Chemicals used :
- Soda ash
- HTH

Sludge quantity :
- 3 kL per month

Table 1A: Chemicals and Metals expected in the effluent of Company E:

Major metals expected	Major chemicals expected
Zinc	Zinc oxide
Cadmium	Sodium hydroxide
chromium	Sodium cyanide
	Brightener
	Hydrochloric acid
	Free hydroxide
	Free cyanide
	Hexavalent (chromic acid) and trivalent chrome from the passivation solution
	Water

Observations :

- No proper sampling point. Sample taken directly from settling tank.
- The settling tank is too small. As a result retention time is low to allow for proper settling of solids.
- No treatment for hexavalent chrome.
- No treatment for cyanide.
- No automatic pH correction unit.

Suggestions for Improvement

Areas of concern	Suggestions
Contamination of the ground/soil. Concrete on the floor is corroding away. The floor has pools of standing solution everywhere. The plating area in Room 1 is very muddy. Don't know exactly what the solution on the floor is. There is no evidence of the solution being neutralised etc.	• The old floors must be thoroughly cleaned with detergent and all broken and uneven areas must be carefully repaired to a smooth surface. • A leak proof material must be applied to the re-concreted or repaired floors. • Finished concrete floors should be covered with a corrosion resistant material of brick or tile and then with a resinous monolithic coating.
The pre-cleaning, washing and passivation baths are in bad condition. Some are cracked on the top. The plating tanks are very rusty especially the cadmium plating Tank. The cadmium-collecting tank is also badly rusted.	Baths should be dumped of its contents, them cleaned. A period should be set aside for maintenance. Baths with cracks should be replaced as soon as possible before the cracks propagate and unnecessary spillage's occurs. The plating tanks should be dumped of its contents, cleaned, the rust should be rubbed down and a rust resistant coating should be applied to protect it. The cadmium-plating tank is in bad condition. It needs to be replaced.
In the waste effluent there is no treatment of hexavalent chromium.	The treatment procedure is as follows : • Reduce hexavalent chrome to trivalent chrome by the addition of neutrachrome. • Adjust pH between 8 and 10 to allow metals to precipitate out. • If you have an alkali stream you can use this stream to help pH adjustment provided all cyanide in this stream is killed off first. • Allow the sludge to settle. • Sludge has to be removed by a reputable waste

	removal company. • Clear liquid can be disposed off into the sewer according to the municipal by-laws.
The baths have never been cleaned. When the plating solution is depleted of certain reagents – more reagents are simply added to the bath.	A fixed time should be set aside for maintenance where the plant is shut down, the contents of the baths, tanks are dumped and then the baths, tanks are cleaned. This will ensure that the baths, tanks last longer.
Drag-out is high especially from the CN Zinc (barrel plating) electroplating tank.	• Reducing bath viscosity can reduce drag-out between baths. One of the most common methods is to operate the plating process at the lowest concentration possible. Another method is to operate at the highest possible temperature. • Adding wetting agents to reduce surface tension also minimises drag-out. • Properly positioning the parts on the rack is important both for quality as well as drag-out reduction considerations. • One of the most critical factors is the speed with which the part is transported away from the bath. Two techniques are: Maximising drip time – drag out volume is reduced but time is lost. Using drip shields or boards to capture and return drag-out as a rack or barrel is transported away from the process; using drip tanks to collect drag out. • A drag out tank can be installed. A drag out tank is a rinse tank that is initially filled with water but is stagnant and drag-out accumulates in the tank. The contents of the tank are used to replenish drag-out and evaporative losses occurring in the process tank. Water is added to the drag-out tank to maintain the operating level.
There is a need to educate the workers on waste minimisation. Greatest problem is the co-operation of the employees.	Employee training should cover : • Prevention of waste generation at the source. • Routine process chemistry additions and sample taking. • Handling of spills and leaks. • Operation of pollution control and control techniques. • Overall benefits to health and safety. If employees lack interest then incentives should be provided like : • Bonuses. • Employee of the month.
Electrical heating coils in the degreasing baths are left on the whole night. They are only switched off over the weekends. The reason being that it takes too long for the degrease baths to reach the desired temperature of 60°C. Therefore, there is a wastage of energy.	A timer should be installed in each bath or one timer should be connected to all three baths. It should be programmed to switch the heating coils on automatically at midnight to 2 PM when the rates are low. This will ensure the reduction of heating costs and the electrical costs will be greatly reduced.
The cooling system for the zinc-plating tank in	• The cooling system should be repaired.

room 1 doesn't seem to functioning properly. Water is used by the workers to cool the metal on the tank before releasing the barrels.	• The tanks can be insulated so that less heating duty is necessary and thus less cooling duty is necessary. The cooling system already installed may then prove to be adequate.
The hose which supplies water from the cooling system in the zinc-plating bath to the rinse water bath before passivation is left on all the time. Therefore, it adds to the wastage of water.	A counter-flow rinsing series should be installed here. A counterflowing rinse series consists of a series of tanks where fresh water enters the tank furthest from the process tank, in the opposite direction of the workflow. As work runs through a counterflowing series the first tank becomes more concentrated than the next. The flow rate is calibrated to achieve the desired concentration in the last or cleanest tank.
Too much of water is lost in the effluent due to various reasons which have been discussed basically in the process descriptions above.	• Drip times should be increased to ensure proper drainage. During the drip time the baskets should be held above the baths and not over the floor. This will ensure that unnecessary water and chemicals is not lost to the effluent. • The two overflow rinse tanks in the Zinc plating process (barrel plating) should be replaced with a counter current rinse tank system. This will reduce water costs by a tenth here. • Water used in the cooling system should be stored in a tank and then used in the rinse tanks when necessary. This water could also be cooled and re-used as cooler duty. • Allow as much drainage time as feasible over the process tank from which the workpiece or basket has been withdrawn.
There are only static rinse baths in Room 1	• Could be replaced by counter-flow rinse baths.
In room 2 there is a sharp, pungent odour (probably the acid). Both plating rooms are very smoggy. A ventilation system is not installed. There are two fans in Room 1 but there are no fans in Room 2.	Ways to reduce the air emissions into the workplace. • Exhaust hoods and good ventilation. Open tank operations form which mist and, spray or volatile gases can escape are particularly in need of such equipment. • Every effort should be made to design hoods which enclose as much of the tank surface as possible. This will result in better ventilation using smaller ducts and fans, and lower power consumption. • Mist eliminators should be fitted over acid cleaning baths and electroplating baths.
In room 2 there are no overhead cranes available to help the workers to maintain good drainage because the baskets and the components are very heavy.	Overhead cranes should be installed to ensure that maximum drip time is allowed.
In Room 2 a hose is used to rinse after galvanising. No rinse baths available.	One of the following routes can be taken : • A counter-flow rinsing series should be installed here. If this proves to be too expensive any static rinse bath can be used. Either way, there will be a great water reduction. • ECO (economical) Rinse bath can be installed. ECO rinses are static rinses in which the workpieces are immersed in the rinse tank before and after treatment in the plating bath. The term

	dragin-dragout may be applied to this procedure. Dragout is lowered by 50% because the same quantity of liquid is transferred to the treatment bath (by the unreacted work pieces) as to the subsequent rinse tank (by the treated pieces).
There is no set time for galvanising. The time varies. Components are taken out when the workers feel that they are galvanised.	A timer and sensor should be placed on each barrel. When the set time for plating is complete a warning light should go on or a beeper or siren should go on. This will improve productivity.
In the cyanide plating tank the barrel seems to be moving too fast. Solution is splashing out slightly. There is a danger of it getting onto somebody's face. There also seems to be some friction between the barrel and the side of the tank. Some electrical spark is emitted each time. This is very dangerous.	Adjust the speed of the bath and check what the source of the sparks are. It could be friction because the surface of the barrel as well as the plating bath is badly corroded.
No sampling point on settling tank. Samples taken directly from the settling tank by the municipality.	A sampling point should be installed. It is very dangerous to take a sample directly from the settling tank. The person taking the sample may accidentally fall into the settling tank.

Company F

Background
The company is a manufacturing company situated in Pinetown, South Africa. The company has been in operation for 19 years, employs 90 people, and is concerned with the manufacture of zinc and steel trims, and the plating of these objects. The main products include nameplates for jeans/shoes, buckles for shoes/belts, and buttons/studs for clothing etc.

Process Description
The processes carried out in the factory are spin casting pressure die casting (PDC), impressed metal stamping, tumbling, and electroplating. A flow diagram of the operation is shown below:

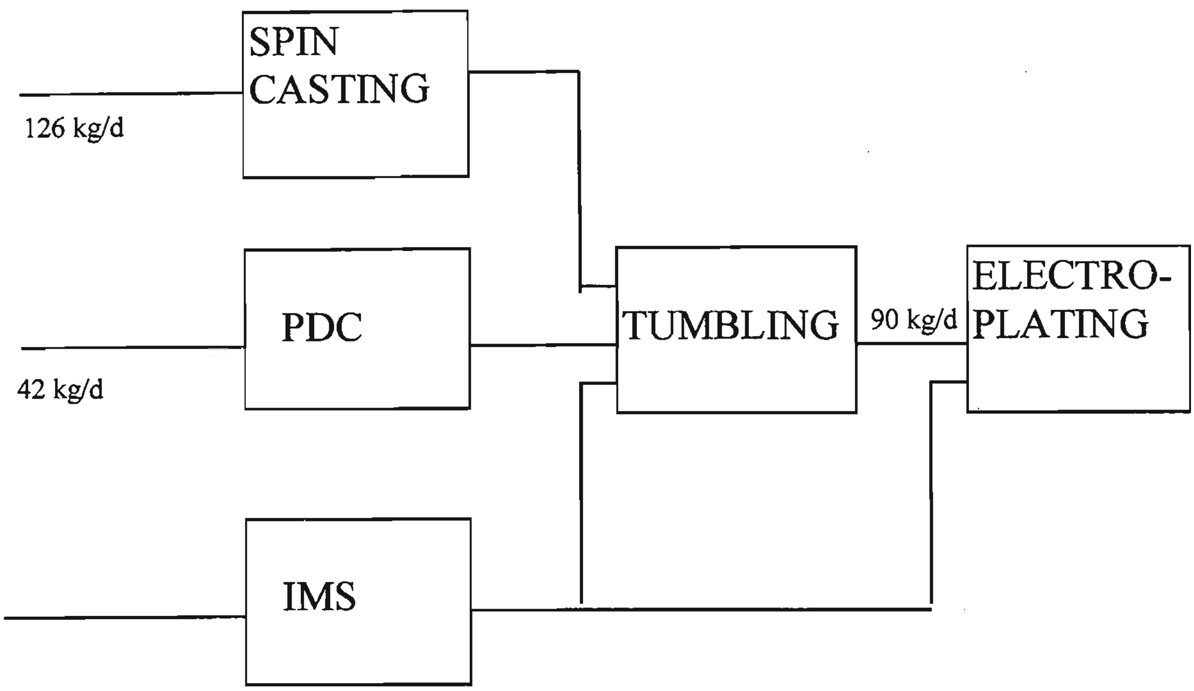

Figure 1A: Flow Diagram of Processes at Company F

Spin Casting

Silicon moulds are made in the factory for specific trims. The mould is placed in a spin caster and molten zinc is poured into the centre on the mould. During the spin casting , the zinc alloy flows from the centre of the mould to the trim imprint and hardens in the shape of the desired trim.

Pressure Die-Casting (PDC)

Molten zinc flows into a steel tool which has the trim imprint in it. The zinc alloy flows into the tool under pressure via a piston. Trims are made much quicker and there are fewer off-cuts as compared to spin-casting. The moulds are also more durable than the silicon moulds used in spin casting.

Impressed Metal Stamping (IMS)

Huge metal stampers, stamp out steel trims from coils of steel wire or steel strips depending on the trim being made.

Tumbling

Tumbling is where the deburring or grinding, polishing and paint removal of trims is done. The trims together with a quantity of grinding medium are rotated in mini-grinders for about 1-2 hours depending on the finish required. Water is used throughout the grinding process to continuously remove fine metal particles, which result from the deburring process. These fine metal particles form the main source of the factory's sludge.

Electroplating

Procedure for plating a die-cast trim (all rinses used are static)

- Wash trims in a soap cleaner
- Spin in the electro-cleaner and rinse in water
- Place in sulphuric acid
- Return to water (water must be clean - use hose)
- Barrel of trims are placed in a copper tank for 45min -1 hour.
- To check the quality of the plating, place a handful of the trims into sulphuric acid. There should be no bubbles.
- The barrel is then placed in the nickel tank for 45min.-1 hour.
- Depending on the finish required, it would then go to gold, brass, zinc or silver.

The same procedure applies for steel trims except for the following:-

- the steel trims are first dipped in a degreaser and then hydrochloric acid.
- the trims do not pass through procedures 5 and 6 above.

Effluent Treatment and Disposal
Approximately 2 tanks (5000 lt. each) are discharged daily.

These tanks are treated with HTH to detoxify the cyanide and caustic soda lye to precipitate out heavy metals.

Cost of Water/Effluent Treatment

- Water costs R2,51/kilolitre,and the company uses approximately 16 kL/day. This reflects a monthly expense of about R 1 100.

- The Durban Metro charges R600/month for their services of testing the effluent on a daily basis.

- HTH costs R14,70/kg and caustic soda costs R2,29/kg.

- Sludge is dumped between 1 to 2 times / annum.
- Clean-out of tanks occur once every 2 weeks.

Suggestions For Improvements

- Urinals
  Two urinals at the company are continuously consuming water throughout the day. They are designed to flush automatically, even when they are not in use. A press-button type flusher would be more cost effective and will reduce water consumption.

- Recycling Water
  About 5000 litres of water per day is utilised in the tumbling section. The waste stream resulting from this section contains no toxic substances. Hence, through simple filtration to separate the non-toxic sludge, the water can be recycled back to the tumbling section.

Company G

Background
The company is a manufacturing concern situated in Durban. It employs 26 people and has been in existence for 12 years. The company manufactures costume jewellery and other related decorative items, and performs copper, nickel, brass, and gold plating.

Process Description
Items to be plated are placed in labeled basins, transferred to barrels and placed in a soap bath for 2 to 4 minutes. Thereafter it is rinsed for 3 to 5 seconds in a static bath. The barrel is then transferred to an acid etch tank, where it is left for 15 to 20 seconds. Rinsing takes place again, followed by plating. A final rinse follows. For gold plating, the items are first nickel-plated. Plated items are transferred to water filled basins before entering the heat-dryer at 60°C. Dried items are placed in a bucket-type colander and dipped into the topcoat solution drum. Leaving the bucket over a second drum drains excess solution out. Coated items are then transferred to a table where it is spread out and fan-dried.

Effluent treatment and disposal
The company does not treat effluent heavy metals and cyanides, and has no settling tank for solids removal

Suggestions for Improvement

- Introduction of Copper and Brass drag-out tanks.
- Attempt to use a series of static rinse tank for Nickel-plating since high cost chemicals are used.
- Approach the Durban Metro to set-up a separate "water-meter" for the company, which should be monitored regularly.
- Increase barrel drip times to reduce drag-outs
- The electrical-wiring system needs attention, since most of the connections are overloading the main power supply.
- To reduce evaporation from the surface, a spray suppressant is essential for Cu plating solutions. This is to maintain a foam blanket over the solution surface.
- The company is to consider treating the hexavalent chromium using sodium metabisulphite or ferrous sulphate. The trivalent chromium can thereafter be precipitated out together with other heavy metal cations using either sodium hydroxide or soda ash.
- A settling tank and an automatic pH correction unit need to be installed.
- Attempt to record plating procedures and chemical usage, as no file exists on the chemical consumption.
- Set up a monitoring programme for chemical addition to know exactly what is added, where, how often and in what quantities
- The most durable type of flooring is based on an epoxy resin/aggregate mix, which provides a heavy duty, jointless floor which will resists abrasion, impact, heavy loads, acids, alkalis and plating solutions.
- An important feature is that it has no jointing to trap solutions and does not create dust.
- If concrete floors are utilised, the floors must be treated with sodium silicate, which produces a harder and cleaner surface with increased resistance to abrasion. It also reduces the permeability of the concrete to water, oil and other liquids.
- The timer to control the water overflow should be replaced by an automatic timer that operates during working hours.

- This automated timer reduces the water consumption even during the lunch-breaks.
- Install flow-meters to monitor the water flow into the rinse tanks if an automated timeris not used
- Set up a safe storage area for the chemicals as they are presently easily accessible to the workers
- Improve general housekeeping by drying up stagnant water regions. This provides a safer working environment
- Recovery of carelessly misplaced plated items may be facilitated by the use of a large magnet
- To reduce the amount of solution spilled during the transfer of barrels from the plating bath to the drag-out tank, a tray should be placed across the two tanks with the tray slanting down into the plating solution. During barrel transfer, the excess chemical solution drain back into the solution tank and the excess solution from the drag-out.

COMPANY H

Background
The company is concerned with the manufacture of metal fasteners and rivet tools, and the electroplating of these objects. Electroplating is therefore one step in the manufacturing process. The company's main markets include car dealers, electrical companies, and telephone manufacturers.

Processes
The plating and effluent plants were investigated in detail.

The Plating Process

The plating plant at this company allows for the following types of plating:

- zinc
- nickel
- copper
- brass
- antique copper/brass

The majority of the products are zinc-plated. Consequently, it was this plating line that was considered in detail. Zinc plating serves as a rust-proof finish for certain base metals. However, since this does have the tendency to corrode under certain atmospheric conditions, certain products are also passivated, ensuring additional protection for the metal.

The manufactured objects, due to their small magnitude, are placed in barrels which are then immersed into the zinc plating bath. The number of products in any particular barrel varies depending on the size of the individual product. Similarly, the amount of time for which it is immersed varies, depending on the required amount of plating. Typically, it varies from 25-60 min. The object is then immersed into the required passivate, as specified.

The zinc plating process occurs as follows:

- The barrel is initially submerged into an electrolytic degreaser to clean the product [approx. 2 min ; temp = 60 °C]
- Thereafter, the barrel is placed into a neutral rinse tank, and thereafter into an acidic rinse so that pH may be lowered. [approx. 30 s in each]
- The barrel is then immersed into an acidic solution (HCl) [approx. 30 s]
- After an acid drag out, the barrel is placed into a rinse tank to remove excess acid. [approx. 30 s]
- Thereafter, the barrel is immersed into an alkaline rinse tank so that the pH may be raised. [approx. 30 s]
- The barrel is then immersed into the zinc plating solution, for a certain amount of time (varying from 25 – 60 min) [varying from 25 - 60 min]
- After removing the barrel from this bath, the barrel is to be held above the bath for a while, so that excess solution on the bath may be recovered.
- The barrel then passes through 2 rinse tanks (counterflow rinsing) [approx. 30 s in each]

- Thereafter, the products are passivated, depending on the requirement. The barrel is immersed into the required passivate [approx. 30 s], and thereafter a final rinsing occurs [few seconds in each].

Effluent treatment and Disposal

All wastewater that leaves the different parts of the plant are treated prior to disposal. The acid concentrates, alkali concentrates, as well as the alkali rinses are all initially separated.

Since the alkali rinses contain cyanides, the cyanides need to be treated prior to disposal. This is done as follows: it undergoes oxidation upon the addition of sodium hypochlorite ($NaOCl$).

The other toxic chemical that requires careful treating prior to disposal is chromium(vi). The source of this chemical are from the various passivates that are used. The chromium (vi) is reduced to chromium (iii) by sodium hydrosulphite ($Na_2S_2O_4$). Thereafter, a precipitated hydroxide (chromium hydroxide) forms, which then forms part of the sludge.

Thereafter, all these streams (the alkali and acid streams and the streams from the cyanide oxidation + chrome reduction) are mixed, and the pH adjusted via the addition of either sodium hydroxide ($NaOH$) or HCl, such that neutralization occurs.

Flocculation then occurs.

This is then followed by settlement of the sludge (in the settling tank). The sludge then enters the sludge tank, from where it is pumped to the filter press (a dewatering process). From here, the excess water flows into the sewer, while the solids are taken by Waste-Tech.

Suggestions for Improvement

- A leak in one of the rinsing tanks has been observed. The operators are also aware of this and have requested that this bath be replaced. It is suggested that this be done as soon as possible, so that further costs may be avoided.

- Regulation of water used by the factory is imperative. This would not only serve as an indication of the volume of water used in the factory, but will also show fluctuations in water consumption. It is also necessary because this will ensure that the factory is being charged for the correct amount of water being used.

- The expenses incurred in the effluent treatment plant are proportional to the volume of effluent passing through the plant. Consequently, decreasing this volume would result in a decrease in these expenses. This may be achieved by reducing the volume of water used in the factory. Generally, the plating plant accounts for most of the water usage in the plant. However, at present, the plating plant has no means of determining this volume of water, and has no indication of whether excessive water is being used. Consequently, it is suggested that flow meters are installed so that the amount of water used by the plating plant may be monitored. This would also result in savings in water. Presently, the factory consumes approx. 60 kl per day.

- As outlined above, the reduction in the volume of water used would result in savings. This would be achieved if the rinse water volume used may be decreased. At present, the amount of rinse water used is controlled manually i.e. the taps are turned on when barrels are being plated. The amount of water that is used is established by pH tests, as well as considering the appearance of the water.

  Estimates were obtained by measuring the time required to fill a container of known volume. It should be noted that this method is fairly inaccurate because the flowrate varies; depending on the quantity of water that the operator feels is necessary, and the water is also turned off at certain intervals. Nevertheless, this estimate indicated that two thirds of the water (approx. 40 kl) consumed by the factory was actually used in the zinc plating line (excludes other platings). It is thus clear that the volume of water used in the zinc plating line is large. Subsequently, the installation of an automatic device which can control the flowrate, so as to maintain a certain degree of cleanliness in the rinse waters, should be considered.

- it has also been suggested that the filter cake be further de-watered so that the volume of sludge that needs to be disposed decreases, resulting in a decrease in the disposal cost. However, it was discovered that costs are also levied based on the concentration of heavy metals present in the sludge. De-watering would cause an increase in the concentration of the heavy metals, and hence, an increase in disposal costs. Nevertheless, it is possible that slight de-watering may facilitate a saving without causing a great increase in heavy metals concentration. The basis of the disposal costs needs to be established.

Company I

Background

The company is a manufacturing enterprise situated in Pinetown, and employs 350 personnel. The company has been in existence for over 35 years and manufactures a range of spanners and tools for use in the automotive industry. Processes on site are typical for this product and include drop-forging, socket pressing, induction heating, machining, metal hardening and electro-plating.

Process Description

The metal finishing operations consist of a plating line, a blackening line, and a phosphate line. The company performs nickel and chrome plating on its manufactured items.

Effluent Treatment

Treatment of effluent occurs every 2 to 3 days, and a 90 000L tank is emptied every 1 to 2 days.

Suggestions for Improvement

- Increase drip times
- Use acid rinse for rinsing after cleaner
- Install counter flow rinsing on blackening line
- Cover baths to prevent evaporation
- Investigate recycling of Ni solution
- Alter arrangement of tools on jigs to minimise carry over of chemicals
- Change from hexavalent to trivalent chrome plating
- Separate hazardous and non hazardous wastes to reduce disposal costs
- Install meter on bore hole water
- Monitor chemical addition to ensure only required amount of chemicals are added
- Replace overflow rinse with spray rinse
- Eliminate the use of cyanide
- Replace trichlor with Formula 40
- Install controlls on plating line to check temperatures and concentrations
- Evaporate Cr drag-out tank and reuse in plating tank
- Introduce small overflow rinse bath in place of static bath
- Operate filter press correctly to minimise sludge
- Resuse rinse water from phospahting in tumbling department

Company J

Background
The company is an electroplating job shop that has been in existence for 30 years. The company performs zinc, tin, and cadmium plating of small to medium sized metal objects for individuals and metal-working firms. Cadmium plating is normally applied to iron and steel products, which will be exposed to corrosive environs (marine environments and radiators of cars, etc.). Zinc plating is used to galvanize iron and steel and provides excellent corrosion resistance (out-door furniture , etc.). Tin plating is applied to objects, which come into contact with food (cake stands, etc.).

Process Descriptions
Three main electroplating processes, Zinc, Tin, and Cadmium plating are employed on 5 lines. The 5 lines are :

- CAD line - cadmium plating
- Tin line - tin plating
- Jig line - zinc plating done with aid of jigs
- Barrel line - zinc plating done by barrel
- Heavy line - zinc plating of large objects in tanks

Cadmium plating
Cadmium is usually deposited from an alkaline cyanide solution. In the CAD plating solution, the company uses:

- Cadmium oxide
- CAD balls
- Sodium cyanide
- Caustic soda

When the plating solution is deficient in cadmium, the work-piece is not plated uniformly in terms of texture and colour. Make-up salt solutions such as cadmium oxide are added to the plating solution. The actual chemistry is rather complex. But what is known is that the work-piece is the cathode.

Zinc plating
For the electro-deposition of zinc various solutions are available, either as acid or alkaline. Acidic solutions are normally zinc sulphate / chloride. Alkaline solutions are normally sodium-zinc cyanide. In the plating solution, the company uses:

- Zinc as metal
- Sodium cyanide

Addition of zinc oxide / zinc cyanide is employed to correct the zinc / caustic soda / cyanide content of the plating solution.

Tin plating
The company uses an acid tin solution to deposit tin on the work-piece. The solution usually consists of :

- Stannous sulphate
- Sulphuric acid

Effluent treatment and disposal

On average , the company produces a tank of effluent a day (this is solids suspended in a water solution). The company has no inventory system of the chemicals used to treat the effluent. The person who is responsible for this task, simply adds as much chemicals as he sees fit.Most of the heavy metals , are precipitated as insoluble hydroxides or sulphide containing compounds . This is achieved by the addition of suitable reducing agents , or pH adjustment of the effluent.

Cyanide removal is achieved by oxidation to residues. In the case of hexavalent chromuim , it is necessary to first reduce the metal to a form which is more easily precipitated. The reduction of Cr (VI) is achieved by the addition of sodium meta bisulphite.. The solution pH is maintained at 10 by the addition of caustic soda or acid..

Suggestions for Improvement

- The company needs to develop a system to record the chemicals purchased and quantities used to treat the effluent and to maintain the plating solution.
- Increase drip time of jobs over baths to reduce drag out
- Water from the spray-rinse is just allowed to drain away. This water needs to be recycled and can be used as rinse water in static rinse tanks.
- The drainage system needs to be improved as water spills on the floor and rinse overflow remains on the floor.
- Heaters need to be immersed completely into the solution to be heated. Most of the immersion heaters were exposed to the atmosphere.
- Insulate heated tanks to reduce he heat loss from the hot solution.
- Hot solutions should be covered so as to reduce evaporation of the solution and to reduce air emissions.
- The company should switch from zinc cyanide plating to zinc chloride / zinc alkaline plating.
- Eliminate CAD plating by encouraging customers to use either zinc or zinc / nickel plating which gives similar results.
- Employee education – An awareness of the need for waste minimisation on the part of the individual is important if a waste minimisation program is to be successfully implemented.
- Alter the shape of the work piece to ensure maximum drainage.

COMPANY K

Background
The company is a powder coating company that has been in operation for 2 years, and employs 7 people. The company pretreats and then powder coats metal products in a variety of colours. The market for these products is varied.

Suggestions for Improvement

- In order to save chemicals it has been recommended that the solution from the rinse tanks should be transferred periodically to its respective predecessor to make up for evaporative losses in the heated tank. This single action has many advantages:, namely-
  - recovery of chemical results in less wastage of the chemical.
  - less wastage of the chemical results in lower costs.
  - instead of the chemical being discharged down the drain, it is being advantageously used.

- In order to make up the volume of the rinse tank, fresh water is added.
  In practice, it is found that the method cannot be applied to the degreaser and its rinse tank. This is so because much oil is removed in the degrease rinse. Thus it has been recommended that this be applied to the derust tank and phosphate treatments.

- It has been suggested that the basket be suspended above the degrease, derust and phosphate tanks for at least *five* minutes before immersion into the rinse tanks.

Company L

Background
The company is a plating shop that has been in existence for 11 years. The company is situated in Pinetown, South Africa and employs 8 people. Zinc plating is the only process undertaken by the company. Their largest customers are from the burglar guard industry. The objects plated are constructed mainly of mild steel.

Process Description
The first procedure in the preparation of mild steel is the removal of oil by an alkaline-based degreaser. The mild steel is further rinsed and acid treated to remove ingrained dirt. It is then plated and rinsed and ready to be collected by the customer. The processes are discussed in more detail below.

Cleaning
Removal of oil from the work pieces is done by an alkaline-based degreaser.. This solution contains 15g/l of caustic soda. The work pieces are dipped in a solution of this, at a temperature of approximately 60-90 degrees Celsius. This speeds up the reaction rate. The work pieces are then hand washed with an Acid enriched solution. The removal of rust from the work pieces is done by leaving them in a solution of HCL of 17% concentration. The work pieces are removed after 40 minutes and rinsed in a clean water bath.

Zinc Electroplating
A 10V-3000A power supply , forces zinc ions from solid zinc to be plated onto the work pieces. This is done via an electrolyte which is made up of: Sodium Cyanide, Zinc, Caustic Soda, Zinc Brighter, Sodium Sulphide, Zinc Oxide.

Blue Passivation
After the process of electroplating the work pieces undergo a static rinse. Blue passivation is a process to clean the work pieces from the potentially hazardous electrolyte. The work pieces undergo a final rinse and are then dried by sunlight and ready for the market.

Suggestions for Improvement
The lack of space within the factory is a serious draw back in the installation of new tanks and equipment to minimise waste. The other most obvious reason is the lack of capital. The options identified for the reduction of waste are described below.

- Suitable overhead structures can be used to allow the components coming out of a tank to hang and drip for appropriate duration's of time, thus preventing the loss of the solution due to cling.
- Suitable air compressors can be used to improve the dripping of the work pieces by a stream of fog-treatment spray.
- Reduction of stagnant water can be achieved by the tiling of the floor surface.
- Create an awareness among workers to reduce spillages.

- Unprotected steel tanks should be shielded against stray currents with materials such as PVC. Replace existing tanks.

- Use float level controls to improve management of overflows and spills

- The prevention of air emissions can be effectively done by covering the bath with a layer of foam.

COMPANY M

Background
The company is a hot-dip galvanising enterprise situated in Prospecton, Durban, South Africa. Items galvanised are mainly structural steel, and the company's main market is for security companies.

Process Description
Grease and oil are removed from the surface of the steel to be galvanized in a degreaser bath using an alkaline degreasing solution. A fairly concentrated caustic soda solution is used at a temperature of 85 °C. After rinsing in water, the rust and mill scale are removed from the surface by pickling in dilute hydrochloric acid (14% w/w). The temperature of the bath depends on atmospheric conditions. Acid inhibitors are also added in the pickling bath to reduce acid attack on the clean metal surface. This ensures a smoother surface of the steel, which improves the galvanizing layer of zinc. The inhibitor also reduces fuming of the acid. As the acid concentration decreases, fresh acid can be added to bring concentrations to desirable levels. However, the acid is discarded when the iron content reaches 80-100 g/l.

After pickling in the acid for 20 – 30 min, the work is rinsed and is now ready for fluxing in the flux bath. The purpose of fluxing is to remove or dissolve the oxides on both the steel and zinc surfaces, to ensure that the steel and zinc forms a pure metallic bond with
each other. The fluxing agent used is ammonium chloride. Zinc chloride is also used with a wetting agent stable in acidic solution. The temperature of the flux bath should be maintained between 75-80 °C. After fluxing, the surface of the molten zinc is skimmed to remove oxides and flux residue (ash), before the work is dipped into the zinc bath. The temperature of the zinc bath is maintained at about 450 °C. The dipping time ranges from 2 to 8 minutes, depending on the thickness of the zinc layer to be produced. After withdrawal, the work is cooled in air and thereafter quenched in the passivator tank. The passivator solution is a 0.5 % (w/w) sodium dichromate solution.

Effluent treatment
The most important wastes are the spent acid, ash, dross and splashed zinc metal. There is no on-site treatment of any of the wastes generated. The spent acid and rinsewater is stored in effluent tanks and taken away by METSEP for regeneration of the spent hydrochloric acid.

Suggestions for Improvement

Good housekeeping generally results in good efficiency of any plant. Basic operating procedures must be followed at all times. By ensuring the correct orientation of the workpiece suspended from a jig, this will ensure minimum dragout and good dripping from the workpiece. This will reduce the amount of chemicals lost via dragout and dripping. Making employees aware of these things can help in minimising dragout and dripping from the workpiece.

Other options for improvement includes countercurrent rinsing, use of rinsewater to dilute the acid, and reduction of splashing of zinc by drying the workpiece first.
A more detailed explanation of these options follows:

- Reduction of Rinsewater
  By use of a countercurrent rinsewater cascade, the water consumption will decrease. The best efficiency is obtained by having a bottom water supply and a top water run-off for each tank Alternatively, one can use one or more static rinse baths in

sequence, before a final continuous flow tank. Both these options reduce the rinsewater consumption and hence increases the concenration of the acid in the liquid waste stream.

- Rinsewater Storage Tank
  By having a storage tank for the "used" rinsewater, one does not have to dispose off of the rinsewater. This rinsewater can be used later to dilute the 33 % concentrated acid to 17 % w/w. This will be a saving of about 27 Kl of water every time the acid becomes spent, which is about once or twice a month. The disposal cost of the liquid waste stream will also be reduced as there will be a lesser volume to transport and dispose off. This will also ensure that the liquid waste steam always has a water content of less than 70-80 %.

- Reduction of Splashing of Zinc
  The splashing occurs because of the flux solution remaining on the workpiece. When the workpiece is immersed into the molten zinc, the flux solution vapourises and when the vapour escapes, splashing occurs. Therefore, by reducing the amount of solution entrapped on the workpiece before dipping, for example by electrical induction heating, this will effectively reduce splashing and therefore decrease the zinc wastage. Hot air dryers can also be used.

Company N

Background
The company is a manufacturing company that has been in operation for approximately 21 years. The company is concerned with the manufacture of automobile valves. The product is sold within South Africa, and is also exported to the United Kingdom. Metal finishing in the form of chrome plating is one of many steps involved in the company's manufacturing process.

Processes
The manufacturing of valves for automobiles, involves the following processes :

- Cutting of steel
- Welding of similar or dissimilar metals
- Induction hardening
- Polishing
- Chrome Plating
- Grinding
- Forging

Chrome Plating
This is a manual plating process involving the use of jigs. The process is a batch process, and there are 12 tanks in total.

The valves are placed on flat jigs which are fastened by means of bolts. These are immersed into a soak clean tank of volume 250L and temperature 70 deg. C. Then, Chemlene O3, an alkali degreaser, in the soak clean tank removes the coolant oil from the valves. The valves are then moved into an electrocleaning tank (volume 260L and temperature of 50 deg. C) in which the chemical Udyprep 220 acts on the valves. This chemical is also an alkali degreaser. It is important to note that the main component of these alkali degreasers is sodium hydroxide ($NaOH$). From the electro clean tank the valves are then rinsed in a static rinse tank of volume 220L and ambient temperature. After rinsing the valves are immersed into the chrome etch tanks (volume 260L and temperature of 55 deg. C).

The valves are then plated with chrome in the chrome plating tank of volume 260L and temperature of 55 deg. C. From here the valves are dipped in the dragout tank to wash of the excess chrome. After this is done the valves are immersed into a neutraliser tank(volume 220L and ambient temperature) which contains a solution of neutrachrome. This solution neutralises the chrome which is carried over from the dragout. Once the valves are removed from the neutraliser they are rinsed in a rinse tank (volume 220L and at ambient temperature), after which they are immersed into a hot rinse tank (volume 250L and temperature of 70 deg. C).

Effluent Treatment
Effluent is passed into 2 holding tanks via a covered drain. The covering is an iron grill.
Solutions from the Soak Clean and Electro Clean tanks are passed into these holding tanks. Spilled chrome solutions are also passed into these tanks. The effluent is treated and fed to the sewer once the authorities have passed it. The authority being Department of WASTEWATER MANAGEMENT , Pollution Division - North & West , Durban Metro. Passing of the effluent indicates that the levels of chemicals and pH in the tanks are in accordance with the regulations.

Suggestions for Improvement

- Floors are made of concrete, and therefore need resinous coatings on them.
- Machines have oil trays so to prevent spillage on floors.
- Cigarette stumps were found in working area, next to machinery which implied that employees were engaged in smoking. This could be quite dangerous in it could lead to a fire/explosion if flammable chemicals were present or small metal particles could settle on the cigarette and thus be taken in by the employee.

COMPANY O

Background
The company is an electroplating job shop that specialises in the plating of household goods such as cutlery, tea sets, and lampshades; and car parts, such as wheel rims and bumpers. The general public is the company's primary customer.

Process Descriptions
The main processes carried out at the company are:
- Copper Plating
- Nickel Plating
- Brass Plating
- Chrome Plating
- Silver Plating

The steps involved in each process is listed below:

Copper/Nickel Plating

- Polish component to prepare for electroplating
- Rinse in clean water
- Soak clean component in solution
- Hose with clean water
- Soak in electrocleaner
- Hose with clean water
- Acid etch in 10% sulfuric acid
- Hose with water
- Brass plate article
- Cyanide rinse
- Hose with water
- Acid etch with 10% sulfuric acid
- Hose with water
- Nickel plate in solution
- Rinse in Nickel drag out tank
- Hose with clean water
- Copper plate for 2 min
- Cyanide rinse
- Hose with water
- Immerse in 2% sodium dichromate passivator
- Hose with water

Brass/Chrome Plating

- Polish component to prepare for electroplating
- Rinse in clean water
- Soak clean component in solution
- Hose with clean water
- Soak in electrocleaner

- Hose with clean water
- Acid etch in 10% sulfuric acid
- Hose with water
- Brass plate article
- Cyanide rinse
- Hose with water
- Acid etch with 10% sulfuric acid
- Hose with water
- Nickel plate in solution
- Rinse in Nickel drag out tank
- Hose with water
- Chrome plate
- Chrome drag out tank
- Chrome Rinse
- Hose with water

Nickel/Silver Plating

- Polish component to prepare for electroplating
- Rinse in clean water
- Soak clean component in solution
- Hose with clean water
- Soak in electrocleaner
- Hose with clean water
- Acid etch in 10% sulfuric acid
- Hose with water
- Brass plate article
- Cyanide rinse
- Hose with water
- Acid etch with 10% sulfuric acid
- Hose with water
- Nickel plate in solution
- Rinse in Nickel drag out tank
- Hose with clean water
- Flash silver plate in strike solution
- Silver plate in solution for 20 minutes
- Rinse in silver drag out tank
- Silver Rinse Tank 2
- Silver Rinse Tank 3

Effluent Treatment
All the waste streams i.e. Cyanide rinse, chrome rinse, acid bath, hose water drain into a common sump located below the shop floor. Due to the relatively small size of the operation, clean outs are not carried out.

The second and third rinses of the silver process are added together into one container. Sodium hypochlorite is added to the container to neutralise the cyanide that is present. The sodium hypochlorite is added until starch paper is observed to turn blackish/blue thus indicating that there is no cyanide present. The container is then added to the brass/copper cyanide rinse so that any excess sodium hypochlorite may be used up. More sodium hypochlorite is then added to neutralise the cyanide in this tank before it is dumped. The cyanide is dumped approximately 3 times per month.

Approximately 810 g of calcium hypochlorite are needed to treat a 200 litre drum of cyanide rinse.

The solution from the chrome dragout tank is used to top up the chrome plating tank. The solution in the chrome rinse tank is dumped. However, first the chrome that is present is neutralised using Neutrachrome. This has the effect of reducing the hexavalent chromic acid to trivalent chrome. Trivalent chrome precipitates as a metal hydroxide. The particles precipitate out and a sludge collects at the bottom of the tank. The water is siphoned off the top, and the sludge is stored on the premises waiting for suitable disposable.

Approximately 509 g of Neutrachrome is needed to treat a 200 litre drum of chrome rinse. It is added to the chrome rinse the day before the rinse is dumped. The chrome rinse is dumped approximately 3 times per month.

Neutrachrome has as advantage over sodium bisulfite in that it can be used in plain steel tanks.

The nickel drag out solution is used to top up the nickel tank, thus compensating for evaporation losses. The first rinse from the silver process is used to top up the silver strike and silver plating tanks. The copper and brass tanks are topped up with fresh water.

When the acid etch solution gets weak, it is required to be replaced. The acid that is dumped is neutralised with old alkaline cleaner before dumping. The pH of the resultant mixture should be between 9.5 and 10.5. If the pH needs to be increased further, caustic soda may be used. Acid is dumped approximately once a month.

The waste water that comes from the hose, drains from the hosing area into the sump below. Any effluent that is dumped, also drains into this common sump.

Suggestions for Improvement

Safety Recommendation

It was observed that the operators washed out their tea dishes using the plating shop hose. It was also observed that the dishes were dipped in the acid etch tank (containing 10% sulphuric acid). It must be noted that this tank might have traces of cyanide, which is highly toxic, and thus poses a serious health risk to the operators. It is strongly recommended that the operators be prevented from continuing this practice.

The following suggestions were made for the minimisation of waste and improvement of the process.

- Installation of Water Meter

  At present there is no meter on the inlet line of the water. It is therefore impossible to accurately quantify the water usage.

- Insulation on Tanks
  The chrome, nickel, hot soak cleaner, and electrocleaner are heated from 12 a.m. to 2 p.m. daily. The installation of insulation would reduce the amount of energy needed to heat the tanks to their operating temperatures.

- Covering of Drag Out Tanks
  The drag out tanks is used to top up the plating tanks. However these tanks are open to contamination when not in use. The nickel tank in particular is highly sensitive to contamination. It is recommended that the tank is covered with a plastic sheeting when not in use.

- Increase Dripping Time
  Increasing the dripping time, reduces the amount of drag out, and hence reduces the amount of solution dripping on to the floor. This in turn, saves on the amount of chemicals used, and also decreases the amount of heavy metals in the effluent. Allowing sufficient dripping time for treated work pieces is the simplest and most cost effective method of pollution control. It is recommended that the work pieces be allowed to drain over the plating tank. This means that any plating solution dragged out with the work piece will drain back straight back into the tank. This involves no extra capital investment. The dripping time should be increased by at least 20 seconds. Increasing the dripping time would also reduce the amount of calcium hypochlorite and neutrachrome needed to treat the rinse baths before dumping.

- Repositioning of Tanks
  Operating time may be significantly reduced by repositioning the tanks such that the distance between successive tanks is reduced. Repositioning of the chrome drag out and nickel drag out tanks, will also reduce the drippage onto the floor. More space may be found in the shop by removing the spare nickel tank.

- Top up Electro Cleaner with Hose Water
  After an article has been cleaned in the electro cleaner it is hosed down with clean water. The electro cleaner is a heated tank and thus suffers large amounts of evaporation losses. Previously fresh water has been used to top up the electro cleaner. It is suggested that the hose water be collected and use to top up the electro cleaner. This would reduce the water usage, amount of chemicals required, as well as the amount of effluent generated.

- Top up Hot Soak Cleaner with Hose Water
  The hot soak cleaner is a heated tank and there are substantial losses through evaporation. It is suggested to use the hose water that has been collected after hot soak cleaning to top up the hot soak tank. This would reduce the water consumption, amount of cleaning chemicals required as well as the amount of effluent generated.

- Top up Chrome Drag Out Tank with Chrome Rinse
  The chrome rinse is dumped after being treated with neutrachrome. In order to decrease the amount of neutrachrome used, and to recover the hexavalent chrome in the chrome rinse, it is suggested that the chrome rinse be used to top up the chrome drag out tank. The remaining chrome rinse may be neutralised with neutrachrome before dumping. This method would also minimise the amount of neutrachrome needed to treat the chrome rinse before dumping.

- Top up Nickel Drag Out Tank with Hose water
  In order to reduce the amount of nickel in the effluent, it is recommended that the hose water that is used to rinse the job after nickel plating, be used to top up the nickel drag out tank.

- Use ECO Rinse for Chrome and Nickel Plating
  Due to the high amount of drag out in chrome and nickel plating, it is recommended that use be made of an ECO rinse. This is a rinse in which the workpieces are immersed in the rinse tank before and after treatment in the plating bath. The dragout is lowered by 50% because the same quantity of liquid is transferred to the treatment bath (drag in) by the untreated work pieces, as to the subsequent rinse tank (drag out) by the treated pieces. This would also minimise the amount of neutrachrome needed to treat the chrome rinse.

COMPANY P

Background
The company is an electroplating job shop situated in Pinetown.

Suggestions for Improvement

- Read water meter
- Monitor chemical use and addition
- Replace overflow rinses with static
- Use rinse baths to top up baths
- Remove excess oil with newspaper
- Recover powder
- Control oven use
- Improve quality control
- Trained workers in waste minimisation
- Reduce carry over by increasing drip times
- Reduce evaporation by covering open baths
- Improve insulation to prevent heat losses

COMPANY Q

Background

The company manufactures and electroplates fine nickel meshes. The company's customers are the textile, sugar, and printing industries. The company has been in operation for 15 years, and it's metal finishing processes are managed by an electroplating engineer. The main processes employed are nickel electroforming from nickel sulphamate and nickel sulphate solutions; copper plating from copper sulphate solution; and hard chrome plating from chromic oxide solution.

Process Descriptions

The desired product, a fine nickel mesh, is produced by electroforming which takes place on a specially prepared, stainless steel, "master roller". A roller is usually used for the production of three nickel meshes before it has to be re-treated. Machining is required to ensure that the roller and the subsequent product meets the strict specifications in terms of dimension.

Copper plating is performed to provide a soft surface for the engraving while the chromium serves as a tough, hard layer to protect the roller surface. The engraving forms the basis for the formation of the wire mesh. The non-conductive epoxy which is sprayed upon the roller, fills the indentations formed by engraving. Grinding of the job after the epoxy spray reveals a chromium layer upon whose surface the nickel is deposited rather than on the epoxy-filled engravings. One copper and one chromium plating tank are used in the preparation of the master roller.

Engraving of the rollers for the sugar nickel meshes requires the use of lasers and is performed in Johannesburg.

For nickel meshes destined for the sugar industry a further chromium treatment is required. There are four nickel plating tanks for the textile nickel meshes and two nickel tanks for the sugar nickel meshes.

Deionized water is used in all the plating tanks. Further, deionized water is also used in rinses before the jobs enters the plating solution as well as after the plating is done, when the job is rinsed over the plating bath.

Rinse tanks are all spray rinses (three tanks have spray nozzles, the others have only hoses) and as such all rinse water is drained immediately to the effluent tanks.

The plating tanks are unusual in that they consist of a "storage area" at the base of the tank in which the plating solution resides. When plating, the solution is pumped to a tray above the storage area and a drainage tap closed. The job is not fully submerged in the plating solution but is rotated to ensure even plating. The plating solution is continually pumped to the tank and overflows back to the storage area. Although relatively little plating solution is actually required for the plating, large volumes are nevertheless used to ensure that the temperature of the solution does not rise uncontrollably, given the high current density. The tanks have automatic temperature controls which consist of heaters and cooling water. The cooling water is cooled in a cooling tower as well as a refrigeration unit.

Effluent Treatment
All effluent water is pumped to effluent tanks at the back of the factory. The effluent is treated by addition of caustic soda to raise the pH. A pH of 10 is desired so as to enable precipitation of the metal hydroxides. The pH is checked by means of litmus paper. Once a tank is full, it is checked by the Metro for cadmium, chromium, copper, nickel and zinc concentrations as well as pH. If these concentrations are within the set limits, the company is allowed to dump the effluent. At present, the company does not have a mechanism for disposal of the metal hydroxide sludge.

Suggestions for Improvement

- The installation of spray nozzles can reduce rinse water consumption by 50 %
- In the textile nickel mesh line, rinsing of jobs over the plating tank will reduce dragout
- In the sugar nickel mesh, the correct use of the existing dragout tank needs to be enforced
- Recycling of waste water:
  -After the alkaline bath an acid rinse is required to ensure that all the alkaline is removed. As all the plating tanks are acid, the rinse water should also be acidic. Therefore, it might be possible to use the rinse water instead of the 10 % sulphuric acid.
  -Currently, the cooling system for the sugar chromium plating tank is inadequate and extra cooling is provided by running tap water through a jacket around the tank. This water is then sent to drain and is therefore a terrible waste of water. Although the company does plan to replace the plating tank with a newer one (with a better designed cooling system), in the intervening period the effluent water should be recycled and used as rinse water.
- Fitting of spray nozzles to all rinse and washing hoses. This could reduce rinse water volume by 50 %.
- Reduction of hexavalent chromium to trivalent chromium should be performed separately before sending to the effluent tanks for precipitation. This can be done by dipping the jobs in a treatment tank before rinsing. Trivalent chromium is much easier to reduce than its hexavalent counterpart. A proprietary solution can be used for reduction.
- A problem currently experienced at the company is the increasing nickel concentration in the plating tanks. Nickel anodes are more expensive than the plating chemicals such as nickel sulphate, especially as some anodes are being imported from overseas. Possible solutions to this problem are:
  -use of inert anodes (platinumized titanium) together with the nickel anodes,
  -use of lower current densities, or
  -recovery of nickel onto anodes by reversing the polarity of the baths and using inert cathodes.
- Greater care should be taken when removing the filters from the nickel plating tanks. Large quantities of plating solution are captured within the filter and this loss can be reduced by allowing dripping of the job or by a quick rinse of the filter.

COMPANY R

Background

The company is a large hot-dip galvanising enterprise that has been in operation for approximately 3 years. The main product is galvanized steel items. The market comprises of major leading steel companies of which 60% is based in Gauteng. The company also handles about 40% of export work.

Process Description

The process implemented is Hot -Dip Galvanising. This is a process of coating an item of steel with molten zinc with the purpose of protecting the steel against corrosion.

The items are first arranged on a jig in such a way so as to optimise the number of items galvanized at a single time. After the items have all been jigged they are then ready to be immersed in the first degreasing tank and then the next. The items are immersed in the degreasing tank for approximately five to twenty minutes. The concentration of the solution has to be around 33g/l to 38g/l. The bath is run at 80°C.

The items are then immersed in the first rinse tank. Here water is used to remove the chemicals that are carried over from the degreasing process. The items are now ready to be 'pickled' in a solution of hydrochloric acid and H.F.I , the pickling additive. The concentration of the HCl is 33% and the concentration in the bath is 16%. The concentration of *H.F.I* needs to be 0.5% to 3%. The specific gravity of the H.F.I is 1.0 ± 0.01.

The hydrochloric acid should be discarded when the iron concentration is greater than 10% by volume. When the concentration of HCl reaches 5%, the solution is used for stripping. Five pickling tanks are available however not all are used for a single job. The item is then sent to a pickling rinse where water is used to remove the acid from the items.

Immersion in the flux follows the acid rinse. The flux is a solution of zinc chloride and ammonium chloride of 250g/l concentration plus an extra 100g/l of zinc chloride. The concentration of ammonium chloride should be 0.007% by volume.The flux should be operated at a temperature of around 80°C. The pH of the flux should be around 5 and the specific gravity at 1.15g/cm^3. The flux prepares the items for the zinc bath by enhancing the bonding between the zinc and steel.

Galvanizing of the zinc onto the steel follows the flux process. The solution in the zinc bath needs to be at a temperature of 445°C TO 455°C.

Passivation follows. The zinc coated steel is immersed in a solution of sodium dichromate and chromium trioxide with a required concentration of 0.2% to 0.3% as chromate and 0.14% to 0.18% as chromium. The temperature needs to be around 60°C.

Quality assessment follows. If black marks, excess zinc lumps, bare spots, etc. are detected on an item, the item needs to be re-fraced.

Effluent Treatment

The effluent is the collection of wastes from :

- Overflow of the rinse tanks which is disposed off almost every 4 days.
- Sludge from the degreasers.

- HCl tank which is disposed off approximately after every 8 months.
- Spills.
- Drips.

Overflow from the rinse tanks
The water overflow rate to the rinse tanks is 140ml/s for an inactive tank and 300ml/s for an average size job of two tonnes. The waste goes into a sump and is then pumped into a waste dump and after approximately 4 days the waste is treated by the neutralisation method and disposed off to the sewer.

Sludge
Sludge is seldom produced in the degreaser tanks. Whatever sludge is produced is also sent to the waste dump and treatment is similar to the above.

Hydrochloric Acid
The hydrochloric acid solution is disposed off when the iron concentration in the tanks is greater than 10%.[3] Disposal occurs approximately once in 8 months. The solution is sent to the waste dump and treated as mentioned in (1) above.

Spills
Spills are immediately treated once it occurs. The major spill that occurs (which is very seldom) is hydrochloric acid spillage. Soda Ash is immediately used to neutralise the spill and the waste is washed away to the waste dump. Other spills are just washed away to the sump.
Zinc spills are collected and recycled.

Drips
Drips are minimised by suspending the items over the tank until very little dripping occurs. The drip rate was estimated to be 5ml/s. These are washed away to the sump.

The sludge collected is a product of the reaction of the degreasers with the grease and/or oil. The concentration of soda ash used for waste treatment is 100% sodium hydroxide in powder form.

Suggestions for Improvement
After investigation it was found that the area that required much attention was the consumption of water. The following suggestions were proposed to reduce the consumption of water :

- Implementation of Counterflow as opposed to Overflow rinsing ,
- Implementation of Drag-Out rinsing as opposed to Overflow rinsing ,
- Installation of a Conductivity meter in the rinse tanks ,
- Installation of Flow devices ,
- Recycling of Waste water ,
- Doing away with *Orprep 70* and
- Spray Rinsing.

COMPANY S

Background

The company is a plating shop that has been in operation for 34 years. The company is situated in Pinetown, South Africa and employs 10 people. The owner of the company has had no formal electroplating training, but has worked in the industry for approximately 50 years. The company is concerned with hard chrome plating of mainly reworked mechanical parts, and its main market is the hydraulics industry.

Process Description

Machine parts for reworking are first ground down on lathes to remove the worn, damaged metal. Thereafter the jobs are cleaning by wiping with a cloth soaked with thinners. A bath of Zonax metal cleaner is also available and is used for cleaning of the smaller jobs. The metal cleaning bath is kept at a temperature of approximately 90°C. Jobs which have been ground down are not exceptionally dirty and the use of thinners is the preferred method of cleaning.

Sections of the job which are not to be plated are painted with Fortolac Stopping-Off lacquer and covered with stopping-off tape. Any holes in the job are fulled with polystyrene (except those very small holes).

Cleaning and lacquering of smaller parts are performed on a workbench, while the larger jobs are placed over the rinse tank.

Once cleaned, the jobs are then placed in the plating bath. Large jobs are hung from a pulley while the smaller parts are tied to wires and hung from rods which lie across the baths. All jobs are hung in the vertical position. The jobs are secured in position by means of vice grips.

The first process which occurs in the plating tanks is etching. This is performed by reversing the polarity of the plating bath for 1 - 2 minutes. The duration of etching is determined by the type of metal. The plating tanks operate at between 45 and 60 °C. The bath is kept within this temperature range by a cooling coil connected to a cooling tower. The temperature of the bath is checked every few hours with a thermometer and the flow of water is adjusted according to the temperature. This adjustment is based upon the operator's experience. To reduce heat and evaporative losses Chroffles plastic balls are placed in the bath. These balls have a limited lifetime however, as they melt when in contact with the hot cathode.

The plating process takes several hours and the jobs are usually left in the tanks overnight and also over the weekend. This means that the cooling water is run continuously.

Once the plating is completed, the jobs are lifted out of the bath and while suspended above the bath, the jobs are rinsed off with the water from a drum next to each plating tank. (This drum is fulled at the begin of each day and usually becomes contaminated with a little chromic acid). Smaller jobs are also washed off in the drag-out. The jobs are then taken to a rinse tank and rinsed off with water from a hose. This system is quite effective as very little water is utilised and is suitable for this factory where the number of jobs processed per day is small (given the size of most jobs as well as the long plating time). The rinse water does not remain in the rinse tank but is pumped to the rinse water effluent tank which stands at the back of the factory.

Effluent Treatment
Very little effluent is generated in the plant. The only waste generated is the rinse water and a liquid extract from the air extraction unit and both these wastes are given to another metal finishing company.

Suggestions for Improvement

The company is inherently efficient given the nature of the work done. However a few areas have been identified in which improvements can be made.

Drag-out is not a great problem given their procedure of rinsing of the jobs over the plating tank. Plating solution is sometimes lost, however, in the stopping off tape applied to sections of the job especially when the section is irregularly shaped. Plating solution collects in the folds and irregularities of the tape and is not properly rinsed off. This loss can be reduced by:

- better taping of the surface so as to prevent folds and crevices in which plating solution can collect,
- not submerging taped areas in plating solution if not necessary, and
- removing the taping over the plating bath (as is done for the larger jobs) and rinsing the taping before disposal.

Plating solution is also lost (in small quantities) when rinsing of the jobs over the plating tank. Losses occur when workers are not careful and allow splashing of the plating solution. This splashing is also dangerous to health and safety of the workers as they do not wear safety goggles.

The drag-out tank seems to contain a fairly high concentration of chromic acid. Currently, large amounts of this solution is lost in drag-out as workers do not allow dripping.

COMPANY T

Background
The company is a plating job shop concerned mainly with nickel/chromium plating. The company has been operating for approximately 30 years but has been operating under new ownership for the past 2 years. The items plated are mainly shop fitting and industrial items.

Process Description

- The job is first stripped off its paint, if it has any, by burning it in a fire. The metal is then cleaned and polished in the workshop. From the workshop it goes to the first tank, which is the soak cleaner. The soak cleaner is a cleaning tank. The metal is immersed in the tank for approximately 5 to 10 minutes. Air blowers mechanically agitate the solution. The soak cleaner operates at approximately 50°C.
- The next tank is the electro-cleaner. This tank is also a cleaning tank except that it has a current flowing through it. The immersion time is approximately 5 minutes.
- The third tank is the rinse tank, which uses water as the rinsing medium.
- The metal is then immersed in the copper tank for approximately 5 minutes. It should be noted that copper plating is very seldom used.
- The metal then goes through a rinse tank.
- This is followed by an acid pickling tank containing 30% HCl . This basically refers to the cleaning of the metal in acid, usually for the purpose of removing oxides or scales.
- Another rinse tank follows.
- The following two tanks are the nickel baths. These operate at a temperature, on average, between 50°C to 60°C. They are mechanically agitated by air blowers and the immersion time for the jig is approximately 20 minutes. The jig is then immersed taken to the nickel dragout followed by another rinse.
- The jig is then dipped in the chrome dragout and then immersed in the chrome bath for 60 seconds. The Chrome tank operates between 40°C and 50°C.
- It is then dipped in the chrome dragout again after the chrome bath.
- This is followed by the neutra-chrome tank. This is necessary to neutralise the chromic acid, and convert the chromium ion from its hexavalent state to a trivalent state.
- This is followed by a cold rinse and then a hot rinse and allowed to dry.

Effluent Treatment
The effluent is stored in underground holding tanks of *unknown* size. The owners have no information or records of the actual size of these holding tanks. At the time of this assessment, the nickel concentration was exceeding the regulation limit of 25 PPM. The nickel concentration was standing at 88 PPM as analysed by Chemserve Trio. The company, Chemserve Trio, suggested taking a sample of about 50 litres, reducing the current pH of 7 to about 3 to 4 and then increasing the pH to 8 or 9. This task was performed and the contents allowed to settle. A sample of the solution was then sent to Chemserve Trio to be analysed. The results proved the task to be successful. Hence, the pH of the effluent will be dropped and increased to reduce the nickel concentration in the holding tank. It is estimated that the solution in the holding tank will be disposed 2 to 3 times per year to the sewer. The sludge will be disposed every five years by Wastetech.

Suggestions for Improvement

- A chrome fume extractor must be installed as breathing of the chrome fumes can prove to be hazardous. Chrome fumes are known to be carcinogenic among other severalties. Also, a less expensive method would be to introduce a large tray or plate above the bath in which the fumes can condense and drip back into the bath.
- Superclean greatly reduces the surface tension of the chrome electrolyte, inhibiting the droplets from splashing out of the bath when hydrogen bubbles burst. It is suggested that constant testing for the chromic acid be performed. This will indicate whether superclean needs to be added and by how much.
- To reduce the water loss, it is suggested that the meter be replaced. This will enable one to determine the leakage rate underground, and possibly find the flowrate of the other water supply line, if it exists.
- The gaps between baths should be closed by including drip trays. This will reduce the dragout volume as well.
- The dripping time must be increased to reduce dragout and in turn chemical costs.
  This can be judged depending on the job or at least until most of the solution has dripped back into the bath.
- The positioning of the jig is also very important. It is suggested that jigs be longer, hollow jigs be placed at a steeper angle to reduce dripping time and, more importantly, the dragout volume.
- The hangers onto which the jigs are hooked are exposed to the plating solution and this in turn can result in that particular area of hanger to be plated. This is considered as loss of the plating metal. To reduce unnecessary plating, plastic covering should be around all the hangers except at the points of contact, i.e. the part where the jigs are hooked.
- A cable of some sort connected to the roof can be used to hoist or pull the jigs from the baths. It will then be easier to prolong dripping time and hence the reduce dragout.
- As far as possible the baths should be kept clean to prevent contamination.
- A timer should be installed so that it can be known if the plating time has expired so that a job does not stay in to long or too short in the plating bath. This could also result in a waste of the plating material due to more metal being plated at longer times of exposure. The timer can also assist in dripping times.
- Blowers and heaters are expensive during operation, especially if they are left on while no plating is being done. A proximity switch or a solenoid valve should be installed for better control.
- A lot of metal salts were observed to be on the ground. This could be reduced by exercising more caution during rinsing, where the solution is splashed on the floor. This is also classified as hazardous wastes and can prove to be dangerous to the workers.

COMPANY U

Background

The company has been in operation for 16 years, and is concerned with powder coating of all mild and stainless steel objects. Aluminium objects are also powder coated. The company employs 50 people and is situated in Queensmead, Durban, South Africa. Some of the company's major clients are Hullets Aluminium, Bosal and ABB.

Process Descriptions

The dirty items were placed into a cage and firstly dipped into the degreaser, then rinsed. The cage then goes into a sulphuric acid deruster and the items are again rinsed. The next process was the phosphating, which was done in one of two ways. The first was iron phosphating, which consisted of an iron phosphate dip and then a rinse. The second was zinc phosphating, which consisted of a zinc phosphate dip and then a rinse. After the phosphating the metal was dipped into a chromic acid passivating solution. The above dipping process was made possible with the use of a monorail crane. The metals were air dried and sent for powder coating.

The metals were placed on a slow moving conveyor via jigs or hangers. A current was passed through the jigs, which caused the metal to become charged. The items were then passed through a spray booth were the epoxy based, powder was sprayed on the metal using an electrostatic compressed air spraygun. The charge on the metal attracts the powder. The coated metal was then passed through a gas furnace which runs at about 200°C. The metal had to reach a temperature of about 190 - 200 °C for at least 10 minutes, for the powder to cure. The duration of time spent in the oven would be determined by the thickness of the metal.

Once the powder was cured the powder coated metal was ready to be packaged and transported away.

Effluent Treatment

The continuous overflow rinse tanks flow into three storage tanks which overflow into each other. This allows the solids to settle and form a sludge. The chromic passivator was treated with sodium metabisulphite and caustic lye in order to convert the toxic Cr^{6+} into a non-toxic Cr^{3+}.
This was then pumped into to waste water treatment plant.

Suggestions for Improvement

The continuous overflow rinse tanks need to be changed into batch rinse tanks. The chromic passivator needs to be replaced with a non-chromic one.

COMPANY V

Background
The company is an anodising and electroplating company that has been in operation for approximately 32 years. The main items processed are architectural work, eg doorframes and windowframes, and zinc die castings - small components for domestic use such as refrigerator hinges.

Process Descriptions
The metal finishing processes conducted at the company are discussed below:

Anodising

- Etching:
  The alumimium profiles are secured on frames and lowered into the tank. The thin natural oxide coating present on aluminium surfaces, is removed during etching. The concentration of the caustic is between 50 and 100 g/l, and etching time is usually between 10 and 25 minutes.
- Rinsing:
  Thorough rinsing is required after removal from the etch bath to prevent staining. This is accomplished by dipping the components into a tank filled with water.

- Anodising:
  After proper cleaning and rinsing, the jobs are lowered into the anodising baths, and remain there for a specific amount of time depending on the amount of anodising required. A note of the time is made when the components enter the bath, and when they are removed.

- Colouring:
  This process is not involved in every set of jobs, but only carried out occasionally.
  The profiles are dipped in a colouring tank after anodising and rinsing. Electric current (AC) is used in the process. The colouring electrolyte solution is composed of sulphates of nickel. tin, and copper in addition to the acid. The voltage is adjusted to about 18 V when colouring.

- Sealing:
  After anodising and rinsing (and colouring), the aluminium components are dipped into the sealing tank. The pores in the oxide layer are closed , and thus influences wear and corrosion resistance, chemical resistance, and colour stability.

Copper Plating
- A number of components are secured onto jigs.
- These are first dipped into the soap cleaner and scrubbed to remove grease and dirt.
- Rinsing in water follows.
- The jobs are then dipped into an electrolytic cleaner, and then rinsed again.
- A dry acid neutralizer is then employed before a final rinse.
- Jigs are placed in copper bath by hanging them on movable bars attached to the bath.
- The jigs are moved along the length of the bath by a conveyer system every 2 min.
  Thus the time required for plating is controlled.
- Upon removal from the Cu bath, a static rinse is required. This is used to top up the Cu bath.

- After an additional rinse in water, the jigs are transferred to the Nickel bath.

Nickel Plating

- Jigs removed from the Cu bath are placed into the Ni bath (after rinsing).
- The jigs move along the bath as for the Cu bath.
- After adequate rinsing, the components are transferred to the chromium bath.

Chromium Plating

- Jigs are dipped into the bath.
- When removed they are hung over the bath to drain.
- Rinsing in a series of 5 baths follows.
- The 5th tank is a hot rinse to facilitate drying of the components.

Effluent Treatment

- All rinse tank solutions empty into two large effluent tanks.
- pH tests are conducted daily.
- Sulphuric acid is used to treat the effluent when the pH is too high.
- The pH in one tank is usually higher than in the other. Therefore if the pH in tank 1 is too low, it is sometimes possible to use the contents of tank 2, which is at a higher pH, to raise the pH in tank 1 to approximately 7.
- The effluent is also monitored by the Umbilo Water Purification Plant. Regular testing is carried out. If the tanks pass, the effluent is disposed of. If not, treatment is required, eg. if the cyanide content is too high, sodium hypochlorite is added.
- The sludge that forms is removed by Waste Services approximately every 4 months.

Suggestions for Improvement

- The factory is run very efficiently, and measures are already in place to prevent wastage, such as the timers on the plating baths, which prevent an excess of solution being plated out.

- The amount of water consumed by the company is extremely high. Due to the low cost of water, this is not of major concern to the business. However the impact on the environment is far greater, and it is possible if the workers take greater care when rinsing components to save approximately 80% of the water lost at the final chrome rinse.

COMPANY W

Background
The company is an electroplating is a job shop situated in Durban, South Africa. The main market for this company is the public who bring in items for plating. These are mainly car parts, silver dinner sets, brass ornaments and jewelry. The company does have a few standing orders for plating screws, zips, nuts and bolts but the main source of income is the over the counter work brought in.

Process Description
Depending on the size of the items to be plated they are either plated in a barrel or a tank. Small items eg screws, zips, springs etc are plated in a barrel whilst larger items are plated in a tank. Since the company works on an 'over the counter' basis, the shape and size of the articles plated vary greatly. The metals plated are copper, nickel, chrome, brass, silver and gold. With the exception of aluminium, all other base metals are plated.

Chrome Plating:

- Polished to remove old chrome and clean metal
- Soaked in hot soak cleaner
- Placed in electrolytic cleaner for two minutes
- Rinsed in water (static)
- Acid etched using a 15% Sulphuric acid solution
- Rinsed in water
- Copper plated
- Rinsed in water
- Copper plated in acid copper tank
- Acid etched, again in a 15% Sulphuric acid solution
- Rinsed in water
- Nickel plated
- Rinsed in water
- Chrome plated
- Rinsed in water

Steps 1 - 13 are common to the brass, chrome and silver plating processes and will be henceforth referred to as process A

Brass Plating:
- Process A
- Brass plated
- Immerse in 2% sodium dichromate solution
- Rinse in hot water
- Dry article in oven and lacquer to eventually cure and dry

Silver plating:

- Process A
- Flash silver plate in strike solution
- Silver plate in solution for 20 minutes
- Rinse article in water and wait to dry.

Gold plating:

- Polished to remove all deposits and clean the metal
- Electrolytically cleaned
- Rinsed in water
- Acid etched using 15% Sulphuric acid solution
- Flash copper plated
- Rinsed in water
- Acid etched again
- Rinsed in water
- Flash nickel plated
- Rinsed in water
- Gold plated
- Final rinse in clear water

Barrel Plating
If many small pieces of metal are to be plated, the parts are placed into a perforated plastic barrel in electrical contact with the cathode bar and the barrel is immersed in the bath. The parts are tumbled to achieve uniform plating.

Effluent Treatment
94% of the water consumed by the company is regarded as being effluent requiring treatment. The company is charged 38c/kl for treatment of this effluent. Since the company uses about 300 kl/month this amounts to about R110.

The effluent is tested once a fortnight by a representative from the Durban Metro who checks the pH. In the event of the pH being too high caustic soda flakes are added to the sump

Suggestions for Improvement
- Items to be plated are attached with a copper wire to a hook which is hung from the anode. The hook is made of brass and is immersed halfway in the plating solution. Thus the hook also gets plated. When the plating gets too thick on the hook it is either chipped or ground of and the hook reused. In one month between 30 and 40g of various metals get plated onto the hook. There could be two solutions to this problem: 1. Coat the hooks with a hard wearing resin or rubber coating leaving a small area uncoated for electrical contact. 2. Shorten the hooks so that they do not make contact with the plating solution. The second solution seems more feasible since it involves no cost as the present hooks can be modified on the premises.
- When large items such as bumpers are plated large amounts of solution is lost due to dragout. The installation of drip tanks would minimise this waste.
- Fix all leaking water connections.
- Educate the employees on the benefits of waste minimisation. At present workers know little about the electroplating process and a lot of the knowledge learned has been of a trial and

COMPANY X

Background

The company manufactures and plates a variety of products for vehicles, mainly for buses and trucks, such as, mirrors, exhaust fittings, roof racks etc. The raw materials that are used are steel, stainless steel, aluminium, paint, chemicals, brass, nuts, bolts and products from other companies ie. lamps, etc. The company's main customers are Motor Wholesalers including Mercedes Benz, Nissan, Delta General Motors, and Izuzu Truck.

Process Descriptions

Nickel Plating

The part to be plated is first cleaned using trichloroethylene (TCE). This is a liquid, which is placed at the base of the tank. Steam is passed through here and the TCE vaporises, this vapour is used to clean the part. The vapour condenses and goes back into the liquid phase. In this way the TCE is recycled. Some is lost via evaporation; the amount that is lost can be calculated by recording the amount that is needed to top up the solution of TCE. The metal is dipped and suspended for about 2-3 minutes and is then dipped in cold liquid TCE and is then transferred back to the vapour cleaning process.

The part is then cleaned in a liquid soap solution of Maleic Anhydroxide. This is done for approximately 5 minutes. This solution is warmed by the steam. The Maleic Anhydroxide is a powder which is mixed with water to form the solution. Rinsing in cold water then occurs, after which the part is dipped in cold sulphuric acid for 3-4 minutes. Rinsing takes place again.

The part is then ready to be dipped in the nickel solution. Following another rinsing step, the object is chrome plated. A final rinsing then takes place.

Bonderizing

The metal object is cleaned in the same way as for Nickel plating, the only difference is that the part is not dipped in the cold liquid trichloroethylene after the vapour cleaning process. It is then dipped in cold sulphuric acid to remove the welding marks formed during the pressing process, and rinsed twice in cold water.

The objects are suspended in hot bonderizing liquid(Iron Phosphate), for about 30 minutes. Rinsing in cold water followed by hot water ends the process.

Zinc Plating

The metal part is cleaned in trichloroethylene, dipped in cold sulphuric acid, and rinsed in cold water. It is then washed in a soap bath containing Maleic Anhydroxide followed by further rinsing. Zinc plating then takes place. After another rinsing step (cold water), the job is dipped into nitric acid bath, rinsed again in cold water, and finally in hot water.

Effluent Treatment

There are two waste streams that lead from the plating department to the effluent treatment system. One stream contains nickel and chrome waste and the other contains zinc, cyanide and phosphate. These two streams lead into two separate dams.

The nickel and chrome waste is pumped up to a holding tank. This mixture is acidic as it stands. Hydrochloric acid (HCl) and Sodium Metabisulphate ($NaHSO_3$) is added to this tank and they all react to form a more acidic mixture.

The zinc and cyanide mixture (alkali) is transported in the same way to another holding tank where they are reacted with Caustic Soda (NaOH) and Sodium Hypochlorite (NaOCl), this in turn makes the solution more alkaline. The two holding tanks are continuously agitated by stirrers.
The two mixtures are then mixed together in another tank, which is also agitated, and the resulting solution is one that is neutral, since the one mixture is acidic and the other is alkali.
The pH is continuously checked to ensure that the pH is approximately 7-8. If not, then the quantities of the reacting chemicals are adjusted accordingly.

Suggestions for Improvement

- The average monthly water consumption of the company is approximately 300k*l*.
  The employees seem to be quite content with this figure as all possible measures have been taken to assure that this figure is as low as possible. The heating of the tanks is not done by electricity but by a boiler. This boiler recycles the water that it uses so it is not a source of water wastage.

- The drainage time over the chrome plating tank should be increased to reduce dragout.

- The plating tanks should be mixed daily to prevent the solids from settling on the bottom and forming a hard layer there. If this is done then topping up will be done less often.

- When a hot plating solution is used the drying time can not be very long otherwise the solution will dry and this will make rinsing less effective. The time for drying here can be shortened by shaking the jig gently.

COMPANY Y

Background
Zinc-Electroplating is one of two pre-treatment processes used by this company, the other process is Fracon. The work pieces are mainly mild-steel and large volumes are electroplated everyday. The process is unidirectional and not much of the materials are reused. The main products produced by the company include burglar gaurds, security gates and garage doors.

The products are mostly aimed at Urban communities were security is essential.

Process Description

Cleaning Process
Removal of oil from the work pieces is done by an alkaline-based Degreaser called Chemolene 03. The work pieces are dipped in a solution of this, at a temperature of approximately 40-60 degrees Celsius. This speeds up the reaction rate. The work pieces then undergo an electrolytic cleaning process in an alkaline based electrolyte. The next process of cleaning is the acid pickling which is done at an elevated temperature of 40-60 deg celcius.

Zinc Electroplating
A 6.5-1500A power supply, forces zinc ions from solid zinc to be plated onto the work pieces. This is done via an electrolyte which is made up of : Sodium Cyanide, Hydrogen Peroxide, Caustic Soda, Zinc Brighter, Sodium Sulphide, Zinc Oxide.

Passivation
After the process of electroplating the work pieces undergo a static rinse.
Passivation is a process to clean the work pieces from and give it a silver or yellow colour.

Suggestions for Improvement
- The waste generated by company is a large quantity and the cost of treating it is high. The company has a fairly advanced process for treating waste and is currently in the process of installing a filter press, which will reduce the quantity of waste to be handled.
- With over-head cranes drag-out and spillage can be kept to a minimum thus reducing losses in chemicals and water.

COMPANY Z

Background
The company manufactures various car parts. The company is appoximately 13 years old, and it's main products are car radiators, and car air conditioner components. It's customers are Motorware, Volkswagen, BMW, Delta, and Mercedes Benz.

Process Descriptions
The following processes are involved in the manufacture of radiators and air conditioner parts:

- INJECTION MOULDING: Manufactures plastic tanks for radiators.
- FABRICATION: Fabricates the various aluminium components for the radiator.
- MECHANICAL JUNCTION PLANT: Manufactures mechanically jointed radiators.
- BRAZED ALUMINIUM PLANT: Manufactures radiators in which the aluminium cores are brazed.
- EVACON: Manufactures condensers and evaporators for car air conditioners.
- COMPOSITE DEPOSIT PLANT: Also manufactures radiators in which the aluminium core is brazed but uses a different technology compared to that of the Brazed Aluminium plant.

Pret-reatment
In this process the aluminium cores are pre-treated before being sent for the brazing process.

The objects are firstly immersed in trichlroethylene. This is a degreasing stage which removes the oil present on the aluminium core. The degreaser tanks contain approximately 1000 litres of trichloroethylene. Elements heat up the trichloroethylene in the tanks. Cooling water circulates around the dgreaser stage, hence condensing the trichoroethylene vapours and limiting the amount of trichloroethylene fumes that are released into the atmosphere. The condensed trichloroethylene is returned back into the degreasing system.

Degreasing is followed by etching. The etching solution consists of 27.6% sulphuric acid and 5.0% hydrfluoric acid. 50 litres of the etch solution is diluted with 750 litres of de-ionised water. The etching process removes the aluminium oxide layer from the core preparing it for brazing. The etch solution is changed approximately twice a day, depending on the amount of aluminium in the solution, the concentration of the solution and obviously the production for the day. The aluminium must be less than 2500 ppm and the concentration must be less than 4%. This is checked every 2-3 hours.

The objects are then rinsed in tap and de-ionised rinse water. The conductivity of all these waters are measured every 2 hours. The drag out water has to be less than 5500 micro Siemens per centimeter, the rinse water less than 1000 micro Siemens per centimeter and the de-ionised water has to be less than 60 micro Siemens per centimeter. If these regulations are not met then the tanks are purged with fresh water.

The objects are finally immersed in a flux solution. Flux consists of potassium aluminium fluoride and basically a brazing agent. The ph of the flux is determined daily and has to be less than 5. The concentration is also checked every 2-3 hours.

Suggestions for Improvement

- Trichloroethylene is a very harmful chemical in its liquid form and in its vapour form. The proper clothing is used to minimize exposure to this chemical but it is suggested to use a less hazardous chemical.

- The etching solution consists of extremely hazardous chemicals and it is suggested that a less hazardous solution be used. However, more research has to be looked into this matter and more further work.

APPENDIX 2: BARRIERS AND DRIVERS

The following barriers and drivers were identified at the recruitment meeting in June 1998.

Table 2A: Barriers - 1998

BARRIER	NUMBER OF VOTES				
	Iindustry	Service Provider	Regulator	Other	Total
Low Business Confidence	0	1	1	0	2
Low Business Profitability	6	1	0	0	7
Disbelief of Payback Periods	1	0	0	0	1
Lack of Technical Knowledge	17	3	6	0	26
Lack of Awareness of CP	0	0	0	0	0
Percieved as high risk	1	0	1	0	2
Lack of Management Time	1	0	0	0	1
Operational Constraints	12	0	0	0	12
Lack of Enforcement of Legislation	1	2	1	0	4
Unclear Legislation	11	1	3	0	15
Lack of Outside Pressure	0	0	3	0	3
Lack of Information	14	0	0	0	14
Lack of Human Resources	4	1	4	1	10
Resistance to change	1	0	9	1	11
Production Pressure	9	1	0	0	10
Lack of Finance	21	0	0	0	21
TOTAL	99	10	28	2	139

Table 2B: Drivers - 1998

DRIVER	NUMBER OF VOTES				
	Industry	Service Provider	Regulator	Other	Total
Savings	23	1	8	1	32
Improved Environmental Performance	24	5	17	1	47
More Stringent Legislation	20	6	2	0	28
Pressure from Customers	7	1	2	0	10
ISO 14000	12	1	1	0	14
Improved Plant Utilisation	1	2	0	0	3
Improved Image	4	0	4	1	9
TOTAL	91	16	34	3	144

APPENDIX 3: CASE STUDIES

COMPANY A

Location : Jacobs, Durban, South Africa
Project Champion s: Plating Manager
Mechanical Engineer
No. of Employees : 864 production workers + 71 administrative personnel
Production Time : 24 hrs a day, 6 days a week
Shifts : 2 shifts per day
Age of Company : Approximately 50 years

Background
The company is a manufacturing enterprise concerned primarily with the production of a variety of appliances (stoves, washing machines, tumble dryers, air conditioners, and microwave ovens). These products are sold within South Africa with exporting of stoves to other African countries. The company is a 'capture shop' implying that metal finishing is only one part of the entire operation and facilitates pre-treatment and protection of the different appliance parts before assembly. The main processes carried out on site include pressing, fabrication, plating, assembly and ballast weight preparation.

The metal finishing processes employed by the company are:
- A metal pre-treatment (MPT) enamel line
- A zinc phosphate metal pre-coat treatment line
- A nickel/chrome plating line

The above processes consume a great deal of water, energy, and chemicals, and contribute approximately 90 % of the company's waste. Therefore management have made a commitment to waste minimisation, and as a result, their metal finishing processes have been investigated.

Management Commitment and Waste Minimisation Project Champions
A declaration of commitment to waste minimisation has been signed by the management of the company. Senior management has shown a keen interest in the progress made with waste minimisation at the factory. As a result, the company has committed time and resources to the implementation of a waste minimisation programme. The company has 2 waste minimisation project champions, who work together to co-ordinate waste minimisation activities. The company has been represented at all club meetings.

Preliminary Assessment
This phase involved familiarisation with the plant's main processes, obtaining data concerning consumptions of utilities and raw materials, identifying types and quantities of waste streams, and targeting areas for detailed investigation. The information obtained is discussed below.

Discussion of Main Processes
The metal finishing processes employed at the company are described below.

Enamel Metal Pre-treatment Line

This line consists of 11 tanks. The process is fully automated. The workflow is from left to right. Rinses are overflowing and use tap water. The arrangement of tanks in this line is shown below.

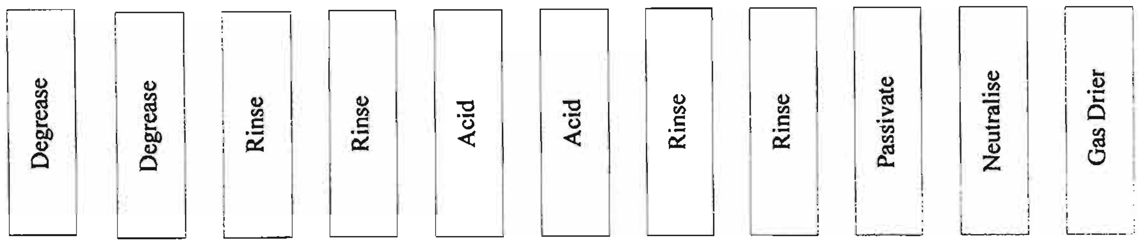

Figure 3A: Process flow of line 1 for Company A

- The panels to be treated are loaded in a basket and cleaned in 2 mild degreasers.
- Rinsing then takes place in 2 rinse tanks.
- The panels are dipped in 2 acid tanks followed by rinsing in 2 more rinse tanks.
- The jobs move on to passivation tank before being placed in the neutralisation tank.
- Depending on the enamel process to be used, the basket either enters the gas dryer or not.

Paint Metal Pre-treatment line

This line consists of 15 tanks. The process is fully automated and the process flow is form left to right. The jobs plated (various sizes and designs of washing machine components) are loaded into baskets which are immersed in the process tanks. The baskets are attached to flight bars, which shift between tanks. To maximise drainage above tanks, the basket is tilted side to side to facilitate drainage from circular components. All rinses are overflowing and use tap water. The Paint MPT process, provides a zinc phosphate coating onto metal to improve adhesion of subsequent coatings, and impart corrosion resistance to the overall substrate.

Sludge is produced in the phosphate tank. This sludge is removed to pits and the water recycled to the process. The arrangement of tanks is illustrated below:

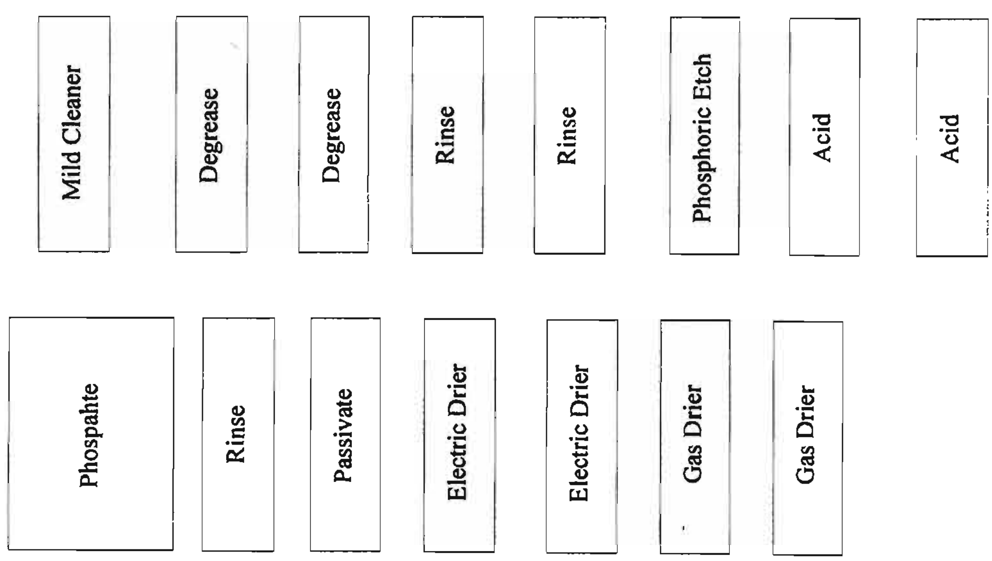

Figure 3B: Process flow of line 2 for Company A

- A basket containing the jobs are first sent through 2 degreasing tanks.

- The jobs are rinsed in 2 rinse tanks before going through 2 acid tanks.
- Following the acid tanks are 2 more rinses after which the basket is dipped into the phophate tank. A phosphate rinse and passivation tanks are next in the process.
- Drying of the jobs takes place in 2 electric dryers and 2 gas dryers.

A description of the contents of each tank is given in Table 3A

Table 3A: Description of Tank contents in Paint MPT Line

Tank	Major Chemical	Purpose	Concentration	Temperature(^{0}C)
1	Oaktite 67	Mild Cleaner	1.5 – 30 g/l	60 - 70
2	Formula 29A	Degreaser	25 – 50 g/l	60 - 70
3	Formula 29A	Degreaser	25 – 50 g/l	60 - 70
4	Water	Rinse		Ambient
5	Water	Rinse		Ambient
6	Phosphoric Acid	Etch	100 ml/l	Ambient
7	Sulphuric Acid	Etch	60 ml/l	40 - 45
8	Sulphuric Acid	Etch	60 ml/l	40 - 45
9	Water	Rinse		Ambient
10	Water	Rinse		Ambient
11	Gardobond 880E	Phosphate	38 ml/l	65 - 70
12	Water	Rinse		Ambient
13	Gardolene 60	Passivate	0.33 ml/l	60 - 70

Plating

This process line consists of 14 tanks which allow for cleaning; degreasing and pickling (metal pre-treatment), and plating, with all necessary rinse tanks. The jobs plated, are various sizes and designs of oven racks hung from jigs. The process is totally automated and the jigs and jobs are attached to flight bars, which shift between tanks. The process work flow is from right to left. This line is concerned with the plating of nickel and chrome onto steel, to improve the corrosion and thermal resistance.

The arrangement of tanks is this line is shown below:

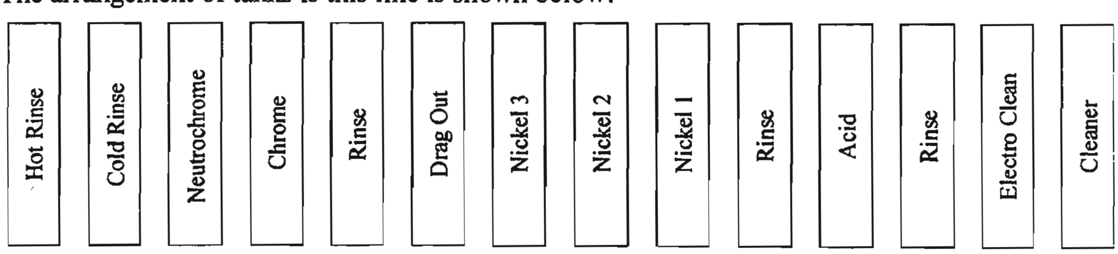

Figure 3C: Process flow of line 3 for Company A

All rinse tanks are overflowing except for the nickel dragout and hot rinse. The contents of each tank are described in Table B

Table 3B: Description of tank contents in the Plating Line

Tank	Major Chemicals	Purpose	Concentration	Temperature(^0C)
1	Chemalene	Cleaner	50 g/l	80
2	P3E Special-N	Cleaner	100 g/l	70 - 80
3	Water	Rinse		Ambient
4	Sulphuric Acid	Etch	150 g/l	60
5	Water	Rinse		Ambient
6	Nickel Sulphate	Plating	275 g/l	55 - 65
	Ni Chloride		75	
	Boric Acid		40	
	Bright 41		3	
	Bright 63		30	
7	Nickel	Plating	same as 6	55 - 65
8	Nickel	Plating	same as 6	55 - 65
9	Nickel, Water	Drag out		Ambient
10	Water	Rinse		Ambient
11	Chrome X400C	Plating	300 g/l	40 - 42
12	Neutrochrome	Neutraliser	50 g/l	Ambient
13	Water	Rinse		Ambient
14	Water	Rinse		70 - 80

Observations

Efforts have already been made to minimise the loss of chemicals to effluent, and to reduce the hazards created by volatile chemicals:

- During chromating operations, chromic acid is heated and a DC current is passed through the solution. The electrolytic process involves hydrogen and oxygen, which bubbles to the surface of the solution, and are released to the air. This results in the formation of a humid chromic mist or aerosol.
- When plating commences, the formation of a homogeneous foam blanket ensures the complete elimination of the notoriously toxic chromic acid spray, thereby making extraction virtually redundant. It saves the Chromic acid normally lost as mist and spray.
- Drainage boards exist between tanks to facilitate the return of chemicals to its respective tank when the jig and job is moved between tanks.
- The nickel tanks are kept relatively free of impurities, by continuous filtration through activated carbon.
- All tanks are directly adjacent to the previous, so spillage to the floor is not of significance.

Data Compiled

Water Consumption

Water is used mainly for rinsing purposes and the testing of washing machines. The monthly water consumption and corresponding costs are given in Table 3C

Table 3C: Monthly Water Consumption for Company A

Line	Consumption (kL/mth)	Cost (R/mth)	Monthly Effluent Cost (R/mth)	Total Monthly Cost (R/mth)
Enamel MPT	1240	3137.20	554.55	3691.75
Paint MPT	2520	6375.60	1126.99	7502.59
Plating line	3000	7590.00	1341.66	8931.66
Total	**6760**	**17102.80**	**3121.21**	**20126.00**

Effluent Treatment

Most of the effluent generated by the company originates from the metal finishing processes on site. The remainder of daily effluent is produced by the Automaid test bays , the mill room and the ballast weight department. The quantity of effluent generated daily from each department is given in Table 3D

Table 3D: Effluent Production in Company A

Department	Quantity (kL/day)
Enamel MPT	62
Paint MPT	126
Plating line	92
Automaid testing	9.9
Mill room	23.4
Total	**381.2**

The company has recently installed an effluent treatment plant. Prior to this, the paint and enamel MPT effluent were piped into a make–shift holding tank and neutralized with soda ash , whereas the plating effluent (which has a pH of approximately 9) was piped directly into the drain.

Problems Identified

The following problems were identified for waste minimisation:

Enamel MPT Line

- The rinses directly after the degrease and acid tanks become contaminated with the solution from previous tanks, therefore making it difficult to maintain the pH of the rinses. The result of this is that much larger volumes of water is being fed into the rinses to keep them as neutral as possible.
- Energy losses are encountered from the gas dryer since it is on all the time but not used all the time.

Paint MPT Line

- A high water consumption has been noted on this line.
- The sludge generation is high.

Plating Line

- Water consumption is extremely high
- A build-up of foam occurs on the alkali rinse where the pH is too high

Generation of Waste Minimisation options

Following the pre-assessment, a number of waste minimisation options were identified.
The *initial* options identified for the specific problems identified during the pre-assessment are discussed below.

Enamel MPT Line

- The hang times for the baskets after degreasing need to be increased thus allowing for greater drainage.
- The drier should only be switched on when it is required. Perhaps it can be switched on when the basket is in the tank preceding it to allow for a start-up period.

Paint MPT Line

- A solution would be to consider countercurrent and cascade rinsing. Increasing the hang times of the jobs for greater drainage is also an option, but is not feasible as it will result in drying. If drying occurs before phosphating, it will lead to marks appearing on the jobs after powdercoating.
- The high volumes of sludge produced by this line is most likely due to incorrect dosage of chemicals. This implies that excess chemicals are being added to the process tanks. This problem is difficult to deal with since the chemicals are dosed manually. A method of adding chemicals automatically, as well as the use of alternative chemicals should be investigated.

Plating Line

- Increase the hang times of the jobs to increase drainage and reduce drag out.
- Because the jobs are oven racks, they do not require total immersion to be rinsed. The rinse tanks should therefore be replaced by spray rinses. Spray rinsing generally uses one-fourth the water of an overflow rinse. Spray or jet-rinse offers the following advantages:
    a decrease in water consumption
    b) the cost of concentrating the solution prior to recycling into the plating bath is reduced
    c) there is considerably less static recovery rinse: 99% of drag-out can be recovered by spray rinse.
- Cascading the acid rinse into the alkali rinse would result in a reduction in foam build-up, and a stabilisation of the pH.
- Conductivity controllers can be installed to regulate flow, based on rinse water conductivity. When the conductivity reaches a set point (ie maximum metal content allowed to avoid inadequate rinsing), the valve is opened and water flows through the tank.
- Alter jigs to improve drainage.

Additional site visits to the company lead to more options being identified:

- Reuse acid rinse water for after electro-clean alkalia process
- Bund areas to prevent spillages entering sewer
- Prevent loss of empty chemical drums by storing them closer to the factory
- Reduce tank volumes
- Prevent evaporation by covering tanks when not in use
- Check concentration of Ni in plating bath on a regular basis
- Investigate replacement of hexavalent Cr with trivalent Cr
- Apply corrosion resistant coatings to all tanks
- Install a drag-out tank after Cr plating
- Use drag-out to top up Ni tank

- Install electricity meters on electric dryers, compressor house and powder coating lines
- Meter LPG use at painting and enamelling pretreatment lines
- Eliminate use of compressed air for bath agitation and use high pressure blowers
- Implement a programme to quantify, fix and monitor compressed air leakage
- Apply external insulation to pre-treatment dryers
- Install water meters on plating and pretreatment lines
- Install rotameters to measuer flows
- Restrict flows to minimum requirements
- Install air restirctors
- Implement oil removal programme (use of newspapers)
- Turn off gas heaters when not in use
- Enforce safety regulations and kits
- Find a substitute for Tricholorethylene
- Install additional rinse tanks

- Install effluent pipes above ground
- Improve pH control system on effluent
- Conduct an air audit
- Investigate the possibility of suppliers taking back lubricants
- Investigate replacement of paint dip line by electro paint - coat
- Install ultra filtration unit on degreasing bath
- Remove and reuse nickel
- Use only RO water on plating line
- Investigate LCA of products
- Control of waste bin so that only sludge is disposed of
- Improve power factor
- Control over dumping of baths such that permission must be obtained first
- Worker education and operators given responsibilities for their lines
- Replacing chemicals in phosphate line such that less sludge is produced
- Implement a programme for regular maintenance and fixing of leaks
- Install a air scrubber over Cr tanks
- Repair carrier racks - the paint is chipping and can affect quality of plating
- Install drip trays between tanks to catch carry-over
- Check piping and joints for leaks
- Recycle drag-out on a regular basis rather than intermittently
- Install a drag-out after Cr tank and before passivation
- Install pressure gauge on incoming water to ensure pressure is constant for constant flow
- Modifying piping and removing excess
- Investigating dumping procedures and impact on effluent plant

Implementation of Waste Minimisation Options

The waste minimisation options implemented by the company are listed below.

Enamel MPT

- Cascade and counterflow rinsing has been introduced to this line, and a saving of 50% in water use was achieved.

Paint MPT

- The introduction of cascade rinsing to this line has resulted in a 40% reduction in water consumption.

Plating Line

- The drainage time of objects over tanks has been increased.
- Orifice plates have been installed to regulate rinse water flowrates.
- Cascade rinsing has decreased water consumption by 33%.
- The modification of jigs to allow jobs to drain at an angle has decreased dragout.

Other Options

- A significant saving in electricity has resulted from a power factor correction.
- Improved control over the waste skip has decreased the number of times solid waste has to be removed.
- A programme on educating workers has begun
- The company has improved control over the dumping of process baths.

Financial Benefits

The implementation of the above options has resulted in substantial savings for the company. These savings are given in Table 3E.

Table 3E: Savings Achieved in Company A

Item	Annual Saving (R/yr)	Pay-back
Water	33 000	2 weeks
Chemicals and Metals	Not quantified	
Electricity	110 000	Immediate
TOTAL	**143 000**	

COMPANY B

Location : Durban, South Africa
Project Champions: Owner
Manager
No. of Employees : 10
Production Time : 14 hrs
Shifts : 2 shifts per day
Age of Company : Approximately 5 years

Background

The company is a job shop that provides galvanising and powder coating of metal objects for various customers. The objects being plated are mainly burglar guards and large gates. The company has experienced problems with water and effluent management, and has therefore been interested in waste minimisation.

Management Commitment and Project Champions

The company has 2 project champions, the manager and the owner, who have made a commitment to implementing waste minimisation. They have been responsible for coordinating waste minimisation activities at the factory, and ensure that the workers are aware of the waste minimisation efforts being made.

Preliminary Assesssment

The company's processes were investigated during site visits. The main process employed at the company is zinc plating. This process is depicted below:

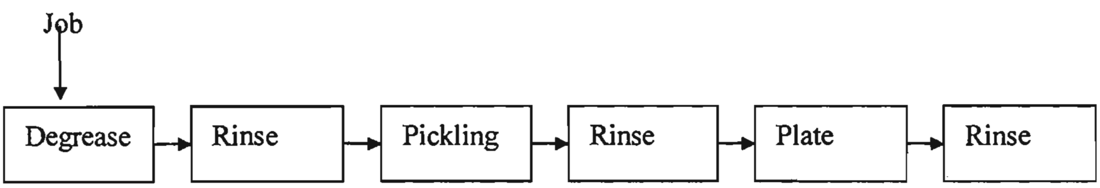

Figure 3D: Process flow of Zinc line in Company B

The jobs are degreased in a caustic solution, while hydrochloric acid is used for pickling . The smaller jobs are rinsed in statics rinses, while rinsing of larger jobs is accomplished with a hosepipe.

Observations

The drainage of spills and dragout is only by fiberglass moulded "gutters" flowing to effluent holding tanks (situated below ground level). The floor was fiberglassed in November '98, to prevent seepage. Odd shaped and "make-shift" containers are used for rinsing purposes. The process baths have not been arranged for the optimisation of the process with respect to space and time. The process is carried out behind a building that accommodates the office and other businesses, and it shaded by fibreglass sheeting. The three largest tanks (zinc-cyanide), are housed in a poorly ventilated room, that has concrete floors. Chemical spillages accumulate in shallow pits and corners of the room. Zinc cyanide, HCl and a caustic cleaning solution are the primary pollutants at Wings. The cyanide is treated by sodium hypochlorite, and the acid with soda ash. These are added directly to the effluent tank.

Generation of Waste Minimisation Options

The following initial options have been suggested:

- The tanks should be repositioned to decrease the distance between them, and hence decrease dripping onto the floor and wastage due to dragout.
- Tanks should be covered when not in use to prevent contamination and evaporation.
- The manager has undertaken to install a water meter, and readings are being taken before and after each shift. This information should be used to monitor water consumption so that problems may be identified immediately.
- The utilisation of drip trays needs to be increased.
- A phosphate tank is currently not in use, and is being housed in the room containing the zinc tanks. Its use as a zinc dragout tank should be investigated.
- The room housing the zinc tanks, requires extraction fans, and the floor should be fibreglassed, to prevent seepage, and to facilitate drainage to the effluent tanks.
- Although drip trays are situated around the zinc tank, workers find it too strenuous to hold big jobs (burglar guards and gates) to drain. It was suggested, that a horizontal bar be erected above the drip trays, so that the job could be hung to drain.
- Workers are not restricted with respect to the amount of water used during spray rinsing (hose connected directly to water mains). It was suggested that the flow rate by restricted to an adequate setpoint, that allows effective rinsing.
- Analysis of tanks are done fortnightly by the manager. Control measures should be implemented to allow quantification of chemical usage.
- Barrels should be redesigned to facilitate better drainage
- Remove oil from rinse tank after degreasing
- Replace cyanide zinc process with an alkaline process
- Train workers in waste minimisation
- Fix leaks in tanks and pipes
- Install spray rinses
- Install air operated return pumps
- Investigate the possibility of installing wall hanging rinses
- Undertake an energy audit

Implementation of Waste Minimisation Options

The company has been very keen to implement waste minimisation options and improve conditions on site. To date the following options have been implemented:

- A horizontal bar has been installed above the zinc tank to improve drainage of the larger jobs.
- Drainage boards have been installed between tanks to reduce dragout, thus saving water and chemicals.
- Emphasis has been placed on educating workers with respect to waste minimisation.
- Chemical consumption is being monitored and controlled.
- Leaks in tanks and pipes have been fixed and routine checks are conducted for further leaks.
- The company has begun monitoring water consumption.
- The company has embarked on a programme to repair leaks.
- A waste audit has been undertaken.

Savings Achieved

The company has benefited from savings in water and chemicals. This is shown in Table 3F

Table 3F: Savings Achieved by Company B

Item	Annual Saving (R/yr)	Pay-back
Water	636	Not quantified
Chemicals and Metals	13 200	Immediate
TOTAL	**13836**	

COMPANY C

Location : Chatsworth, Durban, South Africa
Project Champions: Owner
No. of Employees : 10
Production Time : 9 hrs/day
Shifts : 2 shifts per day
Age of Company : Approximately 14 years

Background
The company is a plating enterprise concerned with the plating of a variety of objects of different shapes and sizes. The company is ISO 9000 accredited, and is therefore audited every 6 months. Zinc plating is the major process employed with tin and cadmium plating taking place.

Management Commitment and Project Champions
The project champion is the owner of the company, who has made a commitment to implementing waste minimisation.

Preliminary Assesssment
The company's processes were investigated during site visits. Zinc plating is the primary process carried out at the plant. Facilities are available for cadmium, nickel and tin plating, but these lines are seldomly used. The major work is received for zinc plating. There is a barrel as well as jig operated zinc line. These lines follow the same process which is illustrated below.

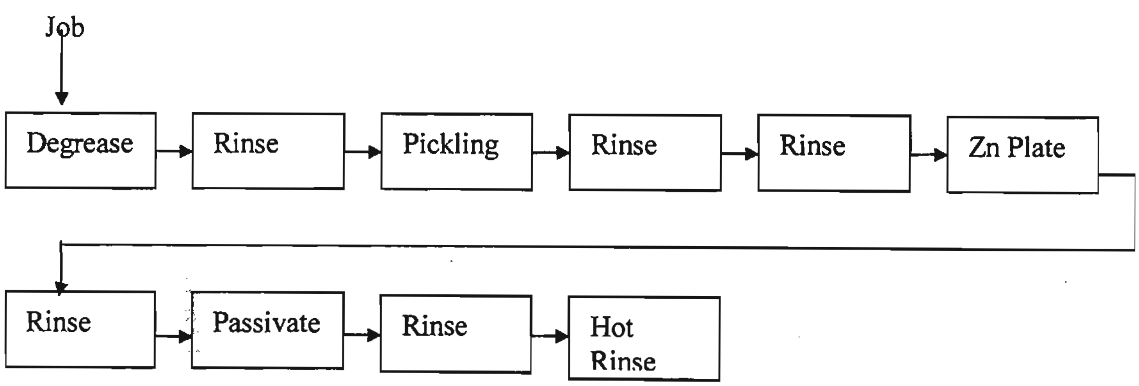

Figure 3E: Process flow of Zinc line in Company C

The jobs are degreased in a caustic solution, while hydrochloric acid is used for pickling. Rinses are overflowing.

Water Consumption
The company has 2 water meters, but water consumption is not monitored.

Effluent
An effluent treatment plant is being built to comply with new regulations. Sludge is currently being stored on site. Between 2 to 3 tons of sludge per month is produced by the factory.

Observations

- Drainage from floors is ineffective. Some rinsing is done onto the floors. This leads to water remaining stagnant on the floors around process tanks.

- Excessive amount of water is used for manual rinsing purposes.
- Insufficient time is allowed for the drainage of articles. As a result, there is a lot of carryover of solution to subsequent tanks.
- Finished jobs are carried some distance to the drying area, and drips water on the way.
- Chemical are locked away, and workers are instructed on the amounts to be added to tanks.
- The floors are generally free of clutter.

Generation of Waste Minimisation Options

The following initial options were suggested:

- Improve drainage system – this may require some work on the floor to direct water to the drain.
- Install flow restrictors on hose pipes.
- Increase drip time of jobs over plating baths to reduce dragout
- Introduce drainage boards between tanks to allow solutions to drain back into their tanks.
- Install overhead draining bars to increase drainage.
- Adjust overflowing rinse water to the minimum flowrate required for adequate rinsing.
- Change from overflow rinsing to static rinse
- Cover hot tanks when not in use to reduce evaporation.
- Educate workers on the importance of waste minimisation
- Undertake reading water meters daily and monitoring water consumption.
- Consider using spray rinsing for the larger jobs.
- Fix all leaks in tanks and pipes.
- Install and use dragout tanks.
- Rotate barrels out of solution to improve drainage.
- Monitor electricity use.

Implementation of Waste Minimisation Options

To date the following options have been implemented:

- Changed from overflowing rinses to static.
- A dragout tanks has been installed.
- Process tanks are being operated at lower specifications than that recommended.
- Chemical consumption is being monitored in house.
- Barrels are being rotated to increase drainage.
- A programme on fixing leaks has been initiated.
- Additional dragout tanks have been installed.

Savings Achieved

The company has benefited from savings in water and chemicals. This is shown in Table 3G.

Table 3G: Savings Achieved

Item	Annual Saving (R/yr)	Pay-back
Water	5 500	Imediate
Energy	88 000	Not quantified
Chemicals and Metals	110000	Immediate
TOTAL	**203 500**	

COMPANY D

Location : Seaview, Durban, South Africa
Project Champions: Owner
No. of Employees : 50
Production Time : 12 hrs/day
Shifts : 2 shifts per day
Age of Company : Approximately 20 years

Background
The company is a small electroplating job shop that provides plating for a number of different customers. Plating is performed on steel, copper, brass, diecast and aluminium.

Management Commitment and Waste Minimisation Project Champions
A declaration of commitment to waste minimisation has been signed by the owner of the company who was initially sceptical of the benefits of implementing waste minimisation. After a few months as a club member, his views changed, and he became very enthusiastic about waste minimisation. As a result, the company has committed time and resources to the implementation of a waste minimisation programme, and the project champion (the owner) has convinced other club members of the benefits of waste minimisation.

Preliminary Assessment
This phase involved familiarisation with the plant's main processes, obtaining data concerning consumptions of utilities and raw materials, identifying types and quantities of waste streams, and targeting areas for detailed investigation. The information obtained is discussed below.

Discussion of Main Processes
The following metal finishing processes are carried out at the company:

- Zinc – Galvanising
- Chrome plating
- Copper plating
- Nickel plating
- Cadmium plating
- Silver plating
- Gold plating
- Irridising
- Anodising
- Tin plating
- Brass plating

The departments concentrated on during the assessment were the Zinc Plant and the Screw Driver Plant. A description of the main process lines in these plants is given below.

Zinc: Galvanising Plant
The main zinc line is depicted below

This line consists of 12 tanks, which allow for cleaning, pickling , rinsing, and plating of the metal objects.

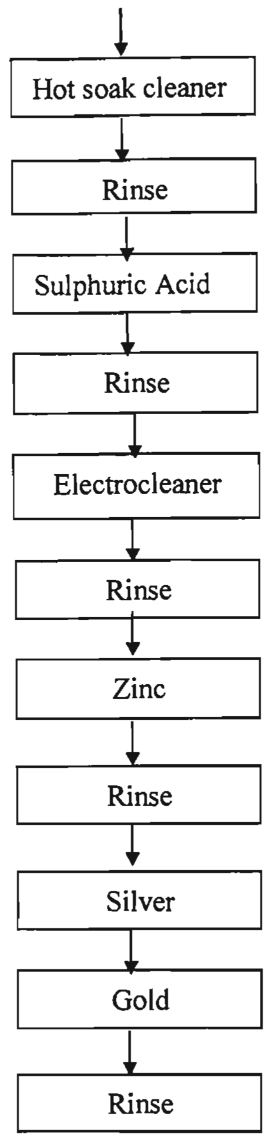

Figure 3F: Process flow of Zinc Plant in Company D

A description of the tankc ontents in this line is given in Table 3H. All other lines in the zinc plant have similar tank contents.

Table 3H: Description of tank contents in main line.

Tank	Process	Volume (L)	Chemicals used in tank	Concentration (g/l) Spec	Concentration (g/l) Actual	No. of times emptied
Hotsoak cleaner	Removes oil and grease stains. Temperature: 50°C Duration: 10 minutes	4392	Chemeo-lene 03	0.5		Every 2 months
Rinse	Removes all traces of cleaner solution and grease stains.	4269	Water	———		Very seldom
H_2SO_4	Remove surface rust and activates the surface. Duration: 10-15 minutes	4076	H_2SO_4	0.1	0.08-0.12	Every 2 months
Rinse	Removes all traces of pickling acid solution.	4196	Water	———		Very seldom
Electro Cleaner	De-smut and final clean Duration: 20 seconds	4082	NaOH NaCN	0.1 0.02		Once a year
Rinse	Removes all traces of electro cleaner solution.	4145	Water	———		Very seldom
Zn 1	Actual electro-plating process	4145	Zn metal NaOH	45 132		Almost Never
Zn 2	is carried out.	4196				
Zn 3	Duration: 15-20 minutes depending on amount of Zn plating required.	2229	Zn metal $NaCO_3$ NaCN	22 80 45	28 80 53.9	
Zn 4		2026				
Rinse	Removes all traces of zinc solution.	4295	Water	———		Very seldom
Silver (Passsivation)	To achieve silver colour. Duration: 20-30s.	4086	HNO_3 $Na_2Cr_2O_3$ Proprietary	0.02 0.5 0.5		Every 3 months
Gold (Passsivation)	To achieve gold colour. Duration: 30-60s.	4059	HNO_3 $Na_2Cr_2O_3$ Proprietary	0.02 2 0.5		Every 1 year
Rinse	Removes all traces of passivation solution.	2695	Water			Very seldom
Rinse	Used for Barrel line.	212	Water	———		
Rinse	Used for Barrel line.	216	Water			

Screw Driver Plant

This plant consists of a plating line, which is comprised of 22 tanks. The process is depicted below:

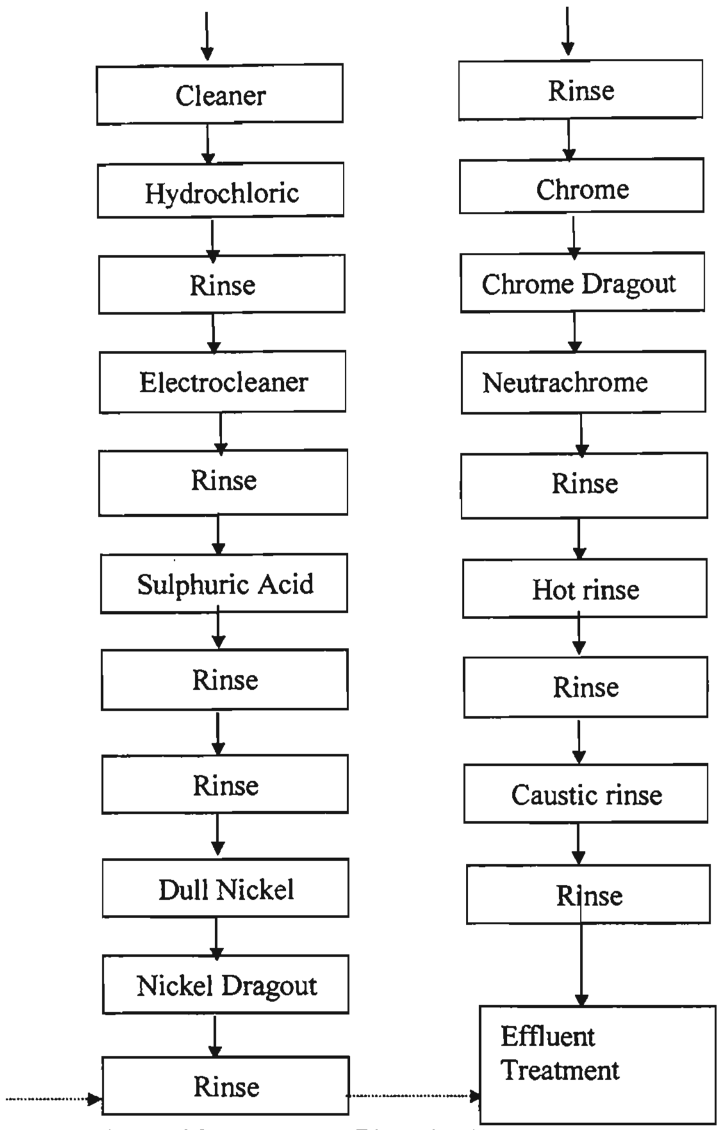

Figure 3G: Process flow of Screwdriver Plant in Company D

A description of the contents and purpose of each tank is given in Table 3I.

Table 3I: Description of Tank Contents in Screwdriver Plant

Tank	Process	Volume (L)	Chemicals used in tank	Concentration (g/l) Spec	Concentration (g/l) Actual	No.of times emptied
Soak cleaner	Removes oil and grease stains. Duration: 2 minutes	264	HP 70	50		Every month
HCl	Pickling. Duration: 2 minutes	250	HCl BTS	0.12 0.02		Every month
Rinse	Removes all traces of pickling acid solution.	247	Water	———		Very seldom
Electric Cleaner	De-smut Duration: 2 minutes.	290	NP 2	80 g/l		Every 2 weeks
Rinse	Removes all traces of electric cleaner solution.	126	Water	———		Very Seldom
Rinse	Rinse.	115	Water	———		Very seldom
H_2SO_4	Duration: 2 minutes.	79	H_2SO_4	0.05		Every 2 weeks.
Rinse	Removes all traces of Acid.	79	Water	———		Very seldom
Rinse	Final rinse before entering nickel plating bath.	250	Water	———		Very seldom
Dull Nickel	Actual electo-plating process is carried out. Temperature: 50°C Duration: 2 minutes.	2255	Nickel Sulphate Nickel Chloride Boric Acid	120 40 40	99.9 28.5 27.8	Very Seldom
Nickel drag-out	Drag-out for nickel plating solution.	250	———	———		Very seldom
Rinse	Removes all traces of nickel solution.	250	Water			
Rinse	Final rinse before entering chrome-plating bath.	250	Water	———		Very seldom
Chrome	Actual electo-plating process is carried out. Temperature: 50°C Duration: 30 s.	485	Chromic Acid Sulphate Catalyst X 400	188.3 0.8 1.8		Very seldom
Chrome Drag-out	Drag-out for chrome plating solution.	252	———	———		Very Seldom
Chrome neutraliser	Converts hexavalent chrome to trivalent chrome.	252	MBS	———		Very Seldom
Rinse	Rinse.	252	Water	———		Very Seldom
Hot rinse.	Rinse and dry.	104	Water	———		Very Seldom

Information Compiled

Water

The factory has two sources of water, namely, Municipality and the Umhlatuzana River. The water from the Municipality is used at the Chrome and RDI plants respectively. The water from the river is filtered and then pumped to the Zinc, Screwdriver and General Plating sections. When the river is flooded, the pump from the river is shut off and only Municipal water is used. The advantage of using the water from the river is that the company does not pay for the supply of this water.

The consumption and cost of municipal water prior to the implementation of waste minimisation is given in Table 3J

Table 3J: Water Consumption in Company D

Cost of water (R/kl)	Quantity (kL/month)	Total cost (R/month)
2.49	2082	5 184.18

Effluent

Copper, nickel, cadmium, silver and zinc are the metals that are expected in this stream. The effluent is treated with sodium metabisulphite ($Na_2S_2O_3$ or MBS), sodium hypochlorite ($NaOCl$), caustic soda or soda ash (Na_2CO_3). An effluent treatment plant has been built on site to comply with legal discharge limits. Solids are effectively removed by filtration. The quantity of effluent produced and the associated costs prior to implementing waste minimisation is shown in Table 3K.

Table 3K: Effluent Quantity and Costs in Company D

Cost of effluent (R/kL)	Quantity (kL/month)	Monitoring Charge (R/month)	Total cost (R/month)
0.521736	6692.08	431.40	3922.90

Targeted Areas

The following areas were chosen for investigation:

- Water consumption,
- Chemical control,
- Reducing metal concentrations to drain,
- Energy use, and
- Effluent control.

Water consumption was high throughout the factory. There were no restrictions on the flowrate of water used for rinsing. Dosing of process tanks with chemical takes place manually. There wasn't much control over this, and as a results an execess of chemicals was being added to the tanks. This not only represents a waste in chemicals leading to higher consumptions than necessary, but also to increased metal concentrations in the effluent. Improved effluent control is important for the company to comply with new regulations. The company also spends a great deal of money (between R 12000 and R 15 000 /mth) on cleaners, which also leads to effluent problems. Energy use is mainly by a drying oven, and heated tanks. The rectifiers are constantly drawing electricity on site even when not in use.

Generation of Waste Minimisation Options
Based on the above problems, a number of waste minimisation options have been suggested during initial site visits for the company. The most important ones are described below.

Zinc Plant
- Change to cyanide free plating
- Install dragout tanks
- Switch to counterflow rinsing
- Ensure taps are closed when not in use
- Reduce rinsewater flowrates

Screwdriver Plant
- Redesign stoppers on screwdrivers to reduce dragout
- Fix all leaks in pipes and tanks
- Install automatic crane to decrease drip times
- Reschedule oven use to reduce heating costs
- Reuse electro cleaner

General
- Monitor water use
- Monitor chemical consumption
- Reduce dragout by increasing drip times of jobs
- Fix all leaks
- Close municipal tap at end of zinc line and use borehole water
- Install more meters on incoming water
- Train staff in waste minimisation
- Optimise jig orientation to improve drainage
- Switch off rectifiers overnight
- Educate customers to use less harmful metals
- Improve insulation on all heated tanks
- Install thermostats to ensure tanks operate at optimum temperatures
- Reuse rinse water in the tricloroethylene

Implementation of Waste Minimisation Options
The following options were implemented by the company:

Water
- The company now has 8 water meters, and monitors water consumption daily. This enables any problems to be identified immediately.
- Rinsewater flowrates have been adjusted to the minimum required for adequate rinsing.
- Additional dragout tanks have been installed in process lines.
- Counterflow rinsing has been introduced to processes.
- Rinsewater is being reused.
- Leaks in tanks and pipes have been repaired.
- Unused taps are shut off.
- More water meters have been installed.

Chemicals

- A storeman has been employed to control the quantities of chemicals being added to baths. This resulted in a saving of 10 to 15 % in chemical costs.
- An automatic crane has been installed over the chrome bath. The jobs are lifted out of the bath and allowed to drain at a slower rate. This has resulted in a saving of 25 kg /month of Chrome. This in turn has reduced the quantity sodium metabisulphite required to treat the chrome in the effluent.
- Old cleaning solutions are now being emptied into another tank, and new solutions are prepared. The jobs being processed are first dipped into the old cleaners and then the new ones. This has lead to the life of cleaning solutions being doubled.
- Drip times over process baths have been increased leading to less carryover of chemicals to rinse tanks.
- The orientation of jobs on jigs has been improved to allow for maximum drainage of jobs, thus reducing dragout and savinf chemicals.
- The cyanide zinc plating process has been replaced with the alkaline zinc process. This process costs the same to operate and eliminates cyanide from the effluent.
- Recycling of acid takes place with no associated costs.
- The oil from the cleaner is being removed
- Some customers have been convinced to change from requiring cadmium plating.
- The electro cleaner is being reused.

The reduction of chemical consumption leads directly to a reduction of metals going to drain, and the amount of chemicals required for effluent treatment.

Energy

- Rescheduling of the oven used for drying of jobs has resulted in a reduction in its use from 8 to 3 hours per day.
- Thermostats have been installed on hot baths. This is to ensure that the baths operate at the minimum required
- Rectifiers that were previously left on overnight even when not in use, are now being switched off at night.

Savings Achieved

The savings achieved from the implementation of the above options is given in Table 3L.

Table 3L: Savings Achieved by Company D

Item	Annual Saving (R/yr)	Pay-back
Water	59 400	Immediate
Chemicals and Metals	68 400	Immediate
Energy	33 000	Immediate
Effluent charges	36 500	Immediate
TOTAL	**197 300**	

APPENDIX 4: SURVEYS CONDUCTED IN 1999 AND 2000

Survey Conducted in March 1999

Questionnaire:

1. No. Employees:
2. Date of establishment of firm:
3. Location in the city:
4. Date joined club:
5. Reason for joining the waste minimisation club:
6. Position of club representative in the company:
7. What was your interpretation of waste minimisation before joining the club?
8. Apart from cost reductions, did you perceive that there might be any other benefits that could be gained from minimising waste.
9. How did your views change after becoming a member?
10. Are you aware of any other waste minimisation projects in the city? What are they? How do they differ from the club in which your company is involved?
11. How do you see waste minimisation fitting into the Durban Metropolitan Council's Local Agenda 21 programme?
12. How was the club started?
13. What potential do you think this club has for continuing in the future?
14. What constraints might prevent the club from functioning in the future?
15. What changes would you make to improve the structure and functioning of the club?
16. How did membership of the club facilitate greater knowledge about waste minimisation practices?
17. What are your views on clubs as mechanisms for bringing about improved waste minimisation practices in industry?
18. What relationships have developed between your company and other club members?
19. What is the basis of this relationship?
20. How do you perceive the clubs as fitting into the broader process of environmental management?

Responses:

Company B

1. 10 employees
2. Company is 22 years old
3. –
4. Joined when the club formed.
5. Good club to be involved in, beneficial for the company.
6. The representative is involved in various areas of management
7. Didn't really know anything about waste min before being introduced to waste min in the club environment.
8. Other benefits to the waste min club are increased knowledge and the practices that can help to save the environment and prevent lots of industrial pollution.
9. Through the club theoretical and practical knowledge of waste min has been vastly increased.
10. –
11. Doesn't really know about how the club got started, motivation for starting

12.and 13. The club has few constraints and it seems very promising that it will continue into the future because it is a good and useful cause.

14. Doesn't think there should be any changes
15. Belonging to the club has meant that a great amount of knowledge and sharing of information so that waste min can take place. Meetings and consultants are a way of getting information
16. Clubs are a good way of spreading information and they could be used to cut down on the wrong actions in other industries.
17. Relationships are very beneficial
18. Clubs mean that industry can contribute to environmental causes by being involved in waste minimisation.

Company D

1. 47 employees
2. 18 years
3. -
4. Since the Club was formed
5. To avoid fines and prosecution form the law due to exceeding metro regulations, to help the environment
6. Director
7. Initially thought his company's waste management was quite good and waste min would be costly but has discovered that many savings have been possible with very little cost.
8. Knows vaguely of Hammarsdale club beginning and possibly some waste minimisation being carried on in Pietermaritzburg.
9. Learnt a lot through the club and realises that waste min is a long term process that boils down to good housekeeping to make sure that your company maintains its waste min procedures, surprised by how it has brought the plating fraternity together.
10. Metro was initially not very interested and possibly a bit sceptical because they have their own agenda but now that they see the difference being made they view it as beneficial for them because waste is being reduced.
11. About a year ago the waste min club begun. He describes a meeting with Durban Metro in which new and upcoming health regulations and pollution laws etc. The waste min club was brought up at this same meeting and it was seen as a way of avoiding fines and other potentially

crippling legal action by metro, as well as a contribution to the environment.

12. The club should carry on into the future and he is positive about the potential for continuance but he feels that the members may change as smaller or less interested companies move away from the club as their relatively minor problems are solved and they lose enthusiasm. But bigger companies with longer-term problems or long term change plans will stay with the club. New members may join on the merits of the clubs success and thus the club will continue.
    New clubs with different industries or with new leadership by those with previous experience are possible. If laws are made stricter then companies will be forced by the regulators to join the club as a way of avoiding illegal production factors.
13. Sees no real constraints to the club continuing
14. No changes to structure and functioning, happy with method of operation and enjoys meetings. One problem may have been the early introduction of students, possibly these students did not have as much expertise as industry expected and it may be more beneficial to bring them in later when industry knew in which direction to point then – in terms of data collection and searching for pollution.
15. Yes, much knowledge has been shared and more extensive knowledge and the club has facilitated experience of waste min. Sharing information, the trip to Denmark and the experience with waste min within the metal finishers has been invaluable.
16. Clubs are seen to be a good mechanism for facilitating waste min in industry, the informality and relaxed and positive atmosphere is much better than legal enforcement and piles of literature.
17. Good relationships have been formed with those involved in the industry, feels that at times the passage of information is one way and he gives out advice on waste min frequently but enjoys sharing information as bigger companies obviously will have more problems and therefore more solutions and can give advice easily.
    Doesn't really know how to fit waste min clubs into the broader aspects of environmental management. Possibly, the clubs could be used in other industrial sectors to reduce waste and pollution. Feels that continued involvement of academic institutions in industry can only be beneficial (on both sides).

Company F

1. Approximately 70
2. 1980
3. Pinetown
4. June 1998
5. To comply with by-laws and improve waste minimisation in house.
6. Production manager
7. Did not know much about waste minimisation.
8. Expected sharing of knowledge and improved relationships with other companies.
9. Success was achieved when waste minimisation options were implemented.
10. No
11. -
12. The club has lots of potential to continue in the future.
13. The lack of commitment by the members
14. The club has been run quite well to date. No changes are required.
15. The sharing of knowledge and ideas among all the members.
16. –
17. Previously was not familiar with any of the opposition, but now discuss views and ideas with other members.

18. Sharing of knowledge.

Company H

1. 200
2. 1975
3. Prospecton
4. June 1998
5. Thought it was a good idea for businessmen to get together and exchange ideas.
6. Works Director
7. Believed that his company was always doing a good job in reducing waste.
8. Only considered cost reductions.
9. Views did not change after joining the club.
10. No
11. –
12. –
13. The potential for continuing is good since the club is vital for this industry.
14. If we cease to have facilitators in the future.
15. No suggestions for improvement.
16. –
17. –
18. Some relationships existed before joining the club, but none have formed since.
19. Customers.

Company K

1. 8 employees
2. Company is 6 years old
3. Rossburgh
4. Joined when the club first started.
5. Joined when the company was approached by the PRG. Was already aware of the need to be environmentally friendly and saw the club as a way of educating himself and as a way of keeping in line with the rules and regulations regarding the industry.
6. The representative is the manager of the company.
7. Did not know too much about waste minimisation initially in terms of the practical activities that can be carried out to minimise waste.
8. Apart from cost, benefits were knowing what was going on in industry and getting suggestions and help to reduce the waste.
9. Yes, ideas of waste minimisation have changed. The practical ways of reducing waste were a real eye-opener. The obligations of the industry to minimise waste and act appropriately have been instilled by interaction in the club. Seems to have a vague idea that there is another club in the city – possibly with chemical and dying firms.
10. No comment
11. Seems to think that the club began as a combined effort of Durban Metro and the University of Natal.
12. Thinks that the club has enormous potential for continuing into the future and is very enthusiastic.
13. Feels that there are no constraints to the club continuing into the future.
14. Would make no changes to the functioning and structure of the club. Feels that the informal structure and functioning of the club is an advantage because it allows members to express their

opinions, it encourages discussions and is an encouraging environment.

15. The club has been a facilitator of much information sharing through discussion and suggestions of waste minimisation practices. Feels that a few changes had been already carried out before joining the club but sharing of information has been helpful.
16. Would not know any other way to bring about waste minimisation. If waste minimisation was forced on industry by legislation it would be a costly and difficult change. The informality of the club is a good way of bringing about change. The club is a way of sharing experience therefore companies can learn and do different things adapted to their needs. The club changes your way of thinking. Even if some of the suggestions made do not apply to your company you are aware of wanting to change, you have more information, your obligations are known and your way of thinking changes.
17. Good relationships have been formed with other companies; the club has an atmosphere of camaraderie and mutual sharing of information.
18. The company has been able to help other companies and in return they have had assistance with suggestions etc through the club.
19. The club fits into the broader processes of environmental management because it helps to produce less waste and possibly the way of thinking can be applied to the home and other aspects of daily life. The club promotes good practice.

Company L

1. 8
2. 1977
3. Pinetown
4. June 1998
5. Wanted help in effluent treatment.
6. Owner
7. Did not know much about waste minimisation.
8. Only thought about the cost reduction.
9. –
10. No
11. –
12. Attended a meeting where benefits of waste minimisation were discussed.
13. Not sure about the potential because smaller concerns are facing production problems.
14. Time constraints.
15. –
16. –
17. –
18. A relationship already existed with another member where assistance used to be given with certain jobs. Friends have been made since joining the club.

Company M

1. 38 employees
2. Company has been ten years under current ownership, is 30 years old
3. Joined club at initial meetings
4. -
5. Wanted to monitor effluent and become more aware of what is going on in similar industries and related industries
6. –

7. Deposit waste in Joburg therefore less waste being produced will give financial benefits
8. Members get benefits from each other through the club, including shared knowledge, which is in addition to benefits of waste minimisation.
9 .More aware of waste min and the companies waste management, club is a mechanism for regulating waste and monitoring
10. Has been involved at the beginning but didn't explain how the club actually got off the ground.
11. Membership has been beneficial for companies therefore potential for continuing is great
12. Constraints are the time available for dedicating to the project by industry, which prevents attendance at all meetings
13. No changes to structure but possibly meetings in the middle of the month rather than at month . end.
14. Enabled finding out problems and procedure in other companies in beneficial and also other companies solutions.
15. Clubs are useful and positive mechanisms
16 Relationships with other companies seems to be mutually beneficial because of knowledge sharing
17. Club acts as a go-between between industry and the regulators such as metro and water affairs and enables wider monitoring of effluent etc.
18. So that compliance with regulations can be adhered to.

Company N

1. 160
2. 1979
3. Westmead
4. June 1998
5. To improve processes and gain knowledge.
6. Safety officer
7. Did not quite understand what waste minimisation was.
8. Benefit from the sharing of knowledge and ideas.
9. Had a better understanding of the concept of WM.
10. No
11. -
12. -
13. Club has good potential for continuing.
14. Lack of manpower and time.
15. No need for improvement. The club is functioning quite well.
16. Previously did not have much knowledge.
17. -
18. No business relationships were formed.

Company O

1. 6 employees.
2. Company is 55 years old.
3. Durban
4. Joined when the club started in mid 1998.
5. Joined the club in order to get abreast with information and with what is going on in industry as well as to find out the correct environmental practices and to hear the views of guest speakers.

6. The representative is the owner.
7. At the initial meeting the details of waste Minimisation were clearly explained by the PRG and this was the initial impression of waste minimisation that the representative had.
8. An extra benefit of the club was the potential to gain broader technical knowledge about the industry.
9. Views have not changed much since belonging to the club. But it is felt that the smaller companies have problems in minimising their waste which the larger companies, and possibly the University, do not understand - sometimes the more lucrative methods are not possible for these small companies because some issues are out of their control, for example water metering. A further club is being developed for the textile industry.
10. No comment.
11. The club was started through the initial encouragement and ideas of the University.
12 The club will continue as long as it provides relevant information for the members of the club. The ultimate question of what to do with the waste even after the volume has been reduced has still to be addressed.
13. Possibly constraints may be financial. At the moment the club is funded by research grants but in the future the members may have to pay to belong to the club and if they feel this is not worth it the numbers of the club may drop.
14. The club structure and functioning is okay and the guest speakers are interesting but the information and suggestions need to be relevant for the small companies as well as the larger ones. Often the small companies feel drowned by the demands and potential for change in the larger companies. Sending people into the first world to get examples of waste minimisation practice is good but the suggestions need to relevant to what can be carried out in our local environment and situation.
15. Knowledge has increased due to membership. Discussion informally during teatimes etc amongst peers and in the forum of the club has been helpful. Formal presentation of knowledge in the club is another way information has been conveyed.
16. The club is a good way of getting industry to minimise waste. People have similar problems and interests and they can help each other. The club has also given the companies some clout with local government because it is a specific organisation along with the credentials of the university rather than one or two powerless companies. The Durban Metro is now taking some of the issues of these companies seriously.
17. Cordial relationships have been developed amongst members.
18 The nature of these relations are mainly knowledge sharing but some business referrals do occur because the companies know of other companies and their activities.
19. The clubs could play a role in environmental management. There will be a few innovators in the club and others will follow. But the clubs need to be targeted at specific industries rather than being broadly based because industries are not interested in what is happening in other sectors.

Company P

1. 8 employees
2. Firm is 15/16 years old
3. Pinetown

1. Joined when the club started, approximately a year ago
2. Joined as a founder member due to pressure from the legislation and the need to decrease costs etc.
3. Club representative is the owner and/or the son-in-law of the owner who is also an employee.

4. Waste minimisation is exactly what it says, a way of minimising waste. Knowing what is being put down the drain, knowing how much water etc is being used and trying to save on the use of these resources.
5. Difficult to say if other benefits could be gained because the company is different from other metal finishers since it does paint finishing, mainly focus on benefits of cost reduction. It is good to have a handle on what is happening with Metro and the club acts as a controlling mechanism for the industry that is good.
6. Views have changed after seeing other companies' successes. More enthusiastic about the possibilities. Not aware of other WMC in the country but knows of clubs and WM projects overseas.
7. Yes and No. Feels that the club still has a lot of obstacles to overcome because Metro still maintains its own opinions and it would be nice to work hand in hand with them rather than them being rather uncompromising.
8. -
9. Club has a lot of potential to continue into the future It has progressed and grown and in the last meeting there was a huge response, so very good future.
10. No real obstacles to the club continuing.
11. Possibly the club needs to focus on aspects of waste min that are relevant to the metal finishers. For example, the trip to the landfill site was interesting but at the end of the day the company still cannot dump their waste in Durban. Need to focus on directly relevant issues.
12. Yes, greater knowledge has been facilitated.
13. The club is a good way to get the metal finishers to reduce waste.
14. Gotten to know other companies that before were only competition or 'co-workers'. Learnt about other companies which do all their plating in-house and which they would never otherwise deal with.
15. Mutual relationship. We all deal in the same industry.
16. If we didn't think the club could act towards improving the environment we wouldn't be involved!

Company R

1. 100 employees.
2. Company is 3 years old.
3. Phoenix Industrial Park
4. Joined the club when it began.
5. The company has a lot of effluent to dispose and the club seemed a way to help with this problem.
6. Company representative is the Operations Manager.
7. Idea that waste minimisation would mean that the company would have no more waste and that effluent would be reduced.
8. Other ideas have been have come about through the club but some of these are not effective for this particular company.
9. Views of waste minimisation changed after belonging to the club, also club members change so new ideas always arise. The trip overseas for one member generated a lot of new ideas. Has an idea that there may be another club in the Durban Metro.
10. No comment.
11. The waste minimisation club was started at a meeting with Durban Metro – where the university introduced the idea of a waste minimisation club.

12. The club has grown from strength to strength and the potential for the club carrying on is great. Most members are active; people have lots of ideas. There is a lot of camaraderie and friendly relations.
13. Possibly if participation and attendance becomes lower then the club may not be able to continue.
14. No changes were suggested. Feels that Susan Barclay is doing a great job.
15. The discussion in the club and the assistance offered through the club has increased the knowledge about waste minimisation.
16. Big industries may not need a club to help them because they have consultants etc. The smaller industries need a club to help them with their waste minimisation.
17. Relationships have been formed.
18. With knowledge sharing the companies relate.
19. Yes, the clubs can help with environmental management. The club can be a beginning and from this club members can branch out and join other conservation groups etc if they want to.

Company S

1. 10
2. –
3. Pinetown
4. June 1998
5. Was interested in other people's views.
6. Owner.
7. No knowledge of waste minimisation before joining the club.
8. More people can get together to discuss problems.
9. No change.
10. No
11. –
12. –
13. The club is a good idea, and has good potential for continuing.
14. Can't think of any constraints.
15. No changes.
16. Became aware of the concept of waste minimisation.
17. –
18. No business relationships were formed.

Company W

1. 10 employees
2. Company is 90 years old.
3. Durban
4. Joined the club when it began last year.
5. Went to a meeting with Durban Metro and were encouraged at the meeting to join the club.
6. Representative is the owner-manager.
7. Did not think that waste minimisation was a big issue prior to joining the club.
8. There are benefits but often these are missed out on due to time constraints that prevent one from attending meetings.
9. Has become very conscious of waste minimisation since joining the club.
10. It has potential to fit in with the environment issues.

11. The club was started at a meeting held by Durban Metro at which the university people attended and encouraged people to do waste minimisation through the club that was being formed.
12. The club has the potential to carry on.
13. Time constraints on company representatives are a major problem to the club carrying on. The small companies find it difficult to lose their representatives for business hours when they go to meetings.
14. Changes made to the functioning of the club could be the timing of meetings. Possibly it would be convenient for smaller companies to hold meetings at the end of the day or outside of working hours.
15. The club has facilitated greater knowledge through the meetings and through the various documents that have been disseminated through the club. Discussion allows learning about the problems of other companies and possible solutions.
16. Clubs are a good mechanism because they promote awareness of the environment and of what people are doing in industry.
17. Working relationships have developed between the company and other club members.
18. These relationships are business relationships but are mainly knowledge sharing. The strongest relationship has been formed with Company D.
19. The clubs can fit into environmental issues if they go wider than they are and move into a broader spectrum of environmental management.

Company X

1. 60
2. 1950
3. New Germany
4. June 1998
5. To gain knowledge.
6. Production Manager.
7. Did not know about waste minimisation before joining the club.
8. Thought it will enable him to look at things differently.
9. No change in views.
10. No
11. –
12. –
13. The club will continue nicely but not for this company.
14. Lack of commitment by members.
15. The club is run quite well as it is.
16. –
17. –
18. No relationships have formed since joining the club.

Survey Conducted in March 2000

Questionnaire:

Which of the following actions can be considered to be waste minimisation?	1 – yes; 2 – no 3 – debatable		
	1	2	3
A company installs an extra tank after the plating bath. Plated articles are dipped into this, prior to rinsing. The solution in this tank is then used to top up the plating bath. Is this 'waste minimisation'?	☐	☐	☐
A company invests in a state-of-the-art effluent treatment plant. This reduces the amount of metals discharged to drain below regulatory requirements. Is this 'waste minimisation'?	☐	☐	☐
A company modifies the jigs to enable better orientation of the articles. This improves the drip-off. Is this 'waste minimisation'?	☐	☐	☐
A company installs a large capacity effluent holding tank. High metal content baths are discharged to this tank together with discarded rinse baths. This results in dilution of the metals before discharge to sewer. Is this 'waste minimisation'?	☐	☐	☐
A company trains two employees to monitor and record the water use in their sections on a daily basis. They must report and explain variations in the water usage. Is this 'waste minimisation'?	☐	☐	☐

A number of short statements are presented below. They are based on interviews and other sources. Read each statement and decide if you: agree or mostly agree; mostly disagree or disagree with that statement. A "don't know" option is also provided.	1 -agree 2- mostly agree 3- mostly disagree 4- disagree 5 -don't know				
	1	2	3	4	5
Motives for joining the Waste Minimisation Club					
The closure of the land fill site (as a consequence of the land slide) was the primary reason for me to join the club	☐	☐	☐	☐	☐
The Durban Metro's new proposed limits for effluent discharge was the primary reason for me to join the club	☐	☐	☐	☐	☐
Reducing my company's pollution was the primary reason for me to join the club	☐	☐	☐	☐	☐
The other platers					
Before the joining the club: I had a fairly good idea of who the other platers were, but I never spoke to them	☐	☐	☐	☐	☐
The metal finishers must unite in order to stand as a unified body	☐	☐	☐	☐	☐
The metal finishers should form some type of forum	☐	☐	☐	☐	☐

	1	2	3	4	5
I am willing to share my experiences in waste minimisation	☐	☐	☐	☐	☐
I don't like the idea of all club members coming to my site	☐	☐	☐	☐	☐
I am willing to let non-competitors visit my site	☐	☐	☐	☐	☐

A number of short statements are presented below. They are based on interviews and other sources. Read each statement and decide if you: agree or mostly agree; mostly disagree or disagree with that statement. A "don't know" option is also provided..	1 -agree 2- mostly agree 3- mostly disagree 4- disagree 5 -don't know				
	1	2	3	4	5
When you first heard of the club idea, what did you think?					
It would probably be a complete waste of time	☐	☐	☐	☐	☐
I might learn a few new plating techniques	☐	☐	☐	☐	☐
Others platers would scavenge my professional knowledge	☐	☐	☐	☐	☐
Academics cannot provide much useful knowledge for a practical plater like me	☐	☐	☐	☐	☐
I was already running an efficient business, there would not be any major savings for me to gain	☐	☐	☐	☐	☐
I had to be careful so that sensitive commercial info would not be disclosed to competitors	☐	☐	☐	☐	☐
Why did you join the Waste Minimisation Club?					
The Metro was promoting it – what did I have to lose?	☐	☐	☐	☐	☐
I joined the club mainly because I was curious	☐	☐	☐	☐	☐
I joined the club to win time and delay the new proposal from the Metro	☐	☐	☐	☐	☐
I joined the club to stand in a better (Metro) light compared to companies that did not enter	☐	☐	☐	☐	☐
I joined because I saw an opportunity to negotiate relaxed conditions with the Metro	☐	☐	☐	☐	☐
I was not too busy at that time, if business suddenly caught up I would just drop the club	☐	☐	☐	☐	☐
I joined the club because I didn't know what waste minimisation was and wanted to learn about it.	☐	☐	☐	☐	☐
I joined the club because I thought it would help save me money	☐	☐	☐	☐	☐
What do you think of the Waste Minimisation Club today?					

	1	2	3	4	5
Some of it has been really interesting	☐	☐	☐	☐	☐
Some of it has been a complete waste of time for me	☐	☐	☐	☐	☐
I got some very practical and useful specific advice (I saw a really good idea and went back to my company and copied it)	☐	☐	☐	☐	☐
It has mostly served as a source of inspiration - the improvements I have made are my own ideas	☐	☐	☐	☐	☐
I am now giving more thought of the pollution that my firm is causing	☐	☐	☐	☐	☐
The major role of the club has been as a means (facilitator) of communication with the Metro	☐	☐	☐	☐	☐
I would like to see it continue, and would contribute towards someone managing and running the club	☐	☐	☐	☐	☐
I have made some changes but I don't think that I can improve much further	☐	☐	☐	☐	☐

A number of short statements are presented below. They are based on interviews and other sources. Read each statement and decide if you: agree or mostly agree; mostly disagree or disagree with that statement. A "don't know" option is also provided..	1 -agree 2- mostly agree 3- mostly disagree 4- disagree 5 -don't know				
	1	2	3	4	5
Benefits of the club					
Being a club member has improved my relationship with the local authorities (Metro, Water Affairs)	☐	☐	☐	☐	☐
Meeting with other metal finishers has been a useful experience for me	☐	☐	☐	☐	☐
I have not benefited at all from being a member of the club	☐	☐	☐	☐	☐
I have saved money and become more profitable	☐	☐	☐	☐	☐
I have a better understanding of the pollution caused by my company	☐	☐	☐	☐	☐
I have a greater understanding of waste minimisation	☐	☐	☐	☐	☐
If it weren't for the savings I have made through waste minimisation, I would not be in business today	☐	☐	☐	☐	☐
The Metal Finishing Industry					
The metal finishing industry is essentially a polluting industry	☐	☐	☐	☐	☐
Within South Africa, it is a profitable industrial sector	☐	☐	☐	☐	☐
Usefulness of material					
I have gone through most of the written material I've received	☐	☐	☐	☐	☐

I have found all the written material useful	☐	☐	☐	☐	☐
The training sessions by Enviros March were really good	☐	☐	☐	☐	☐
The presentation on waste classification was really useful	☐	☐	☐	☐	☐
The presentation on filtration was really useful	☐	☐	☐	☐	☐
The presentation on pollution liability was really useful	☐	☐	☐	☐	☐
The presentation on government funding schemes was really useful	☐	☐	☐	☐	☐
The presentation on benchmarking studies was really useful	☐	☐	☐	☐	☐
I found the site visit to Fascor very interesting	☐	☐	☐	☐	☐
The presentation by Interactive Training Dynamics was very informative	☐	☐	☐	☐	☐
The visit to the land fill sites was very informative	☐	☐	☐	☐	☐
I would like more presentations on ________________ (list from No. 48 to 56)					
Rank the above presentations in order of usefulness to you					

A number of short statements are presented below. They are based on interviews and other sources. Read each statement and decide if you: agree or mostly agree; mostly disagree or disagree with that statement. A "don't know" option is also provided.	1 -agree 2- mostly agree 3- mostly disagree 4- disagree 5 -don't know

	1	2	3	4	5
Attendance at Meetings					
I have personally attended **1 2 3 4 5 6 7 8 9 10 all** meetings (circle the applicable answer)					
My company has been represented at every meeting	☐	☐	☐	☐	☐
Reasons for not attending meetings					
I don't have the time	☐	☐	☐	☐	☐
I had a factory emergency and could not leave the premises	☐	☐	☐	☐	☐
There was poor notice of the meetings	☐	☐	☐	☐	☐
I was given insufficient notice of the meetings	☐	☐	☐	☐	☐
The meetings were not interesting to me personally	☐	☐	☐	☐	☐
I was too busy to attend	☐	☐	☐	☐	☐
I don't think there's anything to gain from attending meetings	☐	☐	☐	☐	☐

	1	2	3	4	5
If the meetings were held after hours I would have attended more frequently	☐	☐	☐	☐	☐
Barriers to Implementing Waste Minimisation					
I don't have the time	☐	☐	☐	☐	☐
I don't have the money	☐	☐	☐	☐	☐
I don't think there are any benefits for my company	☐	☐	☐	☐	☐
Bosses not interested in Waste Minimisation	☐	☐	☐	☐	☐
Future activities of the Club					
The club should continue after the funding is completed	☐	☐	☐	☐	☐
If the club continues, it should be run by the metal finishers themselves and not by an outside person or organisation, and be self - funded	☐	☐	☐	☐	☐
I am interested in being part of the Danced sponsored project in Cleaner Production	☐	☐	☐	☐	☐
I would like more technical seminars on, for example, the theory of electroplating	☐	☐	☐	☐	☐
The club meetings should be held **less / more / same** frequency (circle the applicable answer)					

A number of short statements are presented below. They are based on interviews and other sources. Read each statement and decide if you: agree or mostly agree; mostly disagree or disagree with that statement. A "don't know" option is also provided.	1 -agree 2- mostly agree 3- mostly disagree 4- disagree 5 -don't know				
	1	2	3	4	5
The workers					
At our site, relations between management and workers have improved over the last few years	☐	☐	☐	☐	☐
Changing the attitude of our workers is a major barrier for introducing better housekeeping techniques	☐	☐	☐	☐	☐
My workers are the single most important asset of our company	☐	☐	☐	☐	☐
The language barrier is a serious problem in the production	☐	☐	☐	☐	☐
The workers may have poor literacy skills, but they have a good idea of what goes on in the plating baths - of why they do the distinct steps	☐	☐	☐	☐	☐
My workers could contribute with many valuable suggestions on how to reduce the pollution of our company	☐	☐	☐	☐	☐
It is not necessary to supervise the plating, the workers do the jobs by routine	☐	☐	☐	☐	☐

	1	2	3	4	5
For some plating jobs, I think that the workers know more about plating than I do	☐	☐	☐	☐	☐
My staff have received training in general environmental awareness	☐	☐	☐	☐	☐
My staff have received training in waste minimisation	☐	☐	☐	☐	☐
I would like to train my staff in waste minimisation, but do not have the necessary funds	☐	☐	☐	☐	☐
I am in contact with funding organisations (Dumac; DTI) to arrange finances for training	☐	☐	☐	☐	☐
Relationship to Suppliers					
The technical information from my supplier is important and useful	☐	☐	☐	☐	☐
I would like my supplier to take back any depleted plating baths	☐	☐	☐	☐	☐
I buy chemicals on price only, there is no "relationship" with my supplier	☐	☐	☐	☐	☐
I leave the bath maintenance to the chemical suppliers	☐	☐	☐	☐	☐
Student Reports					
I found the student's assistance valuable	☐	☐	☐	☐	☐
The student offered no useful information and was more of a hindrance than a help	☐	☐	☐	☐	☐
I have used the students recommendations as a basis for my waste minimisation programme	☐	☐	☐	☐	☐

A number of short statements are presented below. They are based on interviews and other sources. Read each statement and decide if you: agree or mostly agree; mostly disagree or disagree with that statement. A "don't know" option is also provided.	1 -agree 2- mostly agree 3- mostly disagree 4- disagree 5 -don't know				
	1	2	3	4	5
Environmental statements					
A company's 'green' image is important for its relation with customers	☐	☐	☐	☐	☐
The introduction of new and more environmental friendly technologies is time consuming and reduces our ability to compete	☐	☐	☐	☐	☐
It is important for companies to be up to date with environmental requirements	☐	☐	☐	☐	☐
The present state of the South African economy does not justify new environmental constraints on companies	☐	☐	☐	☐	☐
I like the idea of going on holiday to game reserves	☐	☐	☐	☐	☐
Compared to similar firms, my firm is in the better half with respect to environmental performance	☐	☐	☐	☐	☐

Statement	1	2	3	4	5
Some jobs pollute, but if I don't do the job, somebody else will – I might as well benefit financially	☐	☐	☐	☐	☐
Some jobs pollute, but if I don't do the job, somebody else will and cause environmental damage. I would rather ensure it is carried out in the correct manner.	☐	☐	☐	☐	☐
I feel better morally for "cleaning up" my act	☐	☐	☐	☐	☐
I would be happy to live next door to my factory	☐	☐	☐	☐	☐
The most efficient way of improving the environmental impact of our company is to focus on technical issues rather than softer, management issues	☐	☐	☐	☐	☐
Relationship with Metro Water and Waste					
It is a major problem that the Metro don't have the same discharge standards for all areas	☐	☐	☐	☐	☐
The inspector probably cannot tell the difference between a rinse bath and a plating bath	☐	☐	☐	☐	☐
If I comply with their current regulations, they will just formulate a new one next month (i.e. they keep moving the goal posts)	☐	☐	☐	☐	☐
The relation to the Metro has improved over the last 12 months	☐	☐	☐	☐	☐
They don't care about industry, they are bureaucrats that stick to the letter of the law	☐	☐	☐	☐	☐
My current relation with the Metro is an *us-and-them*, we basically have different interests	☐	☐	☐	☐	☐
They are basically reasonable people, you can talk to them and discuss unreasonable demands	☐	☐	☐	☐	☐
I would not mind more frequent visits by the factory inspector, if just my competitors were also visited more frequently	☐	☐	☐	☐	☐
I would be prepared to forward suggestions on improving effluent discharge standards - if they were enforced across the board	☐	☐	☐	☐	☐

A number of short statements are presented below. They are based on interviews and other sources. Read each statement and decide if you: agree or mostly agree; mostly disagree or disagree with that statement. A "don't know" option is also provided.	1 -agree 2- mostly agree 3- mostly disagree 4- disagree 5 -don't know

Statement	1	2	3	4	5
Relationship with Metro Water and Waste (continued)					
There should be no regulations on the metal finishing industry	☐	☐	☐	☐	☐
Conflict with the Metro is a healthy sign	☐	☐	☐	☐	☐
I would be interested in self-regulation in place of regular factory inspections	☐	☐	☐	☐	☐
Metal finishers should form an association that would only allow companies that adhere to certain environmental standards to join	☐	☐	☐	☐	☐
The customers					

I have not yet met a customer who was concerned about / showed any interest in the environmental performance of my company	☐	☐	☐	☐	☐
My customers are not interested in my pollution loads	☐	☐	☐	☐	☐
Customers may occasionally enquire about how pollution is addressed, but the customer is essentially interested in price ONLY	☐	☐	☐	☐	☐
I have lost business because the customer was not satisfied with my environmental performance	☐	☐	☐	☐	☐
My customers would go elsewhere for a 10% reduction in price and not ask questions why	☐	☐	☐	☐	☐
I have declined on certain jobs, because I think that the production process pollutes too much	☐	☐	☐	☐	☐
A fair amount of my customers don't have the slightest idea of the type of plating they require	☐	☐	☐	☐	☐
It would be advantageous if customers enquired before hand as to the best design and specification of materials	☐	☐	☐	☐	☐
Customers seek my advice in the design of the jobs to be plated / finished	☐	☐	☐	☐	☐
A fair amount of my customers specify their plating demands according to SABS/ISO standards	☐	☐	☐	☐	☐
A sign promoting that my company is involved in waste minimisation and is reducing its environmental impact would be useful	☐	☐	☐	☐	☐
A fair amount of my customers demand a plating "similar to the one last time" because that one worked fine	☐	☐	☐	☐	☐
I have a considerable influence over the customer's choice of plating	☐	☐	☐	☐	☐
I have worked up a trust relation with some core customers	☐	☐	☐	☐	☐

Results:

Question	Agree	Disagree	Debatable
1	17		
2	8	3	6
3	16		1
4	1	14	2
5	12		5

Question	Agree	Mostly Agree	Mostly Disagree	Disagree	Dont Know	Not Answered
6	1	2	3	9	1	0
7	8	5	1	1	0	1
8	13	3	0	0	0	0
9	8	1	2	4	1	0
10	13	1	0	1	1	0
11	13	1	0	1	1	0
12	15	0	1	0	0	0
13	2	0	5	7	1	1
14	12	3	0	0	0	1
15	0	1	2	13	0	0
16	5	7	1	2	1	0
17	1	2	4	9	0	0
18	0	1	2	13	0	0
19	0	1	6	9	0	0
20	3	4	2	7	0	0
21	5	4	2	4	1	0
22	8	3	1	4	0	0
23	1	0	2	12	1	0
24	5	3	3	5	0	0
25	4	3	3	5	0	0
26	0	0	2	14	0	0
27	8	7	1	0	0	0
28	12	3	1	0	0	0
29	16	0	0	0	0	0
30	1	2	3	10	0	0
31	9	5	1	1	0	0
32	3	8	4	1	0	0
33	13	3	0	0	0	0
34	7	3	5	1	0	0
35	9	3	1	2	1	0
36	4	3	1	8	0	0
37	6	5	1	2	2	0
38	13	3	0	0	0	0
39	0	0	1	15	0	0
40	6	7	2	0	1	0
41	13	3	0	0	0	0
42	15	1	0	0	0	0

43	0	3	4	8	0	1
44	4	5	4	1	2	0
45	7	6	0	1	2	0
46	9	7	0	0	0	0
47	9	7	0	0	0	0
48	7	2	0	0	6	1
49	14	1	0	0	1	0
50	11	3	0	0	2	0
51	12	2	0	0	2	0
52	6	5	1	1	2	1
53	8	2	1	1	2	1
54	6	0	1	4	6	3
55	5	3	1	0	5	2
56	6	5	0	0	3	3
57						
58						
59						
60	2	4	1	5	0	4
61	9	3	0	1	0	3
62	0	0	1	11	0	4
63	0	1	1	10	0	4
64	0	0	1	11	0	4
65	4	4	0	4	0	4
66	0	0	2	10	0	4
67	2	1	2	7	0	4
68						
69						
70	1	1	2	9	0	3
71	4	2	2	4	1	3
72	0	0	4	9	0	3
73	1	0	1	11	0	3
74	13	3	0	0	0	0
75	2	7	2	3	2	0
76	8	4	1	1	2	0
77	6	8	1	1	0	0
78						
79	8	4	1	1	2	0
80	6	6	2	2	0	0
81	11	1	1	2	0	1
82	2	4	3	7	0	0
83	8	6	1	1	0	0
84	6	6	0	4	0	0
85	1	8	2	5	0	0
86	2	4	6	4	0	0
87	4	6	4	2	0	0
88	3	6	6	1	0	0
89	5	7	3	0	0	1
90	1	0	3	10	1	1
91	14	2	0	0	0	0
92	6	6	0	3	1	0

93	0	1	6	9	0	0
94	0	3	2	11	0	0
95	8	6	0	1	0	1
96	0	0	5	10	0	1
97	7	6	0	2	0	1
98	8	6	2	0	0	0
99	2	7	4	3	0	0
100	14	2	0	0	0	0
101	1	7	4	4	0	0
102	13	3	0	0	0	0
103	4	9	0	0	3	0
104	2	2	4	6	2	0
105	6	6	1	1	2	0
106	10	6	0	0	0	0
107	7	4	2	2	1	0
108	7	6	2	0	1	0
109	9	3	3	0	1	0
110	4	5	3	4	0	0
111	3	3	3	3	4	0
112	6	6	2	1	1	0
113	1	7	4	3	1	0
114	3	5	3	5	0	0
115	4	8	2	1	1	0
116	6	5	3	2	0	0
117	6	5	0	2	3	0
118	0	1	2	13	0	0
119	3	7	3	3	0	0
120	2	7	1	5	1	0
121	5	5	2	4	0	0
122	6	2	2	5	1	0
123	8	0	1	5	2	0
124	7	5	1	1	1	1
125	0	0	1	13	2	0
126	9	5	0	2	0	0
127	1	3	0	8	4	0
128	3	3	3	5	1	1
129	7	2	2	1	3	1
130	5	4	2	3	1	1
131	6	4	2	3	0	1
132	7	5	0	1	3	0
133	6	2	3	3	1	1
134	3	5	2	3	0	3
135	9	3	0	0	1	1

APPENDIX 5: DETAILS OF CLUB MEETINGS

Table 5A: Details of Club Meetings

Date	Meeting	Agenda	Guests	No. Present
28/07/98	1	8h30 - 9h00 Tea 9h00 - 9h05 Welcome and opening of meeting 9h05 - 9h10 Matters arising from the minutes of the last meeting 9h10 - 9h30 Feedback from the Pollution Research Group 9h30 - 10h30 Feedback from industry and discussions 10h30 - 11h00 Tea 11h00 - 12h30 Feedback from industry and discussions 12h30 - 13h00 Summary and Closure		25
25/08/98	2	8h30 - 9h00 Tea 9h00 - 9h10 Welcome and opening of meeting 9h10 - 9h30 Feedback from the PRG 9h30 - 10h30 Feedback from industry and discussions 10h30 - 11h00 Tea 11h00 - 12h30 Quantification of savings and discussions 12h30 - 13h00 Summary and Closure		21
25/11/98	3	8.30 - 9.00 Tea 9.00 - 9.30 Outstanding Items 9.30 - 10.30 Feedback from CAB and John Danks on DANCED Tour 10.30 - 11.00 Tea 11.00 - 12.00 Feedback from industry on progress made since last meeting 12.00 - 12.30 Summary 12.30 - Closure		13
02/03/99	4	8.30 - 9.00 Tea 9.00 - 9.10 Welcome and matters arising from the minutes Feedback from the Pollution Research Group 9.10 - 9.30 Monitoring and Targeting - UK Experience David Mercer - March	David Mercer – Enviros March Ian Sampson – Van Onselen	19

		Consulting 9.30 - 10.30 Environmental Legislation and Liability Ian Sampson - Van Onselen O'Connell 10.30 - 10.45 Tea Feedback from Industry 10.45 - 10.55 Company A 10.55 - 11.05 Company F 11.05 - 11.15 Company G 11.25 - 11.35 Company I 12.15 - 12.30 Summary and closure	O'Connell	
18/05/99	5	9h00 - 9h10 Welcome and opening of meeting 9h10 - 9h30 Feedback from the PRG 9h30 - 10h15 Interactive Training Dynamics Les Mcinga 10h15 - 10h45 Tea 10h45 - 12h30 Feedback from Industry and Discussions 12h30 - 13h00 Summary and Closure	Les Mcinga – Interactive Training Dynamics	8
10/08/99	6	8h30 - 9h00 Tea 9h00 - 9h10 Welcome and opening of meeting 9h10 - 9h30 NOSA : Overview of Activities 9h45 - 10h15 Discussion of Club Constitution 10h15 - 10h45 Tea 10h45 - 11h15 Feedback from the PRG 11h15 - 12h30 Feedback from Industry and Discussions 12h30 - 13h00 Summary and Closure		16
19/10/99	7	8h30 - 9h00 Tea 9h00 - 9h10 Welcome and opening of meeting 9h10 - 9h30 Feedback from the Pollution Research Group 9h30 - 10h00 Health and Safety aspects relating to waste minimisation Frank Hedlund 10h00 - 10h30 Tea 10h30 - 10h45 Discussion on Club Constitution 10h45 - 11h30 Feedback from industry and Discussions 11h30 - 12h00 Summary and Closure	Frank Hedlund	17

24/02/2000	8	8h30 Tea 9h00 - 9h10 Opening and Welcome Matters arising from last minutes 9h10 - 9h45 Feedback from the PRG Chris Buckley 9h45 - 10h15 Update on the Health and Safety Project Frank Hedlund 10h15 - 10h45 Tea 10h45 - 11h45 Feedback from Industry and Discussions 11h45 - 12h00 Summary and Closure	Frank Hedlund	19
17/05/2000	9	8h30 Tea 9h00 - 9h10 Opening and Welcome Matters arising from last minutes 9h10 - 9h45 Feedback from the PRG Chris Buckley 9h45 - 10h15 Update on the Health and Safety Project Frank Hedlund 10h15 - 10h45 Tea 10h45 - 11h45 Feedback from Industry and Discussions 11h45 - 12h00 Summary and Closure	Tony Coats	17
18/08/2000	10		Rob McConnel Tony Coates	16
09/09/2000	11	9h00 - 9h10 Opening and Welcome Matters arising from last minutes 9h10 - 9h40 Feedback from the PRG 9h40 - 10h00 Oil-water Separation Amesh Telukedarie – ML Sultan Tech 10h00 - 10h15 Feedback from the MFA 10h15 - 10h30 Tea 10h30 - 11h30 Feedback from Industry 11h30 - 12h00 Summary and closure	Amesh Teluedarie	10
03/11/2000	12	Feedback on Club's Success		5

APPENDIX 6 – DESCRIPTION OF METAL FINISHING PROCESSES

The major metal finishing processes that were most commonly used in the companies investigated are described below.

Cleaning, Pickling, and Dipping

Cleaning is a very important step in the electroplating process as the adhesion of deposited metal depends on this. Degreasing is usually the first cleaning step and involves the removal of heavy oils, greases, and soils. This is necessary before the scale and oxide on the component can be removed by pickling or dipping. Hot alkaline cleaners are used to remove all traces of grease and any passive film on the object surface to give an active surface to which the deposit can adhere. The choice of the metal cleaner to be employed depends on the material to be cleaned. Generally, the higher the alkalinity, the more rapid will be the cleaning. The effect of an alkaline cleaner is influenced by:

- the type of basis metal,
- the cleaner temperature,
- the time of immersion, and
- the condition of use.

Increasing the cleaner concentration, temperature, and time of immersion will accelerate the rate of cleaning. It is important however, that the recommended concentrations for the various cleaners are not exceeded.

Electrolytic cleaning is more rapid in it's action than ordinary immersion cleaning. This is due to the scouring action of the gas evolved on the surface being cleaned. Further, cathodic cleaning is more effective for the removal of greases than anodic cleaning. This is due to the fact that the volume of hydrogen evolved at the cathode is twice that of the oxygen at the anode.

In the MFI, pickling refers to the process of cleaning in acid. Dipping refers to a finishing operation for producing a clean lustrous surface after pickling. It is used mainly for brass, copper, and copper alloys.

Dips and Rinses

Dilute Acid Dips

The removal of oxide and scale from the surfaces of objects can also be achieved by dipping in dilute acid. If electroplating is to be carried out in an acidic solution, then dipping in dilute acid first also ensures the neutralisation of any alkaline present after the cleaning stage.

Rinsing

Effective cleaning and rinsing is essential for successful electroplating of objects. Even if the cleaning operations are carried out very carefully, the results can still be unsatisfactory if rinsing is carried out in contaminated rinse water. Running water is preferred to still water for rinsing purposes, as the latter soon becomes contaminated and requires frequent changing. The ideal arrangement is a separate rinse after each process. The number of rinse tanks necessary does however depend on the size of the plant and the available floor space.

Electroplating

Electroplating is the application of metallic coatings to metallic or other conductive surfaces by electrochemical processes. The object being electroplated is put into a solution of dissolved salts of the metal to be deposited. A current is passed through the solution where the object serves as the cathode attracting metal ions from the solution. Anodes, which are connected to the positive lead, are also immersed in the solution. The potential to be applied for deposition is usually between 2 and 16 volts. Ferrous and non-ferrous metal objects are plated with a variety of metals including copper, cadmium, chromium, iron, lead, nickel, tin, and zinc as well as precious metal such as gold, platinum, and silver.

Due to the potential applied between the electrodes, the ions formed will migrate, the positively charged ions towards the cathode and the negatively charged ions towards the anode. The weight of metal deposited is proportional to the quantity of electricity passed. An important figure to be determined for plating is the current density (quantity of current on a specific area, A/dm2). A more uniform deposit is achieved with low current densities, but longer plating times are necessary to obtain the required thickness of deposit. High current densities, while requiring shorter plating times, cause the deposits to build up excessively on prominent edges of the object being plated. Electroplating is the most common process employed and is illustrated below.[UNEPWG, 1998]

Anodes

Anodes usually consist of plates or bars of the metal to be deposited. The material used should be free of any impurities that may contaminate the plating solutions. Anodes may either be suspended from hooks or contained in baskets.

Plating Solutions

While it is possible to electro-deposit metal from a simple solution of a metallic salt, this is not practical for commercial processes, which use complex plating solutions containing up to eight important constituents. It is now more common to use proprietary prepared salts and mixtures for the preparation of plating solutions as these are of proved reliability and make it unnecessary for the operator of commercial electroplating to have much knowledge of theoretical electrochemistry.

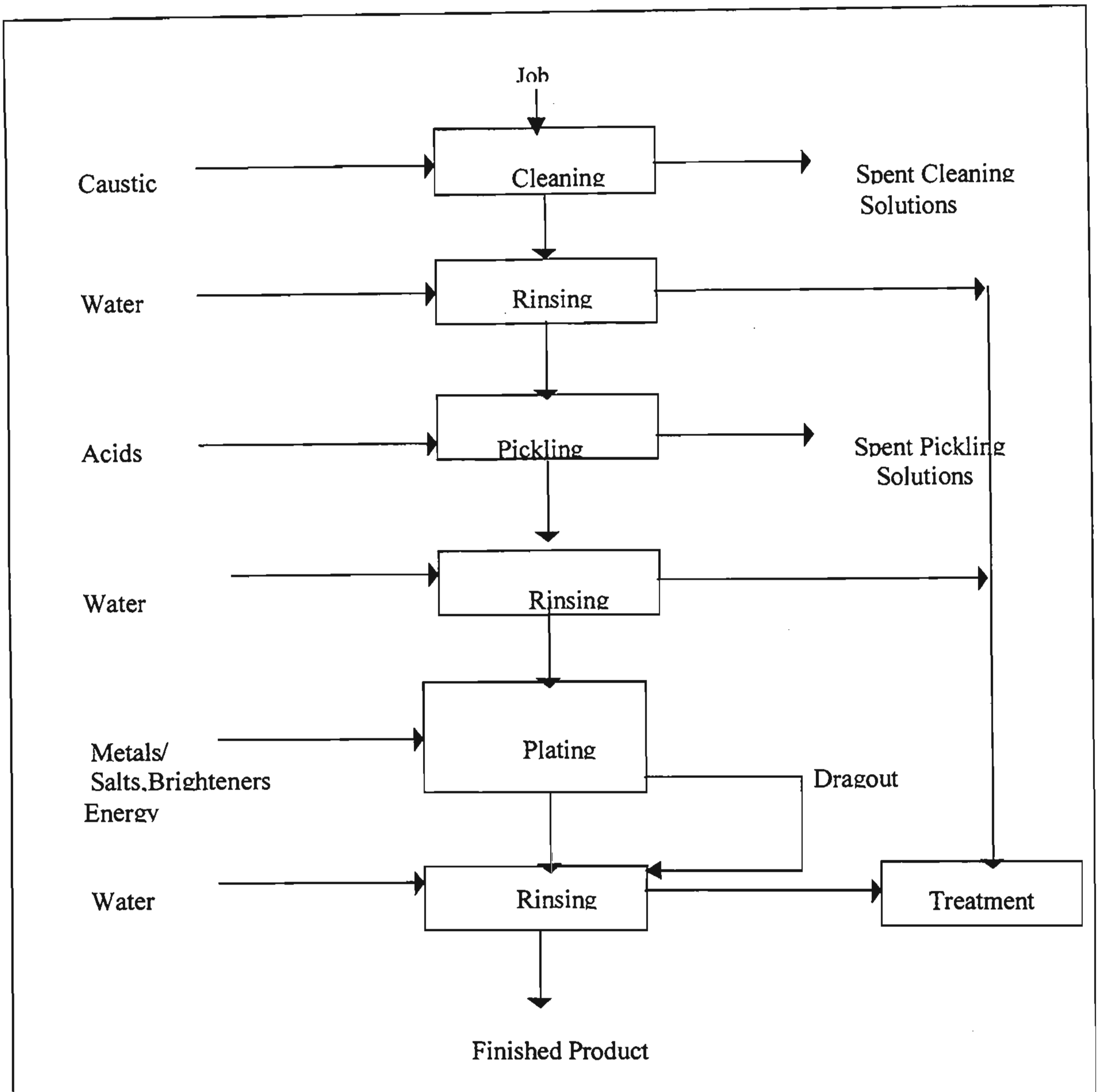

Figure 6A: Electroplating Process

The articles to be plated are mounted on jigs or racks and then immersed into the Ni plating tank. It is important that there be no interruptions in the current supply during plating as this may lead to a laminated deposit. To achieve effective results, the operating conditions should be as specified and the plating solutions must be maintained in good working balance. After bright nickel plating, the articles are well rinsed and then bright chromium plated.

B. Chromium Plating

Chromium plating is generally undertaken to provide a decorative finish or to produce a hard, abrasion-resistant surface.

Bright Cr plating

Nickel has been found to be the most suitable undercoat for decorative deposits due to the ease with which chromium may be applied and the corrosion resistance of the Ni deposit. The usual thickness of Cr deposits is 0.25 to 0.8 microns.

Chromium Plating Equipment

Tanks used are usually lined with a plasticised PVC. An alternative lining is antimonial lead with an inner lining of loose plastic sheets. When starting up new chrome plating tanks, it is important that the temperature of the Cr plating solution be brought up as rapidly as possible to above its normal operating value thus forming a protective film on the lead surface.

Anodes

Tin-lead alloy anodes are used for Cr plating. They help to maintain the solution in balance by re-oxidising the trivalent chromium to chromic acid.

Rate of deposition and usual plating time

For decorative deposits, a plating time of 5 to 10 minutes is used. Various types of plating solutions are available for Cr plating and the operating conditions vary with each type. Temperatures are typically in the range 38 to 45 ^{0}C and the current density is usually around 11 to 16 A/dm^2.

Chromium Plating Procedure

Articles to be plated are hung on plating jigs racks. The Ni plated components are rinsed well in water before being transferred to the bright Cr plating tank. The inter-stage rinsing must be very thorough to prevent the Ni plating solution from being carried over into the Cr bath, as this with result in an increase in the sulphate and chloride content. The delay between Ni and Cr plating stages should be a minimum to prevent the components from drying out. Drying of components will render the Ni passive, thus making it difficult to deposit Cr.

Drag-Out

Drag-out (chrome solution adhering to the work) is retained by the rinse water following the plating step. The dilute solution which forms as a result is used to replace any evaporative losses from the plating bath.

Chrome Neutraliser

The chrome solution carried over on plated components is neutralised and chemically reduced. This eliminates the hexavalent Cr present in the rinse waters and thus simplifies subsequent effluent treatment.

Final Rinsing

The components are finally well rinsed in cold running water and then put through hot water to facilitate drying.

C. Zinc (Zn) Plating

Zinc is a hard, crystalline metal that is electronegative to iron and gives excellent corrosion resistance, particularly in industrial and urban environments.

Specifications and Rates of Deposition

For general protective purposes, it is usual to apply Zn deposits having a minimum thickness of between 8 to 25 microns.

Zn Plating Equipment

The equipment employed for Zn plating may differ according to the type of solution used.

- Cyanide Solutions

These solutions require a welded mild steel, rubber, or plastic lined tank. A means of heating should be provided so that the solution can be raised to working temperature. If high current loadings are employed, it becomes necessary to fit cooling coils or plates to prevent an excessive rise in temperature.

- Alkaline Non-Cyanide Solutions

The equipment is the same as for cyanide solutions, with the addition of mild agitation of the solution when rack plating. Filtration of the solution should be allowed for.

Zn Plating Solutions

Various solutions are available for Zn plating. The choice of solution is influenced by the nature of the base metal, whether cast iron or steel; its form;its initial condition; the type of deposit; and above all, the problems with effluent treatment. For cast iron and malleable iron, an acid Zn solution is employed. For steel pressings, a cyanide Zn solution is preferred to produce a matte or bright finish. The cyanide Zn solution is the most widely used Zn plating solution in the MFI.

Galvanising

Galvanising is a non-electrolytic process involving the coating of prepared steel surfaces with Zn. The process produces high quality corrosion protection for steel. The object to be galvanised is dipped into hot caustic solution to remove surface contamination. Scale and rust are then removed in a pickling bath containing either sulphuric or hydrochloric acid. This is followed by rinsing after which the prepared items are immersed in molten Zn @ 450 ^{0}C

The major waste products associated with the process are Zn splatter, and Zn oxide, which forms on the surface of the bath.

Anodising

Anodising is an electrolytic process applied to aluminium(Al) objects to create an insoluble oxide coating. The item being treated is the anode. Natural oxidation of Al does occur in air, but the oxide layer formed is unstable. Anodising forms a structured and dense layer that resists abrasion and thus protects the underlying metal. The process is most suitable for Al because the resulting oxide layer is durable and shares many similar physical props with elemental Al.

Process

Oil and grease is removed from the item to be anodised with a non-etching alkaline soak cleaner. The item is then immersed in a deoxidising etch solution which removes any oxide film, and permits the anodising process to occur uniformly. The anodising step occurs in an electrolyte solution containing 3 –10 % chromic acid. The oxide layer is sealed in a chromic acid solution.

Powder Coating

Powder coating involves the application of a dry resin to coat items. It is used commercially for a wide range of small- to medium- sized metal parts, including lighting fixtures, equipment cabinets, outdoor furniture, shelving, and window fixtures. The coat is formed by spraying an electrostatically charged powder to the surface of the item, which is then heated, thereby melting the powder. The surface of the item, to be coated must be thoroughly cleaned and dried prior to coating. Powder coating materials are typically more expensive than conventional coating materials, but powder that does not adhere to the item can be collected and re- used.

APPENDIX 7: WASTE MINIMISATION OPTIONS IDENTIFIED FOR COMPANIES A TO Z

Company A	Category
1. Alter arrangements of items on jigs to reduce carry over	Technology change
2. Reuse acid rinse water for after electro-clean alkali process	Recycle
3. Bund areas to prevent spillages entering sewer	Housekeeping
4. Replace some rinse tanks with spray rinses	Technology change
5. Prevent loss of empty chemical drums by storing them closer to the factory	Housekeeping
6. Reduce tank volumes	Technology change
7. Prevent evaporation by covering tanks when not in use	Housekeeping
8. Check concentration of Ni in plating bath on a regular basis	Housekeeping
9. Investigate replacement of hexavalent Cr with trivalent Cr	Technology change
10. Install conductivity controllers to monitor rinse flows	Technology change
11. Apply corrosion resistant coatings to all tanks	Technology change
12. Install a drag-out tank after Cr plating	Technology change
13. Use drag-out to top up Ni tank	Technology change
14. Install electricity meters on electric dryers, & compressor house	Housekeeping
15. Meter LPG use at painting and enamelling pretreatment lines	Housekeeping
16. Eliminate use of compressed air for bath agitation and use high pressure blowers	Technology change
17. Implement a programme to quantify, fix and monitor compressed air leakage	Housekeeping
18. Apply external insulation to pre-treatment dryers	Technology change
19. Reschedule dryer loading programme to maximise percentage utilisation	Housekeeping
20. Install counter flow and cascade rinses	Technology change
21. Increase drip times	Technology change
22. Install water meters on plating and pretreatment lines	Housekeeping
23. Install rotameters to measuer flows	Housekeeping
24. Restrict flows to minimum requirements	Housekeeping
25. Install air restirctors	Housekeeping
26. Implement oil removal programme (use of newspapers)	Housekeeping
27. Turn off gas heaters when not in use	Housekeeping
28. Enforce safety regulations and kits	Housekeeping
29. Find a substitute for Tricholorethylene	Raw Material Change
30. Install additional rinse tanks	Technology change
31. Install effluent pipes above ground	Technology change
32. Improve pH control system on effluent	Technology change
33. Conduct an air audit	Housekeeping
34. Investigate the possibility of suppliers taking back lubricants	Housekeeping
35. Investigate replacement of paint dip line by electro paint - coat	Raw Material Change
36. Install ultra filtration unit on degreasing bath	Technology Change
37. Remove and reuse nickel	Recycle
38. Use only RO water on plating line	Technology Change
39. Investigate LCA of products	Product Change
40. Control of waste bin so that only sludge is disposed of	Housekeeping
41. Improve power factor	Housekeeping
42. Control over dumping of baths such that permission must be obtained first	Housekeeping

43. Worker education and operators given responsibilities for their lines	Housekeeping
44. Replacing chemicals in phosphating line such that less sludge is produced	Raw Material Change
45. Implement a programme for regulat maintenance and fixing of leaks	Housekeeping
46. Install a air scrubber over Cr tanks	Technology change
47. Repair carrier racks - the paint is chipping and can affect quality of plating	Housekeeping
48. Install drip trays between tanks to catch carry-over	Housekeeping
49. Check piping and joints for leaks	Housekeeping
50. Recylcle drag-out on a regular basis rather than intermittently	Recycle
51. Install a drag-out after Cr tank and before passivation	Technology change
52. Install pressure guage on incoming water to ensure constant flow	Housekeeping
53. Modifying piping and removing excess	Housekeeping
54. Investigating dumping procedures and impact on effluent plant	Housekeeping

Company B

1. Reposition tanks	Technology Change
2. Monitor water consumption	Housekeeping
3. Install drip trays on floor to collect spills	Technology Change
4. Install zinc dragout tank	Technology Change
5. Improve ventilation in room housing cyanide zinc	Housekeeping
6. Install a bar above the zinc tank to increase drainage	Technology Change
7. Restrict water used for rinsing with the hose	Housekeeping
8. Monitor chemical use	Housekeeping
9. Install drainage boards between tanks	Technology Change
10. Train workers in waste minimisation	Housekeeping
11. Fix leaks in tanks and pipes	Housekeeping
12. Install spray rinses	Technology Change
13. Remove oil from rinse tanks after degreasing	Housekeeping
14. Install air operated return pumps	Technology Change
15. Redesign barrels	Technology Change
16. Investigate the possibility of wall hanging rinse tanks	Technology Change
17. Undertake a waste audit	Housekeeping
18. Undetake an energy audit	Housekeeping
19. Replace cyanide process with a alkaline based process	Raw Material Change

Company C

1. Improve floor drainage	Housekeeping
2. Imstal flow restrictors on hose pipes	Housekeeping
3. Increase drip times	Technology Change
4. Install draining boards between tanks	Technology Change
5. Install overhead draining bars	Technology Change
6. Monitor water use	Housekeeping
7. Fix leaks	Housekeeping
8. Investigate the use of spray rinsing for large jobs	Technology Change
9. Educate workers in waste minimisation	Housekeeping
10. Change overflow rinses to static rinses	Technology Change
11. Install and use drag-out tanks	Technology Change

12. Monitor chemical consumption	Housekeeping
13. Optimise chemical concentrations in the tanks	Housekeeping
14. Rotate barrels out of sloution to increase drainage	Technology Change
15. Monitor electricity use	Housekeeping
16. Invetigate the resue of treated effluent for cleaning	Recycle
17. Investigate the installion of transformers	Technology Change

Company D

1. Install drag-out tanks	Technology Change
2. Reduce rinse water flow	Housekeeping
3. Change to counter flow rinsing	Technology Change
4. Fix all leaks	Housekeeping
5. Close municipal tap at end of Zn line and use borehole water	Housekeeping
6. Shut - off taps permanently that are not in use	Housekeeping
7. Monitor water use daily	Housekeeping
8. Install more water meters on incoming water	Housekeeping
9. Employ chemical storeman to control chemical use	Housekeeping
10. Install automatic crane over Cr bath to increase drip times	Technology Change
11. Increase drip times over all baths	Technology Change
11. Eliminate the use of cyanide	Raw Material Change
12. Reschedule oven use to reduce heating costs	Housekeeping
13. Reuse Electro cleaner	Recycle
14. Slow down cranes on Zn line to reduce carry over	Technology Change
15. Skim oil of electro cleaner to prevent contamination	Housekeeping
16. Undertake staff training	Housekeeping
17. Rebuild floors	Housekeeping
18. Optimise hanging articles on the jig to improve drainage	Technology Change
19. Redesign stoppers on screwdriver plant	Product Change
20. Install effluent treatment plant to reduce SS	Technology Change
21. Switch off rectifyers overnight	Housekeeping
22. Educate customers to use less harmful metals	Product Change
23. Improve insulation on all heated tanks	Housekeeping
24. Install thermostats to ensure tanks operate at optimum temperature	Technology Change
25. Resue rinse water in the trichloroethylene tank	Recycle

Company E

1. Install a drag-out tank after Zn plating	Technology Change
2. Install timers on baths for heating	Housekeeping
3. Install eco rinse after rack plating	Technology Change
4. Install eco rinse bath after barrel plating	Technology Change
5. Increase drip times	Technology Change
6. Replace flooring	Housekeeping
7. Repair cracked baths	Housekeeping
8. Improve treatment for CN	Technology Change
9. Implement a programme for cleaning and maitainance of tanks	Housekeeping
10. Install drag-out tanks	Technology Change
11. Educate workers in waste minimisation	Housekeeping
12. Install make-up and blow down for cooling water tower	Technology Change

13. Install counter flow rinsing in place of hose pipes	Technology Change
14. Improve ventillation	Housekeeping
15. Install timers to regulate plating times	Housekeeping
16. Adjust speed of barrels to prevent spillages	Technology Change
17. Install a sampling point for effluent samples	Housekeeping
18. Insall valves on water lines to reduce water flow into rinsing tanks	Housekeeping
19. Monitor daily water use	Housekeeping
20. Install cooling tower and reuse water	Recycle
21. Remove oil from rinse baths	Housekeeping
22. Install an additonal degreasing tank	Technology Change
23. Moniitor use of chemicals	Housekeeping
24. Install timer on compressor	Housekeeping
25. Install nozzles on hoses to reduce water use	Housekeeping

Company F

1. Replace automatic flushes in toilets with manual	Technology Change
2. Recycle water from tumbling process	Recycle
3. Cover hot tanks at night to reduce evaporation	Housekeeping
4. Fix leaks	Housekeeping
5. Replace overflow rinses with static rinses	Technology Change
6. Install drainage bars, and drip trays	Technology Change
7. Install vaporiser to remove LPG from bottles	Technology Change
8. Rationalise compressed air system to eliminate dead legs	Technology Change
9. Install external insulation of hot wash tanks	Technology Change
10. Supply outside air to moulding chiller condenser coil	Technology Change
11. Optimise start-up times of electric furbances	Housekeeping

Company G

1. Install separate water meter	Houskeeping
2. Increase barrel drip times	Technology Change
3. Monitor chemical additions to tanks	Houskeeping
4. Install Cu & brass drag-out tanks	Technology Change
5. Educate workers on waste minimisation	Houskeeping
6. Install Cu and brass drag - out tanks	Technology Change
7. Use static rinse tanks after Ni plating	Technology Change
8. Check the electrical wiring system	Houskeeping
9. Prevent evaporation losses by using a foam blanket	Technology Change
10. Reduce hexavalent Cr to trivalent Cr	Technology Change
11. Install a settling tank	Technology Change
12. Install an automatice pH meter	Technology Change
13. Improve surface of floor by using anti - corrosive covering	Houskeeping
14. Replace timer on overflow rinse tanks for use only when tanks are in use	Technology Change
15. Establish a safe storage area for chemicals	Houskeeping
16. Use drip trays between tanks to reduce lossses due to drag - out and spillages	Technology Change
17. Implement a stock control system	Houskeeping
18. Redesign work process flow	Technology Change

Company H

1. Increase drip time	Technology Change
2. Investigate the use of an Electrowinning plant to recover metals	Technology Change
3. Fix leak in rinsing tank	Houskeeping
4. Investigate oil leaks on machinery	Houskeeping
5. Keep records of water use and find meter	Houskeeping
6. Install an automtic controller on the rinse baths	Houskeeping
7. Ensure NaOCl is not stored too long as its activity decreases over time	Houskeeping
8. Improve monitoring and control of chemicals	Houskeeping
9. Improve management of shop floor	Houskeeping
10. Recycle treated water to rinses after degreaser	Recycle
11. Replace cyanide Zn with alkaline Zn	Raw Material Change
12. Automate effluent treatment plant	Technology Change
13. Change type of oil used	Raw Material
14. Consolidate solvent supplier	Raw Material Change
15. Determine baseline data	Houskeeping
16. Install additional water meters on the 2 plating lines	Houskeeping
17. Install additional electricity meters to compressor house and annealing ovens	Houskeeping
18. Investigate the potential for electrical load management	Houskeeping
19. Ensure compressor air inlet filters are inspected and cleaned regularly	Houskeeping
20. Consider automatic control of compressor sequencing	Technology Change
21. Apply additional external insulation to annealing ovens	Technology Change
22. Apply insulating ball blanket to plating hot line washes	Technology Change
23. Investigate local dedicated extraction units on plating lines	Technology Change
24. Make more use of task lighting in porduction areas	Technology Change
25. Investigate power factor correction	Houskeeping
26. Upgrade barrels	Technology Change
27. Install drag out tanks	Technology Change
28. Install drag in tanks	Technology Change
29. Investigate alternatives to trichloroethylen	Raw Material
30. Educate employees in waste minimisation	Houskeeping
31. Install more rinse tanks	Technology Change
32. Install spray rinses	Technology Change
33. Install counterflow rinsing	Technology Change

Company I

1. Increase drip times	Technology Change
2. Use acid rinse for rinsing after cleaner	Recycle
3. Install counter flow rinsing on blackening line	Technology Change
4. Cover baths to prevent evaporation	Houskeeping
5. Investigate recycling of Ni solution	Recycle
6. Alter arrangement of tools on jigs to minimise cary over of chemicals	Technology Change
7. Change from Cr 6 to Cr 3 plating	Raw Material Change
8. Separate hazardous and non hazardous wastes to reduce disposal costs	Houskeeping
9. Install meter on bore hole water	Houskeeping
10. Monitor chemical addition to ensure only required amounts are added	Houskeeping
11. Replace overflow rinse with spray rinse	Technology Change
12. Eliminate the use of cyanide	Raw Material Change
13. Replace trichlor with Formula 40	Raw Material Change

14. Install controlls on plating line to check temperatures and concentrations	Houskeeping
15. Evaporate Cr drag-out tank and reuse in plating tank	Recycle
16. Introduce small overflow rinse bath in place of static bath	Technology Change
17. Operate filter press correctly to minimise sludge	Houskeeping
18. Resuse rinse water from phospahting in tumbling department	Recycle
19. Investigate reasons for 3 hour warm-up on furnaces for drop forging	Houskeeping
20. Introduce air blowers for agitation of plant blowers	Technology Change
21. Use ball blankets to prevent evaporation on hot rinse baths	Houskeeping
22. Optimise compressor operation	Houskeeping
23. Conduct an audit on compressed air leakage	Houskeeping
24. Replace wide diameter lighting tubes with slimline ones	Technology Change
25. Introduce a monitoring and targeting programme to relate production to utility use	Houskeeping

Company J

1. Monitor chemicl use in plating baths and effluent treatment	Houskeeping
2. Increase drip time to reduce drag - out	Technology Change
3. Reuse rinse water from spray rinse	Recycle
4. Improve drainage system to reduce spillages on floor	Houskeeping
5. Immerse heaters in baths to ensure proper heating	Houskeeping
6. Insulate tanks	Technology Change
7. Cover hot tanks to reduce evaporation	Houskeeping
8. Eliminate the use of Cd plating	Product Change
9. Educate employees in waste minimisation	Houskeeping
10. Investigate alternative arrangements of pieces on jigs to improve drainage	Technology Change
11. Introduce drip trays between tanks	Technology Change
12. Replace leaking tanks	Houskeeping
13. Install dragout and use to top up plating bath	Technology Change
14. Correct process flow in cadmium line	Technology Change
15. Investigate use of counterflow rinsing	Technology Change
16. Replace the use of compressed air for tank agitation	Technology Change
17. Investigate the use of cyanide free zinc	Raw Material Change
18. Upgrade cooling water system	Technology Change
19. Build a roof over the front yard to protect finished articles	
20. Install new water reticulation system	Technology Change
21. Upgrade floor and bund tanks	Houskeeping
22. Use a drag-in; drag-out system	Technology Change
23. Upgrade zinc barrel plating line	Technology Change

Company K

1. Increase drip times	Technology Change
2. Use rinse water to top up baths	Recycle
3. Ensure that no taps are left open when not in use	Houskeeping
4. Educate workers on waste minimisation	Houskeeping
5. Install more rinse tanks	Technology Change
6. Cover baths to reduce heat losses	Houskeeping
7. Remove oil from degrease rinse	Houskeeping
8. Undertake an energy audit	Houskeeping
9. Montior chemical addition to baths	Houskeeping

10. Record water use daily	Houskeeping
Company L	
1. Install overhead rack to reduce carry over	Technology Change
2. Use float controls to reduce spills	Technology Change
3. Improve drainage from floors	Houskeeping
4. Monitor water use	Houskeeping
5. Resurface floors	Houskeeping
6. Use drag-out to top up process baths	Recycle
7. Introduce incentive scheme for workers	Houskeeping
8. Fix tanks and leaks	Houskeeping
9. Investigate the use of alkaline zinc plating	Raw Material Change
10. Build shelter for drying area	Houskeeping
Company M	
1. Storing rinse water for resue	Recycle
2. Optimise orientation on the jig	Technology Change
3. Install counter current rinsing	Technology Change
4. Use rinse water to dilute the acid	Recycle
5. Reduce Zn splashing by predrying the work	Technology Change
6. Fix all leaks	Houskeeping
7. Education of the employees	Houskeeping
8. Investigate the use of gas to heat the Zn Kettle	Technology Change
Company N	
1. Install automatic level controller in bath	Technology Change
2. Redesign jig to improve draining	Technology Change
3. Install a holding tank to store concentrated solution	Technology Change
4. Cover manhole to prevent spillage of effluent	Houskeeping
5. Read electricity sub meter on a daily basis	Houskeeping
6. Install additional electrical sub meters on tempering oven and compressor house	Houskeeping
7. Install dedicated site water meter	Houskeeping
8. Install dedicated plating meters to each line	Houskeeping
9. Correct power factor from 0.85 to > 0.95	Houskeeping
10. Insulate and cover hot wash bath in the forging department	Technology Change
11. Consider additional insulation on tempering oven	Technology Change
12. Alter product orientation in tempering oven to allow reduced convective loss	Technology Change
13. Adopt a campaign to tackle compressed air leakage	Houskeeping
14. Apply insulating "ball blanket" to Plating line 2 rinse tanks	Technology Change
15. Eliminate the use of compressed air for agitation:installing high pressure blowers	Technology Change
16. Install counter flows on plating lines	Technology Change
17. Reusing caustic cleaner in forging department	
Company O	
1. Install water meter	Houskeeping
2. Insulate electroplating tanks	Technology Change
3. Increase drip times to reduce drag-out	Technology Change
4. Reposition work tanks to reduce spillages onto the floor	Technology Change

5. Use rinse baths to top up process baths	Recycle
6. Top up drag-out tanks with rinse water	Recycle
7. Install Ni drag-out	Technology Change
8. Install additional rinse baths	Technology Change
9. Install triggers on hoses	Houskeeping
10. Monitor hypochlorite use for neutralising cyanide	Houskeeping
11. Use Chrome drag-out as a drag-in	Technology Change
Company P	
1. Read water meter	Houskeeping
2. Monitor chemical use and addition	Houskeeping
3. Replace overflow rinses with static	Technology Change
4. Use rinse baths to top up baths	Technology Change
5. Remove excess oil with newspaper	Houskeeping
6. Recover powder	Recycle
7. Control oven use	Houskeeping
8. Improve quality control	Houskeeping
9. Trained workers in waste minimisation	Houskeeping
10. Reduce carry over by increasing drip times	Technology Change
11. Reduce evaporation by covering open baths	Houskeeping
12. Improve insulation to prevent heat losses	Technology Change
Company Q	
1. Switch to spray rinsing	Technology Change
2. Rinse jobs over baths to reduce drag-out	Technology Change
3. Install drag-out tank after nickel baths	Technology Change
4. Reduce hexavalent Chrome before discahrge	Technology Change
5. Improve use of drag-out tanks after chromium	Technology Change
6. Recycle acid rinse water for after alkaline bath	Recycle
7. Recycle additional cooling water in sugar chromium plating tank	Recycle
8. Fit spray nozzles to all rinse and washing hoses	Technology Change
9. Fix all leaks and tanks	Houskeeping
10. Install additional drag-out tank after chrome plating in sugar-screen plating side	Technology Change
Company R	
1. Install counter - flow rinse rather than overflow	Technology Change
2. Recycling rinse water	Recycle
3. Install conductivity meter to control overflow rinse	Houskeeping
4. Use flow restrictors to regulate flow	Technology Change
5. Replace degreaser chemical with alternative chemical	Raw material Change
6. Improve general houskeeping	Houskeeping
Company S	
1. Use rinse water effluent to top up the plating tank	Recycle
2. Recycle rinse water through cooling tower	Recycle
3. Install nozzles to hosepipes	Houskeeping
4. Rinse job over tank	Technology Change
5. Remove tape and rinse over tank	

Company T

1. Increase drip times	Technology Change
2. Reduce hanger area (Ni)	Technology Change
3. Replace water meter	Houskeeping
4. Fix leaks	Houskeeping
5. Install drip trays between baths to reduce water and drag - out losses	Technology Change
6. Install a timer to ensure correct duration for plating	Houskeeping
7. Improve housekeeping	Houskeeping
8. Clean - up spills as they happen	Houskeeping
9. Install a rack above the baths to ensure correct drip time	Technology Change
10. Improve floor drainage systems	Technology Change
11. Improve general cleanliness	Houskeeping
12. Install drip trays between tanks	Technology Change
13. Rinse jobs over the tanks	Technology Change
14. Install nozzles on hoses to limit flow	

Company U

1. Change overflow rinse to static rinse	Technology Change
2. Replace solid baskets with porous ones to reduce carry over	Technology Change
3. Re-arrange bath dumping procedure to reduce pH of effluent	Technology Change
4. Use rinse water to top up baths	

Company V

1.Change from overflow rinsing to static	Techology Change
2. Educate worker on waste minimisation	Housekeeping

Company W

1. Fix all leaks	Housekeeping
2. Shorten hooks	Technology Change
3. Install rack above tanks to increase drip times	Technology Change
4. Investigate use of spray rinses	Technology Change

Company X

1. Increase supervision	Houskeeping
2. Improve layout of tanks to ensure correct process flow	Technology Change
3. Mixing and topping up of tanks should be done with more care to prevent spillages	Houskeeping
4. Check for leaks on a more regular basis	Houskeeping
5. Increase drip times	Technology Change
6. Do not fill the tanks completely as most jobs are small	Houskeeping
7. Keep tanks at optimum temperatures	Houskeeping
8. Solutions should be covered to prevent contamination	Houskeeping
9. Train staff in waste minimisation	Houskeeping
10. Investigate feasibility of continuing the use of the boiler	Technology Change
11. Investigate out-sourcing of electroplating	Technology Change

Company Y

1. Replace overflow rinse with 2 counterflow rinses	Technology Change

2. Recycle acid rinse to degrease rinse	Recycle
3. Increase drip times to reduce carry over	Technology Change
4. Replace existing compressor with a reciprocating compressor	Technology Change
5. Conduct a compressed air leakage test	Houskeeping
6. Isolate extractor fans	Technology Change
7. Install water meters on plating lines	Houskeeping
8. Use air blowers in place of compressed air for bath agitation	Technology Change
9. Conduct combustion efficiency checks on drying ovens every 6 months	Houskeeping
10.Reduce air leakage and cold air intake from ovens	Houskeeping
11. Install gas metering to both ovens and monitor LPG usage	Houskeeping
12. Install metering on air compressors'	Houskeeping
13. Initiate a monitoring and targeting programme on site	Houskeeping

Company Z

1. Replace tricloroethylene with less hazardous chemical	Raw Material
2. Replace	Raw Material

APPENDIX 8 – NUMBER OF OPTIONS IDENTIFIED AND IMPLEMENTED IN EACH CATEGORY

Table 8A: Options Identified in Each Category

Company	House Keeping	Technology Changes	Raw Materials	Product	Recycle	Total
A	28	19	3	1	3	54
B	9	9	1			19
C	9	7	0		1	17
D	13	8		2	2	25
E	14	10			1	25
F	3	7			1	11
G	10	8				18
H	16	11	4		2	33
I	11	7	3		4	25
J	8	12	2		1	23
K	7	2			1	10
L	9		1			10
M	2	3	1		2	8
N	8	8	0	0	1	17
O	5	4			2	11
P	9	2			1	12
Q	2	6			2	10
R	2	2	1		1	6
S	3				2	5
T	10	4				14
U		3			1	4
V	2	2				4
W	2	2				4
X	8	3				11
Y	8	4			1	13
Z			2			2
TOTALS	**198**	**143**	**18**	**3**	**29**	**391**
% of total	**51**	**37**	**4**	**1**	**7**	

Table 8B: Options Implemented in Each Category

Company	House Keeping	Technology Changes	Raw Materials	Product	Recycle	Total
A	5	3				8
B	5	3				8
C	4	3				7
D	11	8	1	1	2	23
E	4	5			1	10
F	2	3			1	6
G	3	4				7
H	7	4	3		1	15
I	3	3	2		2	10
J	5	8			1	14
K	4	1				5
L	7					7
M					1	1
N	1	2			1	4
O	2	2			1	5
P	7	2			1	10
Q	1	2				3
R	1					1
S	2				1	3
TOTALS	**74**	**53**	**6**	**1**	**13**	**147**
% of Total	**50**	**36**	**4**	**1**	**9**	

APPENDIX 9 – OPTIONS IMPLEMENTED

Company A

1. Alter arrangements of items on jigs to reduce carry over
2 Eliminate use of compressed air for bath agitation and use high pressure blowers
3. Increase drip times
4. Improve pH control system on effluent
5. Control of waste bin so that only sludge is disposed of
6. Improve power factor
7. Control over dumping of baths such that permission must be obtained first
8. Worker education and operators given responsibilities for their lines

Company B

1. Monitor water consumption
2. Install drip trays on floor to collect spills
3. Install a bar above the zinc tank to increase drainage
4. Monitor chemical use
5. Install drainage boards between tanks
6. Train workers in waste minimisation
7. Fix leaks in tanks and pipes
8. Undertake a waste audit

Company C

1. Fix leaks
2. Educate workers in waste minimisation
3. Change overflow rinses to static rinses
4. Install and use drag-out tanks
5. Monitor chemical consumption
6. Optimise chemical concentrations in the tanks
7. Rotate barrels out of solution to increase drainage
8. Monitor electricity use
9. Investigate the resue of treated effluent for cleaning
10. Investigate the installion of transformers

Company D

1. Install drag-out tanks
2. Reduce rinse water flow
3. Change to counter flow rinsing
4. Fix all leaks
5. Shut - off taps permanently that are not in use
6. Monitor water use daily
7. Install more water meters on incoming water
8. Employ chemical storeman to control chemical use
9. Install automatic crane over Cr bath tp increase drip times
10. Increase drip times over all baths
11. Eliminate the use of cyanide
12. Reschedule oven use to reduce heating costs
13. Reuse Electro cleaner

14. Slow down cranes on Zn line to reduce carry over
15. Skim oil of electro cleaner to prevent contamination
16. Undertake staff training
17. Optimise hanging articles on the jig to improve drainage
18. Install effluent treatment plant to reduce SS
19. Switch off rectifiers overnight
20. Educate customers to use less harmful metals
21. Improve insulation on all heated tanks
22. Install thermostats to ensure tanks operate at optimum temperature
23. Reuse rinse water in the trichloroethylene tank

Company E

1. Install timers on baths for heating
2. Install drag-out tanks
3. Educate workers in waste minimisation
4. Install valves on water lines to reduce water flow into rinsing tanks
5. Monitor daily water use
6. Install cooling tower and reuse water
7. Remove oil from rinse baths
8. Install an additional degreasing tank
9. Monitor use of chemicals
10. Install nozzles on hoses to reduce water use

Company F

1. Replace automatic flushes in toilets with manual
2. Recycle water from tumbling process
3. Fix leaks
4. Replace overflow rinses with static rinses
5. Install drainage bars, and drip trays
6. Install vaporiser to remove LPG from bottles

Company G

1. Install separate water meter
2. Increase barrel drip times
3. Monitor chemical additions to tanks
4. Install Cu & brass drag-out tanks
5. Check the electrical wiring system
6. Implement a stock control system
7. Redesign work process flow

Company H

1. Fix leak in rinsing tank
2. Investigate oil leaks on machinery
3. Keep records of water use and find meter
4. Improve monitoring and control of chemicals
5. Improve management of shop floor
6. Recycle treated water to rinses after degreaser
7. Replace cyanide Zn with alkaline Zn
8. Automate effluent treatment plant
9. Change type of oil used

10. Consolidate solvent supplier
11. Determine baseline data
12. Investigate power factor correction
13. Upgrade barrels
14. Install drag out tanks
15. Install drag in tanks

Company I
1. Install meter on bore hole water
2. Replace overflow rinse with spray rinse
3. Eliminate the use of cyanide
4. Replace trichlor with Formula 40
5. Install controls on plating line to check temperatures and concentrations
6. Evaporate Cr drag-out tank and reuse in plating tank
7. Introduce small overflow rinse bath in place of static bath
8. Operate filter press correctly to minimise sludge
9. Reuse rinse water from phosphate in tumbling department
10. Introduce air blowers for agitation of plant blowers

Company J
1. Monitor chemical use in plating baths and effluent treatment
2. Increase drip time to reduce drag - out
3. Improve drainage system to reduce spillages on floor
4. Educate employees in waste minimisation
5. Replace leaking tanks
6. Install dragout and use to top up plating bath
7. Correct process flow in cadmium line
8. Investigate the use of cyanide free zinc
9. Upgrade cooling water system
10. Build a roof over the front yard to protect finished articles
11. Install new water reticulation system
12. Upgrade floor and bund tanks
13. Use a drag-in; drag-out system
14. Upgrade zinc barrel plating line

Company K
1. Increase drip times
2. Educate workers on waste minimisation
3. Undertake an energy audit
4. Monitor chemical addition to baths
5. Record water use daily

Company L
1. Improve drainage from floors
2. Monitor water use
3. Resurface floors
4. Use drag-out to top up process baths
4. Introduce incentive scheme for workers
5. Fix tanks and leaks
6. Build shelter for drying area

Company M
1. Storing rinse water for reuse
2. Use rinse water to dilute the acid

Company N
1. Redesign jig to improve draining
2. Install dedicated plating meters to each line
3. Install counter flows on plating lines
4. Reusing caustic cleaner in forging department

Company O
1. Install Ni drag-out
2. Install additional rinse baths
3. Install triggers on hoses
4. Monitor hypochlorite use for neutralising cyanide
5. Use Chrome drag-out as a drag-in

Company P
1. Replace overflow rinses with static
2. Use rinse baths to top up baths
3. Remove excess oil with newspaper
4. Recover powder
5. Control oven use
6. Improve quality control
7. Trained workers in waste minimisation
8. Reduce carry over by increasing drip times
9. Reduce evaporation by covering open baths
10. Improve insulation to prevent heat losses

Company Q
1. Improve use of drag-out tanks after chromium
2. Fix all leaks and tanks
3. Install additional drag-out tank after chrome plating in sugar-screen plating side

Company R
1. Improve general housekeeping

Company S
1. Recycle rinse water through cooling tower
2. Rinse job over tank
3. Remove tap and rinse over tank