INDUSTRIAL WASTE MINIMISATION IN SOUTH AFRICA: A CASE STUDY IN THE TEXTILE AND METAL FINISHING SECTORS

BY

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ABSTRACT

Environmental legislation is becoming more stringent as people are realising the need for conservation and a reduction of environmental degradation in order to facilitate sustainable development. To ease legislative pressures, companies need to work together in symbiotic networks, whereby co-operation between companies results in far more innovative practices than if the companies acted individually. Success in an industrial network is largely dependent on cleaner production, where industries seek to redirect from waste treatment to waste minimisation. Cleaner production has already received international recognition and waste minimisation initiatives have been used as a tool of cleaner production. Two polluting industrial sectors within South Africa, the textile and metal finishing sectors, were chosen to investigate waste minimisation concepts. One company from each sector was used as a case study. The dissertation followed company network identification, potential to participate within an industrial symbiotic network, and waste minimisation opportunities. Suppliers and buyers, up and down the product line were identified. Relationships with these partners should be advanced such that environmental concerns are at the forefront of any decision-making. In light of developing industrial networks and maintaining symbiotic relationships, the company's potential was investigated by interviewing employees of various ranks. Both companies were partially suited to participate within an industrial symbiotic network and company-specific barriers were identified, such as ineffective internal communication. The waste minimisation investigation followed a four-phase approach of planning and organisation; pre-assessment; assessment; and feasibility study. In both the companies investigated, water savings were identified as the waste minimisation focus area with potential for improvement. In total, potential water savings of over R80 000 per annum were identified. In the textile company, the weaving department and bleach house were further investigated. Cloth weaving errors were attributed to machine stops, as each stop has the potential to result in a cloth fault. In the bleach house the potential existed to reduce the number of rinse tanks. Although a modern and automated process, the plating plant in the metal finishing company was identified as having potential waste minimisation opportunities. Of particular interest was the reduction of solution carry over from the plating tanks into subsequent tanks. Extended drip times were investigated. Additional waste minimisation opportunities included repairing pipe leaks, replacing the degreasing solvent, trichloroethylene, with a less harmful cleaning agent and establishing a symbiotic relationship with the oil supplier, Castrol. Over and above the main waste minimisation opportunities highlighted, other recommendations and potential savings were identified. Each case study emphasises that simple waste minimisation initiatives, without expending capital, reduce demands on natural resource, such as water, and benefit the company financially. Successful waste minimisation leads to further cleaner production initiatives, which may then initiate better network interactions with the further potential of promoting sustainable development.

PREFACE

The work described in this dissertation was carried out in the School of Chemical Engineering, University of Natal (Durban), under the supervision of Professor C.A. Buckley, Mr B. Kothuis and Mrs 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. The fieldwork was undertaken from 1997 to 1998.

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ABBREVIATIONS

CAIA	Chemical and Allied Industries Association
CMC	Carboxymethyl cellulose.
COD	Chemical Oxygen Demand
DEAT	Department of Environmental Affairs and Tourism (South Africa)
DfE	Design for the environment
DME	Department of Minerals and Energy (South Africa)
DWAF	Department of Water Affairs and Forestry (South Africa)
EMAS	Eco-Management and Audit Scheme
EMS	Environmental Management System
ICC	International Chamber of Commerce
ICPIC	International Cleaner Production Information Clearinghouse
IDRC	International Development Research Centre of Canada
NCPC	National Cleaner Production Centres
NDA	National Department of Agriculture (South Africa)
NEMA	National Environmental Management Act 107 of 1998
PREPARE	Preventive Environmental Protection Approaches in Europe
PRISMA	Project on Industrial Success with Pollution Prevention
SMEs	Small and medium sized enterprises
UCT	University of Cape Town
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organisation

CHAPTER 1

INTRODUCTION

The world we have created today as a result of our thinking thus far has problems which cannot be solved by thinking the way we thought when we created them

A. Einstein (1879 – 1955)

Population growth and an increased standard of living means an increased need for goods and services. Associated advancements in industrial processes relate to depletion of natural resources and increased waste generation. Industries that produce contaminated wastewaters, such as the textile or metal finishing sectors, are a major concern in a water deficient country such as South Africa.

1.1 THE SOUTH AFRICAN SITUATION

Water is a scarce and valuable resource in South Africa (DWAF, 1994). The average rainfall is around 470 mm per annum, compared with the world average of 857 mm per annum (Millard, 1999). An estimated 16 million ML of water is consumed annually (Millard, 1999) with a suggested period of approximately 30 years before South Africa is expected to run out (Martin Creamer Media, 1999). The costs of raw materials, such as water and electricity, are relatively inexpensive and thus the need for conservation is not obvious to the South Africa consumer. Furthermore, the South African population of 44.3 million people in 1998 has been estimated to increase to 71.6 million people by 2025 (World Resource Institute, 1999). An increasing population means a larger natural resource demand and thus greater negative impacts on the environment as a whole.

Current environmental legislation in South Africa promotes sustainable development. Numerous environmental acts have been developed to protect the South African people and the environment (DANCED, 1999a). The South African government now encourages pollution prevention and the Department of Water Affairs and Forestry (DWAF) and the Department of Environmental Affairs and Tourism (DEAT) are increasingly applying the Polluter Pays Principle (WWF, 1997; Barnard, 1999). Two industrial sectors that contribute to pollution are the textile and metal finishing sectors.

1.2 THE TEXTILE AND METAL FINISHING SECTORS

The textile and metal finishing sectors are significantly characterised by small and medium sized companies (EMG, 1993). Although their individual contributions may be small, as an industrial collective their environmental impact is significant. These sectors are common in developing countries and contribute to the hazardous waste streams in South Africa (EMG, 1993). The textile and metal finishing sectors have been identified as the third and fourth most polluting in terms of hazardous waste quantity per Rand of output / contribution to gross domestic product (EMG, 1993).

Predominantly batch-wise processing, these small and medium sized enterprises (SMEs) produce wastewaters which vary in volume, composition, temperature and intensity of pollution, and are thus difficult to manage. Such wastewaters are often of a lower quality than that stipulated by the receiving treatment plants, presenting problems and resulting in non-compliance for the company. The National Water Act 36 of 1998, includes the application of water pricing which is likely to see industrial water being charged at significantly higher rates than in the past, and much more stringent quantitative monitoring.

Textile manufacturing has been associated with water pollution from dyes and chemicals involved in the production of artificial fibres (von Weizsäcker, et al., 1997). Metal pollutants such as zinc, copper, and chromium may come from certain dyes. Textile wastewaters are frequently coloured and generally have a high chemical oxygen demand (COD). Organic pollutants originate mainly from desizing, scouring and dyeing operations, the bulk of which is from impurities removed from the fibres during processing. Volatile organic carbon compounds, such as solvents used during finishing processes, pose a risk of air pollution. Inorganic pollutants consist mainly of sodium salts from the scouring, bleaching and dyeing stages (Groves and Anderson 1977).

In the metal finishing industry, corrosive chemicals are used in the pre-treatment of metal surfaces which may involve alkali (degreasing) and acid (pickling) solutions. Chlorinated hydrocarbon solvents used in degreasing are proven to be liver-toxic and are suspected to be carcinogenic (von Weizsäcker, et al., 1997). Process solvents also contribute to air pollution, such as smog, in the form of volatile organic carbons. Heavy metals from processes such as degreasing, pickling, coating, electropolishing and anodising may lead to contamination of receiving water bodies, pollution of drinking water, destruction of aquatic life and bioaccumulation in the food chain.

Due to the size, nature and potential environmental burden of both the textile and metal finishing sectors, industries from these two sectors were targeted to identify potential waste minimisation opportunities. The textile and metal finishing sectors also differ in many aspects and, as such, general waste minimisation principles and results acquired from this study can be used as input for other sectors and regulators. Such differences include:

- labour requirements,
- technological sophistication (relating to different capital commitments),
- competitive pressures (from local and imported products)
- market bases (textiles are often sold directly to retail markets whereas metal finishing products are often sold to sub-assembly manufacturers)
- dependence on the import of raw material (textiles more than metal finishing)

By providing local success stories (case studies) on pollution and waste minimisation in these industries, stronger awareness raising and improvements can be achieved in other industries. By highlighting problems, warnings can be provided and strategies may be developed to overcome them.

1.3 DISSERTATION CONCEPTS AND STRUCTURE

The purpose of the dissertation was to conduct an objective industrial waste minimisation assessment, using one South African company each from the textile and metal finishing sectors as case studies. The International Development Research Centre of Canada (IDRC) provided the main funding for the investigation.

The waste minimisation investigation stems from the principle concept of sustainable development. Industrial activities must be sustainable if the natural environment is to be conserved. Industries may work together in larger industrial systems or enhance symbiotic relationships within a network between suppliers and buyers, to achieve common goals such as cleaner production. A fundamental operating component of cleaner production is waste minimisation. The concepts are inter-related as depicted in **Figure 1.1**.

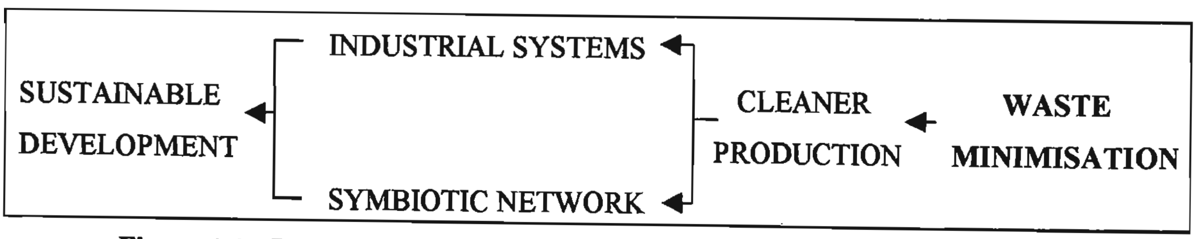

Figure 1.1: Interrelated principles as a precursor for sustainable development.

The dissertation hypothesis is that

> *the application of waste minimisation, a tool for cleaner production, leads to improved operational performance which enhances economic savings and reduces environmental impacts.*

The dissertation layout has been structured accordingly (**Figure 1.2**). **Chapter 2** is a literature review of fundamental concepts leading to waste minimisation including the origin of sustainable development, industrial systems and symbiotic networks, cleaner production and global initiatives, the hierarchy of waste management, an example of a waste minimisation model and the waste minimisation approach followed during the case studies; **Chapter 3** and **Chapter 4** are the detailed case studies with background information on the processes and practices of each industry, and potential waste minimisation opportunities. **Chapter 5** summarises key issues of the investigation, waste minimisation opportunities that were identified and potential benefits and problems that may be experienced as a result of improved operational practices.

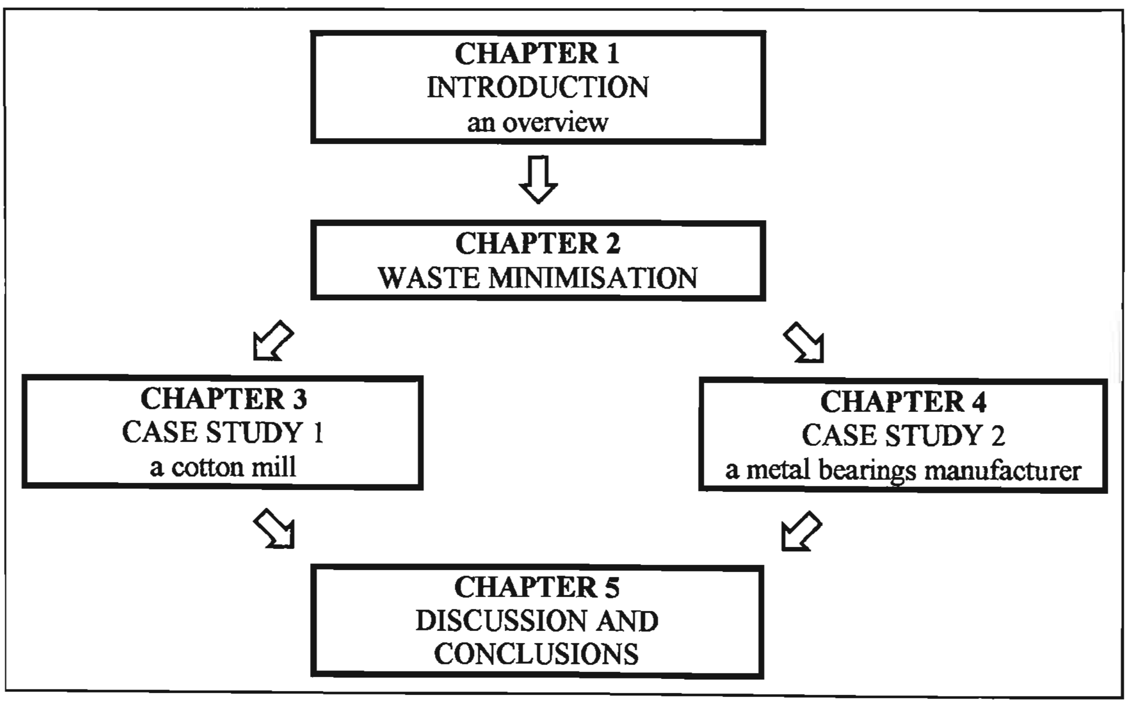

Figure 1.2: Dissertation layout.

CHAPTER 2

WASTE MINIMISATION

Waste minimisation is a strategy that has been adopted as a long-term goal of the National Waste Management Strategy to alleviate South Africa's waste management problems

D. Macozama (2001)

The concept of sustainable development is advanced when industries work together in industrial systems or through symbiotic networks. Success of the network is dependent on the viability of each industry. For industries to operate effectively, procedures must incorporate economic and ecological aspects and promote cleaner production. Waste minimisation is a fundamental precursor to cleaner production.

2.1 SUSTAINABLE DEVELOPMENT

In the 1980's, the International Union for the Conservation of Nature's World Conservation Strategy endeavoured to reconcile ecological and economic concerns by introducing the concept of sustainable development (DEAT, 1997). In 1987, the World Commission on Environment and Development (Brundtland Commission) report, *Our Common Future* (Larson, et al., 1999; Wates, 1996) provided a definition:

> *Sustainable development is development that meets the needs of the present, without compromising the ability of future generations to meet their own needs*

In 1991, the International Chamber of Commerce (ICC) created the *Business Charter for Sustainable Development*, comprising 16 principles for environmental management that foster sustainable development (NSF, 1999). In 1992, the United Nations Conference on Environment and Development (UNCED), also known as the Earth Summit or Rio Summit (DANCED, 1998), resulted in Agenda 21 - a guidance document for sustainable development and the Rio Declaration - a set of 27 principles for achieving sustainable development (NSF, 1999). The World Business Council for Sustainable Development has promoted the concept of triple bottom line reporting, meaning social, economic and environmental aspects must be encompassed. South African legislation also incorporates concepts of sustainable development.

Section 24b of the Constitution Act 108 of 1996 makes mention of a State duty to *secure ecologically sustainable development*, Section 2 of the Environmental Conservation Act 73 of 1989 makes reference to sustainable development as being *the guiding principle for environmental management*, and Section 2(3) of the National Environmental Management Act (NEMA) 107 of 1998, states that *development must be socially, environmentally and economically sustainable*.

Economic incentives are provided by financial aid organisations such as the World Bank, which will only lend money for a project if it can be shown to be sustainable (Millard, 1999). Sustainable development embodies the goals of effective resource management whilst ensuring environmental well being and economic advantage. At the individual company level, environmental sustainability may prove difficult, or impossible, so companies need to work together in symbiotic networks in order to gain mutual benefits and reduce environmental impact.

2.2 INDUSTRIAL SYSTEMS AND SYMBIOTIC NETWORKS

Some companies co-operate in industrial ecosystems, as defined by Ayres, 1996:

> *An industrial ecosystem is a system designed to imitate nature by utilising the waste products of each component firm as raw materials (or 'food') for another*

Collaboration in an industrial ecosystem delivers measurable benefits that justify investment time and money. Operating costs for individual companies, environmental impacts that would normally result from waste treatment or disposal and resource demands in an area dense with industries are reduced. Examples of ecosystems include the Kalundborg complex in Denmark, the Styria region in Austria, and the INES project in Rotterdam (Ayres, 1996, Graedel and Allenby, 1995). In South Africa, Capricorn, located in Muizenberg, and Coega, situated in Port Elizabeth, are developing as industrial parks (Kothuis, 2000).

A further concept related to industrial co-operation is industrial symbiosis. Adapted from The Symbiosis Institute definition, 1999 and Lichtenstein and Hoeveler, 1996:

> *Industrial symbiosis is the mutually beneficial relationships that exist between companies within an industrial network in order to compete more effectively and achieve together what each firm could not achieve alone*

In addition to exploring new relationships with companies that utilise each others waste, an industry can optimise its economic and environmental performance by exploiting the positive synergism and interdependencies which exist between its suppliers and buyers. In any industrial network there exists, direct and indirect, exchange of materials, finances and information between suppliers and buyers. A simplified model of a company's main networking partners is illustrated (**Figure 2.1**).

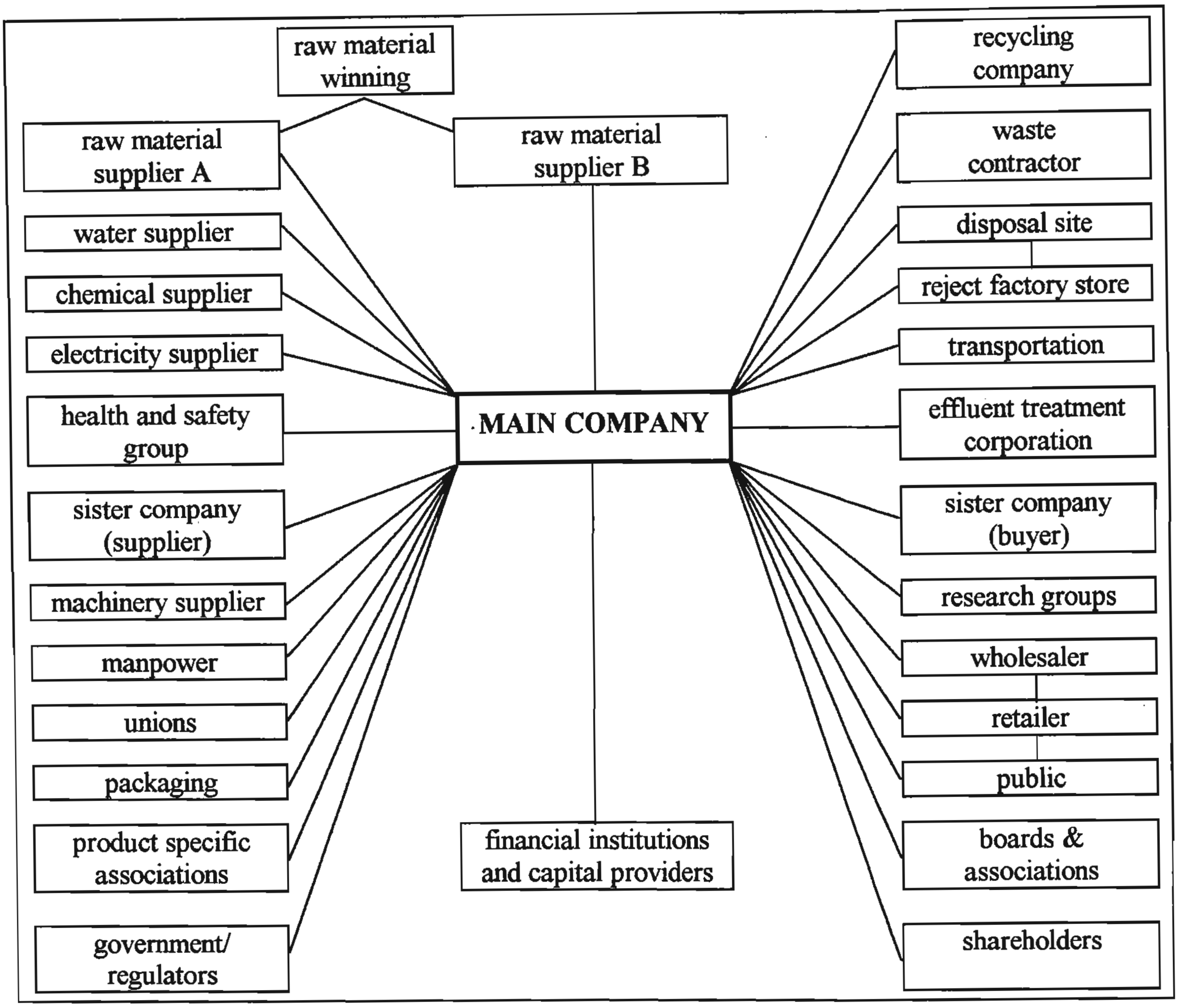

Figure 2.1: Networking links that exist between a company and related organisations.

Gray (1985) has expressed a three phase approach to collaborating efforts in an industrial symbiotic network. Problem-setting is the first phase during which partners identify and gain clarity on issues. The next phase is direction-setting during which values that guide individual pursuits are related to the values underlying the common purpose of sustainable results. The final stage is structuring, to ensure ongoing and effective partner interactions. Companies can draw on the expertise from each other, promote operational efficiency, implement cleaner technologies, increase product competitiveness, and reduce environmental impacts.

An example of a potential symbiotic network relationship is illustrated using a coloured garment. Where fashion dictates a red garment, the textile manufacturer (as a supplier) is bound to produce that product. Furthermore, the manufacturer (as a buyer) will require a red dye from the chemical supplier. The textile manufacturer may, however, work with its dye supplier to develop a more environmentally friendly product by making changes to the chemical composition of the dye. The symbiotic relationship results in the dye supplier manufacturing a competitive, environmental friendly product and the textile manufacturer can also promote its garment as being produced in an environmentally friendly manner. Since harmful waste products are reduced, so too are the related treatment expenses. Such relationships positively impact on a company's triple bottom line, the *socially* favoured product results in increased product sales, related *economic* benefits, and *environmental* benefits from reduced impacts. Good relationships between all partners at the early stages of product development, offers added value in the network and can lead to a breakthrough in the success of sustainable product innovations (Luiten, et al., 1999).

2.2.1 Shift from Supplier to Service Provider

In a traditional supplier-buyer- relationship, the supplier's profitability is a function of volume thus encouraging sales, whereas the buyer tries to minimise costs by purchasing less (**Figure 2.2**) (Reiskin, et al., 2000).

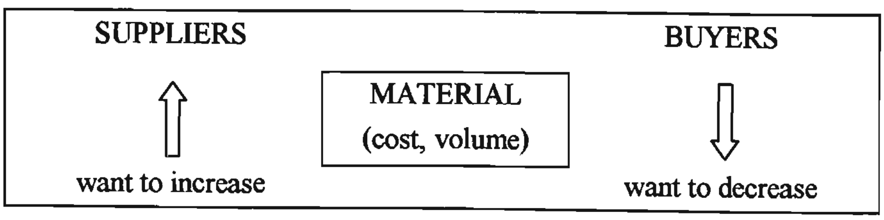

Figure 2.2: Traditional conflicting incentives, where suppliers try to maximise sales while buyers try to minimise purchases (Reiskin, et al., 2000).

Products are ultimately agents of service delivery. As such, there is an increasing shift from product supplier to service provider. For example, instead of a chemical supplier only providing a chemical or dye, the supplier may also provide a service and assume product stewardship. Product stewardship also means that the supplier reclaims old stock, waste products and containers from the buyer to ensure appropriate treatment or disposal.

General Motors experimented partnering with chemical suppliers and transferring aspects of chemical management to them, reaping economic and environmental benefits (Reiskin, et al., 2000). Navistar, a leading producer of truck engines, partnered with Castrol Chemical at one of its facilities and reduced coolant use by 50 % and coolant waste by over 90 % (Reiskin, et al., 2000). Other benefits to Navistar included reductions in production downtime, the number of reworks, and inventory costs with improved inventory management. Castrol has moved from an industrial lubricants vendor to an industrial lubricants service provider. As Navistar benefits, so too does Castrol by becoming a preferential supplier, with increasing business and a good company image. Similarly, Electrolux has moved from an appliance manufacturer to an industrial cleaning service firm (Reiskin, et al., 2000). Over time the customer will see the supplier more as a resource than a vendor (Reiskin, et al., 2000). The shift to service provider will result in a decrease in the commercial interest in producing products and an increase in loss avoidance and environmental awareness (von Weizsäcker, et al., 1997).

2.2.2 Communication and Transparency as Network Barriers

The most obvious barrier to symbiotic networking is a limited scope of communication. Although supplier-buyer interactions may be frequent, process improvement options are seldom discussed for reasons such as a lack of time, manpower, awareness, or interest. Confidentiality is intensified between manufacturers of similar products, or in companies that are experimenting with new machinery or developing new processes due to competition. A lack of information transparency often leaves buyers uncertain as to necessary precautions and emergency procedures, such as in the event of a spill, or the appropriate waste treatment method. Additional complications are experienced when a manufacturer, using the undefined product wishes to implement process changes. The outcome is often unpredictable and therefore change too risky, preventing potential improvements. A company that with-holds product information or fails to adhere to common law practices instils suspicion and stands to lose its customers. Transparency establishes trust amongst organisations and open communication with the public guarantees support instead of criticism created by the unknown. Benefits of open communication between networking partners and transparent operations need to be better publicised to drive companies to interact.

Environmental responsibility is becoming integral to competitive advantage. Companies need to pollute less and produce more output per unit of input, to remain competitive, thus calling for a shift in production and consumption paradigms. As environmental concerns are progressively incorporated into business and social structures, processes will require restructuring. A driving force for innovation is cleaner production: using less resources and causing less environmental damage than alternative means with which it is economically competitive. Cleaner production disseminates faster in sectors with strong organisational networks (DANCED, 1998).

2.3 CLEANER PRODUCTION

The term *cleaner production* was coined when the United Nations Environmental Programme launched its Cleaner Production Programme in 1989 (UNEP, 1996):

> *Cleaner production is the continuous application of integrated preventive environmental strategy to processes, products and services in pursuit of economic, social, health safety and environmental benefits*

Cleaner production encompasses changes to the three main aspects of operation including:

- processes: to conserve raw materials, eliminate hazardous raw materials and reduce the quantity and impact of emissions and wastes;
- products: to reduce negative impacts along the life cycle of a product from raw material extraction to its ultimate disposal;
- services: to incorporate environmental concerns into the design and delivery services.

Cleaner production also reduces a company's material intensity. Factor 4 and Factor 10 concepts estimate that a reduction of raw material and energy use to achieve a certain product or service is 75% or 90% respectively (Eder and Fresner, 1999). If resource productivity were increased by a factor of four, the world could enjoy twice the wealth currently available and halve the stress placed on the environment (von Weizsäcker, et al., 1997).

The integration of cleaner production into an environmental management system (EMS), such as the Eco-Management and Audit Scheme (EMAS) and ISO 14000 is on the increase (Eder and Fresner, 1999). ISO 14000 primarily exemplifies that a company has a well-defined EMS in place and is striving towards compliance and continual improvement in environmental performance (Rao, et al., 1999). Incorporating cleaner production strategies into its EMS, a company benefits ecologically and financially, and becomes internationally competitive.

2.3.1 Global Initiatives

Internationally, cleaner production has received official recognition. Numerous governmental and non-governmental organisations have become involved in cleaner production initiatives as discussed in the 1998 National Waste Management Strategy and Action Plans for South Africa (DANCED, 1998). Among the most prominent European co-operative cleaner production projects are the Dutch PRISMA project; the Aire and Calder, and CATALYST Merseyside projects in the UK; the SPURT project in Denmark; the LANDSKRONA project in Sweden; and the ECOPROFIT and PREPARE projects in Austria (Eder and Fresner, 1999).

The Project on Industrial Success with Pollution Prevention (PRISMA) 1988 - 1991, involving 10 industrial companies from Rotterdam and Amsterdam, identified barriers to waste and emission prevention, and methods of overcoming them (Dielman and de Hoo, 1993). PRISMA proved that successful prevention was possible and offered benefits to companies and the environment (Partidario, 1999). The Aire and Calder project, a similar initiative to the PRISMA project, was launched in the United Kingdom in 1992 (Johnstone, 1996). This waste minimisation project, involving 11 companies, demonstrated the benefits of a systematic approach to emission reduction and focused on procedural changes and cleaner technology (Partidario, 1999). The Preventive Environmental Protection Approaches in Europe (PREPARE) was established in 1992 to identify projects in preventive production technologies and cleaner products. PREPARE is a pan-European project, based on the success of PRISMA (Eder and Fresner, 1999).

The United Nations Environment Programme (UNEP) began its cleaner production programme in 1989 (Eder and Fresner, 1999). It works with more than 100 organisations to implement cleaner production initiatives in over 60 countries. The UNEP International Cleaner Production Information Clearinghouse (ICPIC) provides data on about 600 technical cleaner production case-studies all over the world (Eder and Fresner, 1999). Together with United Nations Industrial Development Organisation (UNIDO) it has established National Cleaner Production Centres in many countries, including Africa.

2.3.2 Initiatives Taken in Africa

In South Africa, cleaner production is specifically mentioned in the White Paper on Environmental Management Policy for South Africa (DEAT, 1997) and in the National Water Act (Act 36, 1998). UNIDO and UNEP have established National Cleaner Production Centres (NCPC) throughout Africa including the United Republic of Tanzania (1995), Zimbabwe (1995), Tunisia (1996), Morocco (1999), Ethiopia (2000), Kenya (2000), Mozambique (2000) (Hogsted, 2000) and South Africa (2002).

In these countries, the aim was the widespread adoption of cleaner production and national capacity building. Common barriers that were identified included a lack of records of material flows, energy use, emissions and waste streams; lack of environmental management skill; low education and awareness on environmental issues; lack of observance to the already existing weak environmental laws; use of outdated technology and techniques; a lack of funding; company organisational problems; and lack of management commitment (UNEP, 2000).

Cleaner production proved to be beneficial both financially (through improved efficiency and productivity) and environmentally (through material, energy and water conservation, and reduced resource consumption, pollution, emissions, waste, waste disposal and treatment). The project also aided in the development of environmental management policies and standards, and capacity building in terms of environmental awareness and training of industry and government (UNEP, 2000). Enforcing simple housekeeping proved to be a no- or low-cost option with immediate pay-back periods (Zulu, et al., 2000). These included fixing leaks, closing off unnecessary taps, controlling chemical addition, monitoring water use and flows, optimising use of heated equipment, improving process operations, reusing rinse water and other baths, and training staff (Buckley and Barclay, 2000). Other cleaner production options which required capital expenditure included process change, automation, material recovery, and installation of new equipment (Mombemuriwo and Munjoma, 2000). Further barriers and incentives from other cleaner production initiatives throughout the world have been summarised in **Section 2.3.3**.

2.3.3 Barriers and Incentives of Cleaner Production

Companies are often unaware of opportunities and advantages related to innovative and environmentally sound products and processes (DANCED, 1998). There are few comparative data and bench marking tools available which means that companies are often uncertain of their relative performance in terms of cleaner production (DANCED, 2000). The availability of cleaner technologies is difficult to establish (Patel and Peart, 1998) and within smaller companies the process of technology diffusion and dissemination is slow (DANCED, 2000). SMEs experience cultural problems related to lack of awareness, poor communication, resistance to change, lack of organisational flexibility, shortage of time and adequate human resources for environmental training programmes (Partidario, 1999). Economic constraints include high interest rates and capital-intense modifications (Partidario, 1999). A declining exchange rate (until recently), increases the cost of imported machinery and newer technologies. Investors often perceive SMEs to be a high risk factor and often loans are declined. The risk that investments may not yield the expected return is problematic in adopting cleaner production (DANCED, 2000) and as such many companies favour short-term, end-of-pipe approaches (Partidario, 1999).

Experience has proven that cleaner production will only be adopted where there are significant financial reasons to do so and because environmental and health protection laws require it (Patel and Peart, 1998). However, certain companies feel that if there are no complaints and if they are complying with the regulations, there is no need to make any changes (Buckley and Barclay, 2000). For others, relevant regulations are difficult to access because environmental issues are contained in so many different acts, ordinances, rules and regulations (Barnard, 1999). Conflicting, unclear and frequently changing government policies can act as a disincentive for regulation compliance (Chandak, 1994). Often the higher realms of political decision making think in macro terms and do not share the same immediate perceptions of environmental priorities as their professional staff (DANCED, 2000). Enforcement of environmental legislation and function execution have been spread over a multiplicity of institutions and between national, provincial and local government tiers (DANCED, 1999a). Co-ordination problems and conflicts of interest result from dualistic conservation / exploitation assignments (Schwella and Muller, 1992).

In the past in South Africa, environmental legislation implemented by the Department of Environmental Affairs and Tourism (DEAT) was also controlled by bodies with opposing conservation interests, such as the Department of Minerals and Energy (DME), the National Department of Agriculture (NDA) and the Department of Water Affairs and Forestry (DWAF) (Rabie, et al., 1992). Even now, the fragmentation of control detracts from effective management and often leads to a total absence of control (Barnard, 1999). Ideally, control of environmental aspects should be vested in one law and the variety of management guidelines should be replaced with a single guideline (Barnard, 1999).

Insufficient manpower to enforce legislation is a problem facing smaller, local authorities and results in non-compliance often going undetected. Where fines are charged, they are generally insignificant and the environmental impact thus not considered serious. Many larger companies prefer to pay the fines rather than make long term plans to resolve the problem at source (DANCED, 2000). Regulatory controls will only be effective if fines result in legal compliance being cheaper than non-compliance (Patel and Peart, 1998). In South Africa, resource and disposal costs are low, providing no financial incentive to reduce consumption or waste. Standards related to wastewater concentrations encourage compliance by dilution both at a factory level and a municipal level. A lack of incentive to reduce environmental impacts beyond the limits fixed by standards makes companies unwilling to make investments for radical innovations. Environmental matters are generally considered as cost generating rather than an opportunity for development and cost savings (DANCED, 1998). Mechanisms to encourage environmental awareness include the common law by allowing ordinary citizens to sue polluters for causing nuisances or damages; banning harmful substances; more lenient tax deductions for the introduction of environmentally sound practices; or conversely introducing emission tax payments (Patel and Peart, 1998). Durban Metro Water Services has an incentive which stipulates that a company using cleaner production techniques may apply for relaxation of the discharge limits (DANCED, 1998). In summary, cleaner production requires efficient resource use and operations, innovative policies and management practices by government and industry, and a change in attitude and behaviour of consumers to ensure responsible environmental management.

Industries that practise cleaner production can position themselves to respond dynamically to changing environmental pressures thus ensuring their economic survival in the long term, a win-win situation. All stakeholders must be involved in the introduction of cleaner production especially consumers because, when sensitised, they will demand environmental products and services. Certain governments have established environmental technology verification programmes whereby manufacturers of the technology are allowed to display a particular mark, in much the same way as consumable products in some countries carry an 'eco-label' (Patel and Peart, 1998). The eco-label provides assurance that the environmental impact of the product has been reduced without significantly compromising the use and durability of the product (Burdett, 1997). Cleaner production is an avenue to greater profitability and reasons such as tax reduction, market perception or meeting export requirements may encourage industry to adopt cleaner principles. As the South African market becomes more integrated into global economy, competitive pressure to practice cleaner production will grow. Companies that follow cleaner production principles will seek to redirect from waste treatment to waste minimisation.

2.4 WASTE MINIMISATION AND MANAGEMENT

In the past, waste management was not regarded a priority issue in South Africa (DANCED, 1999b) and focus was geared at end-of-pipe solutions, such as treatment and disposal. Consultants and suppliers also promoted such solutions as they benefited from related sales, such as treatment plants and chemicals. Many industrial managers now understand that waste is a resource out of place - a symptom of bad management that hurts the bottom line (net profit) (von Weizsäcker, et al., 1997). Focus is moving away from merely redirecting waste from one medium to another, to a more proactive, waste minimisation approach. The UK EPA, 1990 has provided a pertinent definition:

Waste minimisation is any technique, process or activity in which wastes are avoided eliminated or reduced at source or which allows for reuse or recycling of the wastes for benign purposes

The DEAT is authorised in section 24 of the Environment Conservation Act (Act 73 of 1989) to investigate waste minimisation through waste reduction and utilisation. The White Paper on Integrated Pollution and Waste Management for South Africa (Notice 227 of 17 March 2000) is part of the process of developing such waste minimisation structures. Waste minimisation is one of the principles set out in the White Paper on Environmental Management Policy for South Africa (Notice 749 of 15 May 1998) to be applied to environmental management (Patel and Peart, 1998). Waste minimisation is a driver for innovative growth and in the right framework can enhance the diffusion of technology and related social developments. Waste minimisation has proven to be financially viable in the development of Waste Minimisation Clubs in Durban and Hammarsdale in 1998 where annual saving of over R6 million have been reported (Buckley and Barclay, 2000; Odendaal, 2001).

Waste related to the production, use and disposal of products should be minimised as close to source as possible before applying waste treatment methods. Although various waste management approaches exist (**Figure 2.3**) only reduction at source minimises the amount of waste, the environmental threat that it poses and waste disposal impacts and costs.

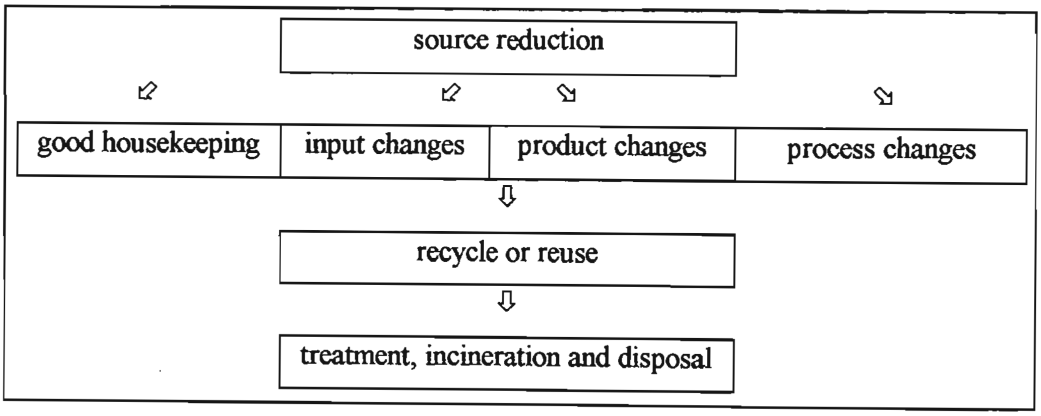

Figure 2.3: Different waste management approaches, from most to least favoured option.

It is important to note that as material passes from source to consumer, the value of the material increases. The highest value would be just prior to the purchasing of the finished product by the consumer. Thus identifying waste minimisation opportunities as early in the manufacturing process as possible is financially beneficial.

2.4.1 Source Reduction

Source reduction may be as simple as enforcing good housekeeping or may involve changes to input materials, products or processes so that the overall environmental pressure from the circulation of materials is reduced.

2.4.1.1 Good Housekeeping

Low worker education and skill, and poor management is often associated with poor housekeeping and often operators are unaware of the impacts of their operations (DANCED, 2000). Workers should continually be trained on loss prevention, improved material handling and inventory practices, production scheduling, and separation of hazardous and general wastes (DANCED, 1998). Good housekeeping means closing taps which are not in use, fixing leaks, reducing packaging and office waste, repairing equipment wherever possible, and buying durable products. The Durban Metro Water by-laws try to encourage waste reduction by penalising wastage of water through leaking pipes (DANCED, 1998). Practising good housekeeping is an effective waste minimisation technique and does not necessarily require capital investments.

2.4.1.2 Input Changes

Input changes may involve purification or substitution of toxic or hazardous materials. Examples include water pre-treatment to reduce foreign particles and process contamination, and substituting chlorinated solvents with less harmful cleaning agents. Although the concept of input change is simple, risks involve unpredictable product quality due to input modifications. For example, the use of a less harmful, cleaning solvent in a metal finishing plant may not adequately polish the metal resulting in later plating problems. Small-scale investigations should be conducted before input changes are implemented.

2.4.1.3 Product Changes

Companies should be encouraged to manufacture more durable, repairable, upgradeable, easier to disassemble products. In so doing, resource consumption is reduced, as is the amount of products returned to the company after use and waste introduced into the waste stream. Another means of product change is adjusting the stability of waste residues and may be achieved by choosing to use materials that can be made suitable for reuse in the disposal stage or that are less eco-toxic (Eder and Fresner, 1999).

Ultimately, all contributors to the environmental life cycle of the product should be aware of and ensure minimal environmental impact of any manufacturing process by following a Design for the environment (DfE) principle (Ayres and Ayres, 1996). DfE means products should be safe for their intended uses, reusable and/or recyclable, disposed of in a sound and responsible manner, consumption of energy and materials should be optimised, and all applicable legal requirements should be met or exceeded (Barnes, 1998). The Responsible Care Programme, is another approach, first introduced in Canada in 1984 by the Canadian Chemical Producers Association. This programme commits chemical companies to improved safety, health and environmental performance, and recognises and responds to public concern about chemicals and chemical operations (DANCED, 1998). The South African counterpart was launched in 1994 by the Chemical and Allied Industries Association (CAIA) (DANCED, 1998).

2.4.1.4 Process Changes

Process changes may include redesigning production lines or equipment to operate more efficiently, or it may require capital investments to purchase newer or better technologies. Outdated equipment and poor maintenance leads to increased resource consumption and generation of undesired waste (DANCED, 2000). Although the initial financial outlay of purchasing newer equipment / technology may be high, the pay-back period may be short due to other associated financial benefits. Process change may affect equipment, piping, layout, and operating conditions, and is specifically aimed at reducing the cost of waste and disposal. A process change may mean replacing a chemical cleaning tank with a mechanical cleaning agent.

2.4.2 Recycle or Reuse

Waste recycling or reuse is not a preventative technique, but where generation cannot be avoided, best use of the waste should be made. Recycling means re-introducing waste materials and emissions into the same process, with or without prior treatment (Wang and Smith, 1993). Reuse means using the waste in another process on-site or off-site. Reusing or recycling of waste within a particular company or between companies in close proximity can be beneficial in reducing raw material inputs and disposal costs. The Levi clothing company has taken a proactive approach to waste management by reclaiming used jeans. Where possible these are fixed or adjusted, and resold. Other manufacturers are reconditioning or rebuilding old equipment, rather than building new equipment from the beginning. Xerox, for example, has developed product return practices to recapture old copiers for reconditioning (IGC, 1999). The company has found that even recycling low-value items such as toner cartridges can be profitable (IGC, 1999).

2.4.3 Treatment, Incineration and Disposal

Waste may be treated through neutralisation, detoxification, thermal decomposition, or immobilisation to a less hazardous substance (Ministry of Economic Affairs, 1991), but treatment procedures and incineration are very costly. Landfilling is the cheapest waste handling option, but carries environmental costs affecting the quality of life and public health. Regardless of how well landfills are located, structured and managed they have the potential to release chemicals into surface and underground water and soil, and generate methane (CEEB, 2000).

2.4.4 A Waste Minimisation Procedure

Waste minimisation requires the systematic collection of information to identify opportunities for reducing or eliminating waste. The origin, quantity, and composition of waste, discharges and emissions must be determined, for without an analysis of the flow of materials the company has no indication of its environmental influence. **Figure 2.4** is a waste minimisation guideline which can be adapted depending on the company under investigation and project experiences.

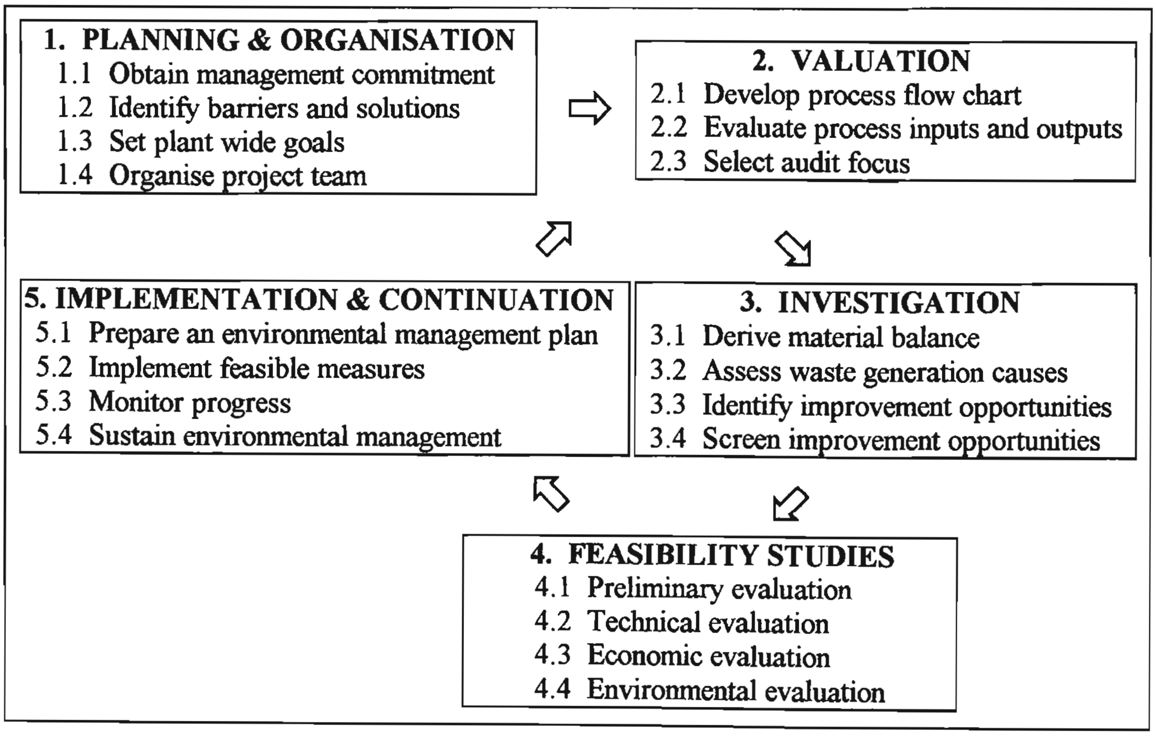

Figure 2.4: A Waste Minimisation Model (van Berkel, 1996).

Van Berkel uses a five-phase waste minimisation process. In the initial *Planning and Organisation Phase*, management commitment, and identification of realistic objectives and goals are necessary if the waste minimisation investigation is to be successful. In the *Valuation Phase* a better understanding of processes and practices is gained. Material balances play a pivotal role in the *Investigation Phase*. This phase either highlights areas that have potential for improvement; or alternatively identifies the lack of relevant data necessitating additional monitoring and reporting. Once potential waste minimisation opportunities have been identified in the *Investigation Phase*, the viability should be assessed in a *Feasibility Study*. Those aspects that prove feasible should be implemented. Of importance in his model is the continuous loop from *Valuation* to *Implementation and Continuation*. This means that on having identified and implemented waste minimisation opportunities in one aspect of a company, the potential for re-evaluation to identify further opportunities is ever present.

2.5 CASE STUDY INVESTIGATION

This dissertation is a component of a larger industrial symbiosis project involving two academic institutes. The Pollution Research Group in the Chemical Engineering Department at the University of Natal, Durban conducted the technical component. The technical aspect focused, in principal, on identifying waste minimisation opportunities in selected companies. The Chemical Engineering Department at the University of Cape Town (UCT), in conjunction with African Environmental Solutions and the Pollution Research Group, analysed industrial network systems, management culture, and restraints. As discussed in **Chapter 1**, a textile and a metal finishing company were used as case studies in this dissertation. The investigation at each company was divided into two sections:

- an illustration of the company's network and its potential to partake in a symbiotic network (information detailed in **Appendices**), and
- the waste minimisation investigation (which comprised the bulk of the study)

2.5.1 Company Network and Potential for Industrial Symbiosis

Working together with a master's student from UCT, Dick van Beers, the industrial network of each company was identified and mapped. Detailed questionnaires were used in the investigation (**Appendix A1**). A broad knowledge of how each company belonged in an overall network structure was established, i.e. how the company was positioned with its suppliers and buyers. The relationship intensities were further analysed by van Beers to determine whether these could be strengthened to benefit both parties, in a symbiotic manner. That particular investigation fell outside the parameters of this dissertation, but a simple networking layout was illustrated to convey ideas that were addressed.

The potential for the company, under review, to develop and strengthen its relationships with its suppliers and buyers lies within the company's ability to undergo change. Four to six individuals from each company were interviewed, from different levels within the organisational hierarchy, ranging from management to shop floor workmen. Detailed questionnaires were used in the investigation of the company's potential to partake in a symbiotic network **(Appendix A2)**. Together with a member from African Environmental Solutions, Ed Kniel, and a project manager from UCT, Bas Kothuis, the values, intent and capacity of each company were subjectively rated. Aspects such as company profile, internal and external company communication, current capacity and finance availability, obstacles and conditions for the implementation of industrial symbiosis and available technological support were addressed. An analysis of the company's network structure and its ability to participate in a symbiotic network also required an appreciation of individual firm performance.

2.5.2 Waste Minimisation Investigation

The first challenge in the waste minimisation investigation was to identify a textile and metal finishing company that would be interested in participating in the study. One company from each of the sectors was needed. The company should be willing to take a proactive approach to reduce its waste and be prepared to share confidential information. The four phase method used for the waste minimisation study **(Figure 2.5)** was based on the Waste Minimisation Model, but adapted for each case study **(Figure 2.4)**.

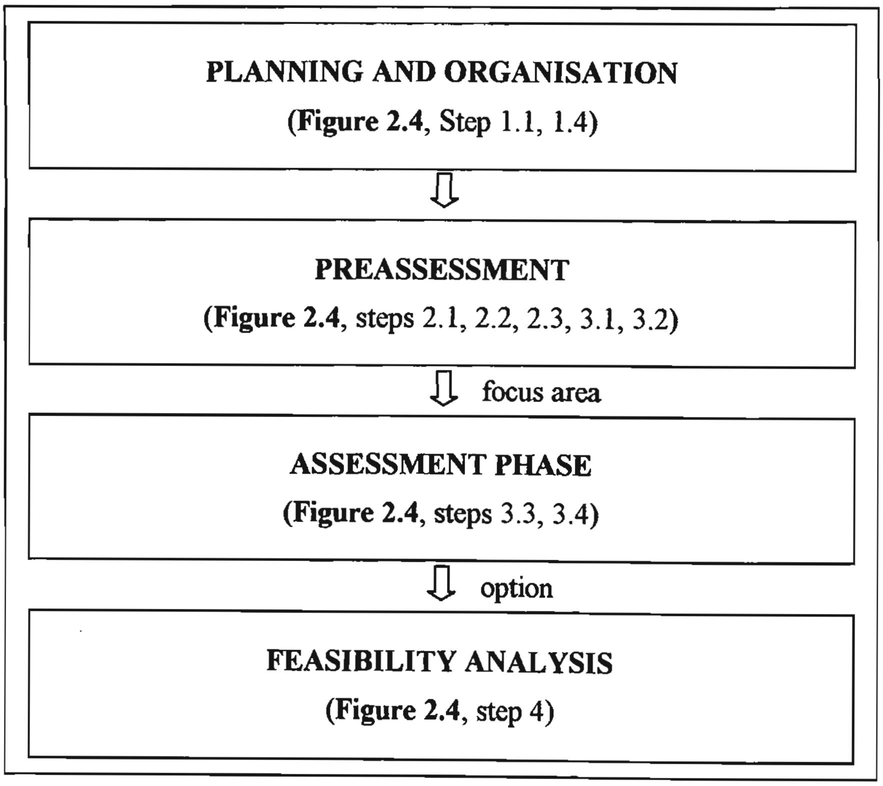

Figure 2.5: Waste minimisation procedure adopted for the case studies.

In the *Planning* and *Organisational Phase*, the project objectives were reviewed. Senior management commitment was obtained to provide the necessary driver for the investigation. A project team was established comprising key people identified by the company and lead by the researcher. The team included process managers and operators that would understand the process, could identify aspects that require focus and that would have the technical expertise needed to make the project a success. Company specific information was treated in a confidential manner, and confidentiality agreements were signed. The *Preassessment Phase* involved data collection, assessing current practices at the company and characterising sources of waste using mass balance analyses of material streams. Certain target processes were identified based on the hazardous nature of the waste, the value of the waste, or the large volume of water consumed. The *Assessment Phase* lead to a more detailed investigation of the target area. Waste minimisation opportunities were identified and, where necessary, analytical measurements were conducted. A concluding *Feasibility Analysis* determined whether the recommended change was technically, financially and environmentally viable. Those options that proved feasible could then be implemented by the company. Detail and focus was company dependent and varied according to time spent at the company, company involvement, environmental issues, size and complexity of company operations and the company's preference for focus areas.

CHAPTER 3

CASE STUDY 1: A COTTON MILL

The first step to making savings is to understand and review water and chemical use throughout the site, so that opportunities for waste minimisation can be identified

S. Muirhead (1997)

The aim of this chapter is to demonstrate that the potential for waste minimisation exists at Company A and that such an investigation can assist enhance operational performance, reduce environmental impacts and benefit the company economically.

Company A began its local operations in 1941. Primarily manufacturing cotton textiles, the company targets the local market, but is part of a larger international organisation. Raw cotton is converted via a number of small batch processes into bandages, surgical dressings, sanitary towels, woundcare and plaster-of-paris products. Rayon and external sources of spun cotton are used in some of the processes depending on production demand and availability. Approximately 1 500 people are employed on site. Less than 300 people are involved in textile manufacturing, thus the textile section can be considered as a medium sized enterprise.

An overview of the company's industrial network and its potential to participate within an industrial symbiotic network was obtained using the questionnaires in **Appendix A1** and **A2**. Results and data associated to these networking analyses are appended (**Appendix B1** and **Appendix B2**). This chapter focuses on potential waste minimisation opportunities in the textile manufacturing section, based on the strategy given in Chapter 2 (**Figure 2.5**).

The planning and organisational phase of the study was initiated with management commitment and the identification of a nine-membered waste minimisation team (**Appendix B3**). The team were to assist Company A in working towards obtaining ISO 14001 accreditation. The preassessment phase examined material flows and identified focus areas for waste minimisation. The assessment and feasibility phase identified waste minimisation options and associated environmental and financial benefits.

3.1 PREASSESSMENT

The objective of the preassessment phase was to gain an understanding of the processes and practices in the textile section, identify waste sources and derive mass balance equations. Dry operations included cotton opening and blending, yarn spinning, and weaving. Wet processes included sizing, scouring, bleaching, and dyeing (**Table 3.1**). Detailed process flows are appended (**Appendix B3**).

Table 3.1: Typical processes in the cotton textile section.

Raw Material In	Process	Product Out	Waste Out
cotton bales	OPENING, CLEANING & BLENDING ↓	fibre	fly, sweepings, fibre laps
		sanitary towels	← (laps)
fibre	SPINNING ↓	yarn	yarn
yarn, water starch (CMC)	PREPARATION ↓	yarn & beams	yarn effluent
yarn	WEAVING ↓	greige cloth	yarn, cloth
greige cloth, water hydrogen peroxide	BLEACHING ↓	white cloth	cloth effluent
white cloth, water direct & vat dyes chemicals	DYEING ↓	dyed cloth	cloth effluent
bleached/dyed cloth	FINISHING	woundcare plaster-of-paris surgical dressing other outlets	various

Prior to arriving at the factory, the raw cotton fibres are extracted from seed pods and compacted into bales. At the factory, fibres from various bales are blended together and cleaned to remove dirt and vegetable matter. Spinning is the mechanical process whereby fibres are passed through a number of thinning out processes and transformed into yarn. Fibres are separated and aligned in a thin web, which is condensed and rolled diagonally to form a continuous, untwisted sliver, a process known as carding. A stretching or drawing process then causes polymer chains in the stretched fibre to straighten along the fibre axis and develop intermolecular attractions (Ingamells, 1993). A final twist may be introduced to strengthen the yarn.

During yarn preparation, yarn is wound onto small volume packages known as a cone, cheese or pirn, or larger beams. Warp threads (on beams) and weft threads (on pirns) are woven together on shuttle or air jet looms to form cloth. Warp threads move as a web through the machine as the weft threads are fed in and out of the web. Before weaving, warp threads are sized, generally with the starch or carboxymethylcellulose (CMC), to strengthen the thread which undergoes mechanical stress during weaving. Woven cloth is known as loom state or greige cloth.

Prior to bleaching or dyeing, the size, the outer waxy cuticle of the fibre, and any remaining natural impurities which may hinder dye absorption must be scoured from the cloth. A process of prolonged boiling in an alkaline solution is used, in closed vessels known as kiers or continuous reaction vessels. Scouring effluent is characterised by high chemical oxygen demand (COD) and pH values, and a strong yellow-brown colour.

Certain cloths are bleached using oxidising or reducing agents to whiten the fabric and to remove impurities such as vegetable matter. Thereafter, cloth may be dyed through a batchwise process using direct dyes, applied in a boiling dyebath with an electrolyte, or vat dyes, applied using oxidation-reduction reactions. Water-soluble direct dye molecules are large and display a significant attraction to the fibre, whereas with vat dyes, water-insoluble coloured molecules are mechanically trapped inside the fibre (Ingamells, 1993). It is good practice to allow the fabric to soak in the bath with all the ingredients except the dye, known as wetting out. This ensures an even distribution of dyebath auxiliaries in the fibre mass. Jig dyeing using half tanks is the major means of cloth bleaching and dyeing at Company A. The jig machine bleaches/dyes fabric in open width. A batch of fabric is continuously rolled backwards and forwards from one roller to another through the liquor. Finished cloth is then transferred to other sections for further processing depending on the required end-product (**Appendix B3**).

Having gained a basic understanding of the processes and following data collection, detailed mass balance investigations were conducted on cotton and water flows (**Appendix B4**). No detailed mass balancing was carried out for chemical usage at this investigation because by minimising cotton and water flows, chemical usage would also reduce.

The mass balance exercise indicated shortcomings in the available data. Particularly for the water balances, further investigations must be conducted by the company to establish the cause of the unaccounted loss. Such unaccounted losses relate to a lack of adequate data collection of all relevant parameters and inefficient control, possibly loss of water through means that have not been identified and thus possible financial losses that could be mitigated with stricter control. In spite of the shortcomings, the weaving and bleach house were identified as potential waste minimisation areas. As the cloth is processed so the costs increase at each stage and thus cloth wasted in these two departments had a higher added value than that from earlier processes. For example, the price / kg material wasted in the opening department had a maximum cost of about R9 / kg, whereas in the weaving or bleach house department wasted material amount to about R30 / kg.

The majority of the cotton waste was generated in the spinning, weaving and sizing processes. In the spinning processes, much of the waste was attributed to the quality of fibre received from suppliers, and climatic conditions, such as humidity, which affects cotton strength and durability (Spinning manager, *pers. comm.*, 1998). A large volume of opening and spinning waste was usable and re-worked in the sanpro (sanitary production) department. Although sizing and weaving waste were combined into one category **(Appendix B4)** the majority of cotton waste (by mass) was generated in weaving. In the weaving department, machine stops have the potential to cause cloth faults which would result in lower production and the waste of high value fabric. Aspects such as machine and worker performances were investigated.

Water inputs and outputs were tabulated, based on records collected from the company **(Appendix B4)**. Water was used for the process baths, but the majority of the use was in the rinse tanks in the bleach house. The average water intake of textile companies in South Africa has been calculated at 159 kL / t fabric (Gilfillan, 1997). Wastewater produced on-site was generated in the bleach and dyeing sections, from spillage during sizing, boiler blowdown, hot water (condensate) storage tank overflow, and sewage. The bleach house was selected due to its demand on water and the nature and volume of effluent produced. Water saving opportunities were investigated.

3.2 ASSESSMENT PHASE - IN THE WEAVING DEPARTMENT

The objective of the assessment phase was to further investigate focus areas identified during the preassessment phase. At the time of the investigation, the weaving department comprised 25 Ambassador shuttle looms, 105 Investa air jet looms and 2 training looms. The older shuttle looms were located in what was named the Parlour shed and the air jet looms in the Investa shed. Daily data were accumulated for four weeks in the month of May 1998. Causes of waste generation were assessed, laboratory analyses of reject cloth, frequency and duration of machine stops, shift and team performance or cloth types were recorded and analysed. Where possible, potential waste minimisation options were identified.

3.2.1 Reject Cloth – Laboratory Investigation

Results obtained from the laboratory's investigations of reject cloth were analysed to determine whether a specific cause of reject cloth was dominant (**Appendix B5**). Some causes were noted more frequently than others, but no single cause was so frequent that further investigations would be validated in terms of significant waste minimisation. Many of the faults could be mitigated through better housekeeping, machinery maintenance and training, without necessarily capital expenditure. For example, ensuring more continuous machine runs could reduce faults associated with the start-up of a process run. At the time of the investigation, the looms could only carry two pirns with the threads tied together manually; as one pirn emptied, weaving continued with the second pirn thread. The machine capacity and structure limited the pirn size and thus the amount of thread and often the connecting thread was not easily accessible. In conclusion, process runs could be extended by adjusting the machine to accommodate larger pirns, increasing the amount of weft wound on the pirn, ensuring proper pirn winding in the preparation stage, and more regular replacement of empty pirns.

3.2.2 Identifying the Causes of Machine Stops

In the Investa shed (105 looms), loom stops were recorded by a computerised system (**Appendix B5**). The system logged the reason for the stop and the machine downtime, i.e. the time it took staff to rectify the problem. Averages of these two aspects were calculated for each logged cause per shift for the month and standard deviations were measured. The purpose of this investigation was to identify problematic and common causes for machine stops because every stop has the potential to cause a cloth fault. By analysing the number of machine stops relative to downtime it could also be determined which stops took a longer time to rectify, which related to lower production.

The graphical results of the most frequent reasons for machine stops with associated longest downtimes as depicted in **Appendix B5** were due to reasons logged as W (warp), F (weft fill) and S (stop). Warp stops were responsible for an average of 628 ± 92 machine stops per shift and an average downtime of 5.7 % ± 2.3. These three primary reasons for machine downtime should be further analysed by the company as an accumulated downtime of about 12 % relates to lost production. This was not analysed in this investigation as the overall potential for waste minimisation was limited. For certain aspects, large standard deviations were noticed. This was attributed to the fact that specific shifts may have had a major problem for one aspect which may not have recurred in other shifts.

In terms of the number of machine stops related to machine downtime, no evident correlation was noted. This could mean that different stop reasons took longer to rectify than others or that downtime frequency was dependent on worker efficiencies. Areas that drew attention because machine downtime was evidently long relative to the number of machine stops included S (stop), NB (no beam) and CR (cloth rollers). Due to a limited understanding of these various machine stops this avenue was not further analysed in this investigation, but the useful aspects depicted could be used by the company to reduce machine downtimes.

3.2.3 Actual Performance Based on Shifts

A further investigation was to determine whether specific shifts had lower performances. During the week, there were two 6 h shifts, a morning (06:00 to 12:00) and afternoon shift (12:00 to 18:00), and one 12 h evening shift (18:00 to 06:00); on Saturdays there was one 12 h shift (06:00 to 18:00) i.e. a total of 128 individual shifts per month. Shift performance was compared based on average machine performance (production time / maximum possible time) in the Investa and Parlour sheds (**Figure 3.1**). A target performance of 82 % was set and used by the company.

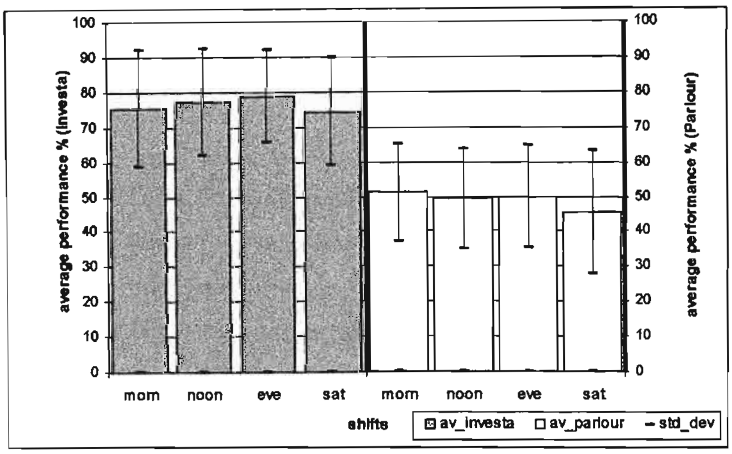

Figure 3.1: Average shift performance based on production time for May 1998 (n=64 shifts).

When considering standard deviations there was no significant variation between shifts, because on certain days machine performance was above optimal and on others far below. However, on comparing averages, Saturday shifts had the lowest performances in both sheds. This was attributed to a high absentee on the week-end and possible fatigue affecting quality and efficiency. Motivational training and drivers could be introduced to improve week-end performance.

Overall performance in the Parlour shed was significantly lower than in the Investa. This was unfavourable as some of the expensive cloth, for example, Quality N°. 1769, could only be woven using dedicated looms in the Parlour shed. The shuttle looms in the Parlour shed were relatively old, and a costly improvement would involve purchasing newer equipment. Alternatively, the looms may be reworked into rapier looms, which operate in a similar but more efficient manner. No alterations were to be undertaken as continuation of the weaving process was under review and the company was investigating the possible import of finished cloth.

3.2.4 Machine Stops and Downtime Comparisons Based on Shifts

The next assumption was that a particular shift influenced performance, in terms of number of machine stops and associated downtime. On average, the number of machine stops were less on the double shifts (evenings and Saturdays) when compared to the single shifts (mornings and afternoons) (**Table 3.2**). The average downtime for the various shifts were similar, with the highest downtime evident in the morning and Saturday shifts (1.4 % ± 0.6 and 1.6 % ± 0.3 respectively) possibly due to maintenance which takes place during the morning shift and a reduced work force on Saturdays.

Table 3.2: Average machine stops and downtime for the Investa shed in May 1998.

Shift	Av. stops / shift	Av. stops / 6 h	Std dev. 6 h (σ)	Av. downtime 6 h (%)	Std dev. 6 h (σ)
Morning	86	**86**	14	**1.4**	0.6
Afternoon	85	**85**	12	**1.3**	0.5
Evening	161	**80**	20	**1.3**	0.6
Saturday	151	**77**	9	**1.6**	0.3

3.2.5 Actual Performance Based on Teams

It was then established that the four shifts were operated by three teams working on a rotational basis over a three week period (**Table 3.3**). It was thus postulated that a particular team might influence performance as opposed to a specific shift. Team performances were compared.

Table 3.3: Team organisation into shifts.

Week no.	Morning	Afternoon	Evening	Saturday
1	A	B	C	A
2	B	C	A	B
3	C	A	B	C
4	A	B	C	A

All teams performed below the company's 82 % target, with the Parlour shed having the lower performance (**Figure 3.2**). Morning performances in the Investa shed were similar regardless of the team (Teams A: 74.9 % ± 16, B: 75.6 % ± 19, C: 75.5 % ± 15), possibly due to operational consequences being the same, i.e. management supervision and machine maintenance.

On average, Team B (77.8 % ± 14) performed the best in the Investa shed, Team A (76.6 % ± 16) and Team C (75.2 % ± 15) having the lower performances. In the Parlour shed, Team A performed the best on average (51.6 % ± 16) due to good average morning and afternoon shifts with Team B (47.7 % ± 16) and C (47.8 % ± 14) having similar but lower performances.

Team B had a consistent performance throughout, with the morning shifts in both sheds having the lowest performances (75.6 % ± 19 in the Investa and ± 45.6 % ± 17 in the Parlour). Morning shifts should be supervised by management until performance is improved. Teams A and C had low Saturday shift performances. Management supervision during Saturday shifts may encourage performance improvements. Drivers may also be necessary to boost better performance, for example, a *Team of the Month* award.

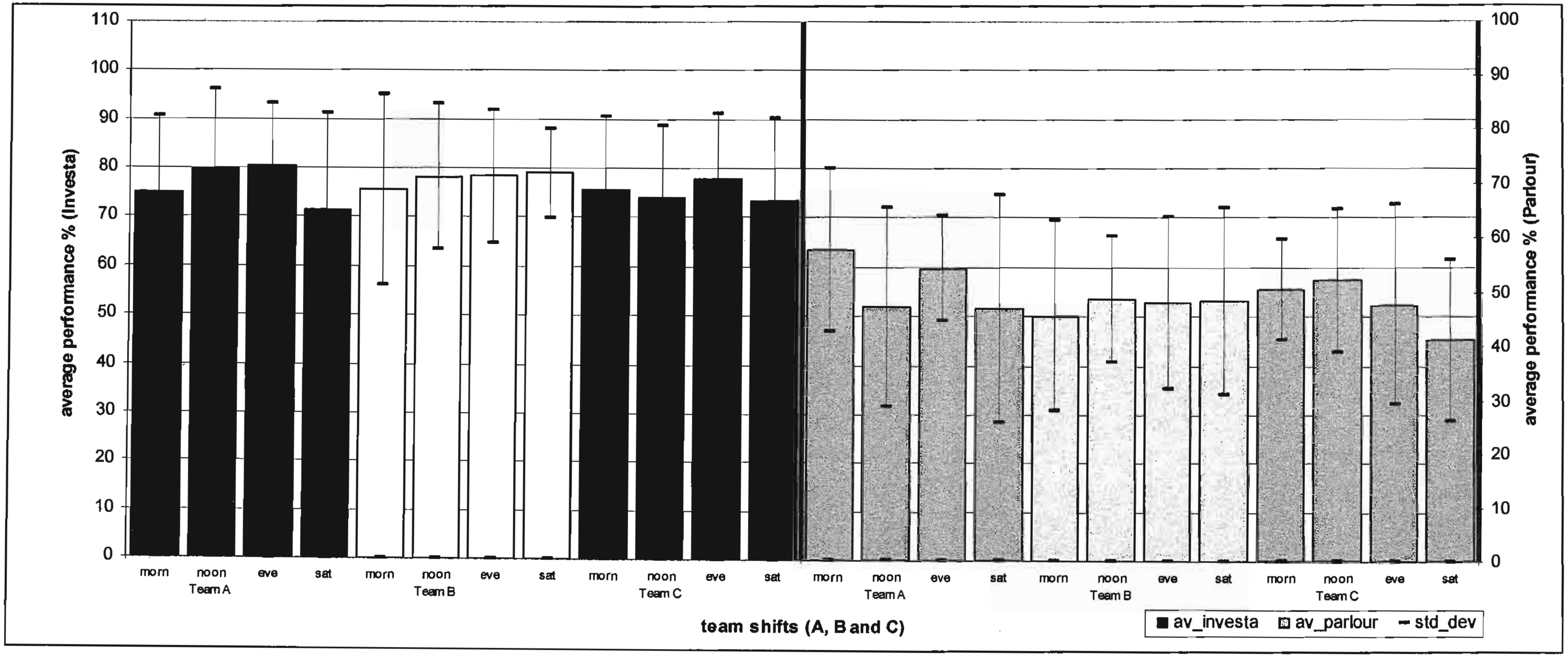

Figure 3.2: Comparison of shift performance based on teams A, B and C (n=64 shifts).

3.2.6 Machine Stops and Downtime Comparisons Based on Teams

Further data analyses were undertaken to determine whether a particular team had a significant influence on the number of machine stops and downtime. Using the logged computer data, the average number of stops and machine downtime in the Investa shed were compared between teams (**Table 3.4** and **3.5**). Due to the nature of the data only one or two Saturday shifts were available for analysis, thus standard deviations were either high or zero.

The number of machine stops were lower for the double shifts for all teams, but no significant differences were noted in the machine downtimes, which were on average 1.5 % per shift. Saturday shifts had the longest downtime for all the teams.

Table 3.4: Team comparisons based on machine stops.

Team	Morning		Noon		Evening			Saturday		
	6 h Average	σ (6 h)	6 h Average	σ (6 h)	12 h Average	6 h Average	σ (6 h)	12 h Average	6 h Average	σ (6 h)
A	84.0	10.0	83.9	8.8	149.2	74.6	26.3	156.7	78.3	0.0
B	89.7	17.7	82.4	17.3	169.7	84.8	15.8	148.9	74.4	0.0
C	83.0	14.1	89.1	10.8	162.5	81.3	17.7	148.5	74.3	27.6

Table 3.5: Team comparisons based on downtime.

Team	Morning		Noon		Evening		Saturday	
	6 h Average	σ (6 h)	6 h Average	σ (6 h)	12 h Average	σ (12 h)	12 h Average	σ (12 h)
A	1.3	0.5	1.2	0.5	1.3	0.8	1.4	0.0
B	1.4	0.5	1.4	0.7	1.2	0.2	1.6	0.0
C	1.5	0.7	1.3	0.3	1.3	0.7	1.7	1.0

The low machine performance in the morning shifts for Team B (**Section 3.2.5**) was influenced by the high number of stops (89.7 ± 17.7) (**Table 3.4**), and the low machine performances in the Saturday shifts for Teams A and C (**Section 3.2.5**) were influenced by the machine downtime, 1.4 % and 1.7 % respectively (**Table 3.5**). These aspects require management supervision to improve production.

3.2.7 Actual Machine Performance Based on the Type of Cloth

Following the data interpretation related to employee influence on production, the type of cloth construction was next investigated. It was postulated that the type of cloth being woven influenced loom performance and so performances specific to each cloth construction were compared (**Figure 3.3** and **3.4**). Within each cloth construction the order of the data follows a morning, noon, evening and Saturday shift, and the number of machines operated per cloth construction was indicated in the top row. As before, large standard deviation were evident.

No specific cloth construction was manufactured with an apparently highly or lower performance. Apart from cloths 229 122, 339 122, EMN 788 and ETS 56, all the other cloths fell below the 82 % production target. Cloths 471 6-less, elastoform 100 and XXX crepe 50 had the lowest performance. On average the evening shifts had the better performances for the majority of the cloths. Again the performances in the Parlour shed were consistently lower and again it should be stressed that higher valued cloths, such as 1769, should be preferentially woven on a newer or refurbished loom to prevent expensive wastage.

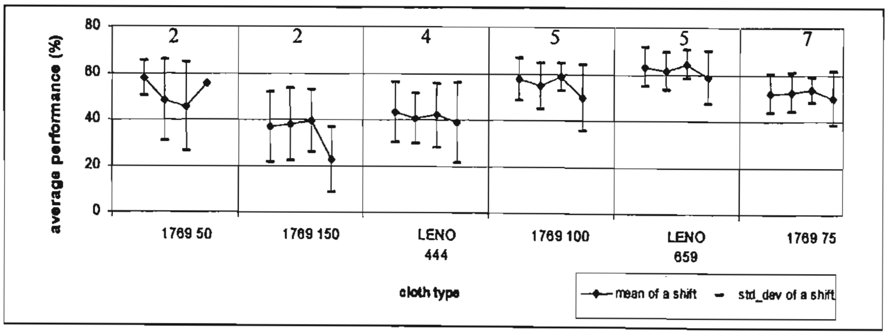

Figure 3.3: Comparison of machine performance in the Parlour shed.

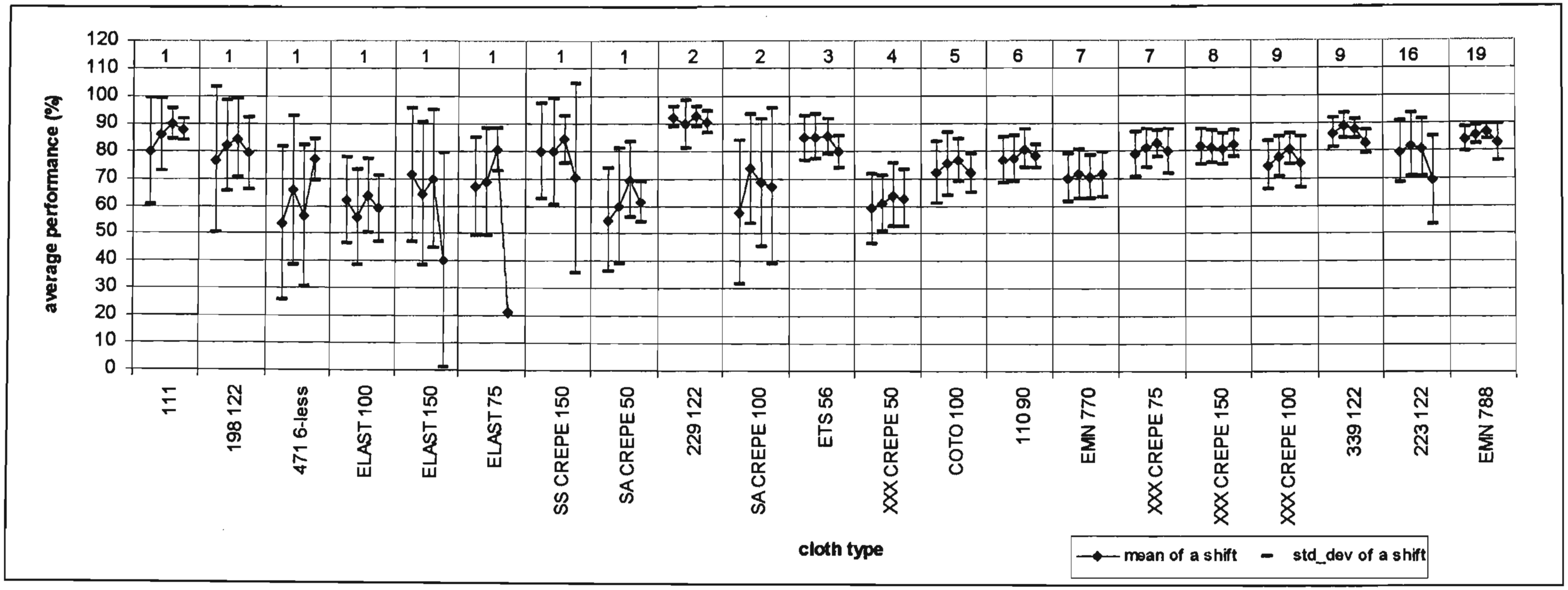

Figure 3.4: Comparison of machine performance of different cloth types in the Investa shed.

3.3 ASSESSMENT PHASE - IN THE BLEACH HOUSE

Water savings were the primary focus for waste minimisation in the bleach house. No water meters had been installed in the bleach house. An immediate recommendation was for the company to install water meters for future monitoring and control of water use and discharge.

Many of the processes, particularly bleaching and dyeing were conducted in half jigs. Cloth was run backwards and forwards through the jig containing a solution of chemicals and water. Some jigs were used repeatedly for a number of processes by draining and refilling the jig with the appropriate solution; a time consuming and cost intensive batching process. Purchasing a continuous beam bleaching machine, may reduce water, chemical and energy consumption, wastewater, time and manual labour. However, possible cheaper imports of finished cloth remained an uncertainty and rendered this option unfeasible. An alternative water reduction method by reducing the number of rinse tanks was reviewed.

The investigation analysed a complete process run of a particular cloth, namely Cloth Quality 223. This bleached absorbent gauze was selected for the investigation because it represented approximately 20 % (by length) of the total production (on average about 20 out of 105 Investa looms manufactured this cloth). Results obtained were specific for this type of cloth weave, and the company must conduct further analyses on the other cloths manufactured based on the principles learnt in this investigation. The cloth followed a specified process flow as depicted in **Table 3.6**. Cloth and liquid samples were analytically examined, based on tests used by the company to comply with SABS regulations (**Appendix B6**).

Cloth samples were tested for fluorescence, acidity and alkalinity, absorbency, and foreign matter (trash) and ash content. These tests are normally only conducted on *finished* cloth thus deviations from specification were expected for all the unfinished cloth samples. Foreign matter and ash content tests were determining factors in accepting or rejecting final cloth quality. Foreign matter content indicated the amount of foreign solvents in the cloth from the processes and ash content determined the amount of incombustibles in the sample. Tests were also conducted on the liquid samples including chemical oxygen demand (COD), conductivity and pH. The COD was measured due to future effluent charges, pH was measured to determine the nature of the sample (alkaline/acidic) and conductivity was measured to determine the ionic concentration of the sample.

Table 3.6: The bleaching process sequence of Cloth 223 and the liquid and cloth samples that were taken for analysis.

Input	Process	Sampled liquid	Sampled cloth
cloth water	batch	✓	
water	rinse 1	✓	✓
water	rinse 2	✓	✓
chemicals	bleach 1	✓	✓
water	bleach 2	✓	
	bleach 3	✓	
	bleach 4	✓	✓
water	hot rinse 1 (80 °C)	✓	
	double tank		
water	hot rinse 2	✓	✓
water acetic acid	cold rinse 1	✓	✓
cloth water	cold rinse 2	✓	✓

3.3.1 Cloth Samples

All cloth samples (**Table 3.6**) met the fluorescence specifications indicating an absence of any optical brightners on the cloth. All cloth samples, bar the last bleaching tank and subsequent rinses failed the absorbency test, which was to be expected from the greige cloth. All the samples were within the pH specification, with the exception of the sample from the first bleach tank, Bleach 1, which was marginally in the alkaline range due to the alkaline nature of the bath solution. All the results from the foreign matter analyses, with the exception of Rinse 1, had an average value that fell within the specification of less than 1 % (**Figure 3.5**). No significant difference was evident between any of the samples. Results from the batched cloth were excluded as the foreign matter in these samples of untreated cloth, directly from weaving, were expectantly high (6.1 % ± 1.2).

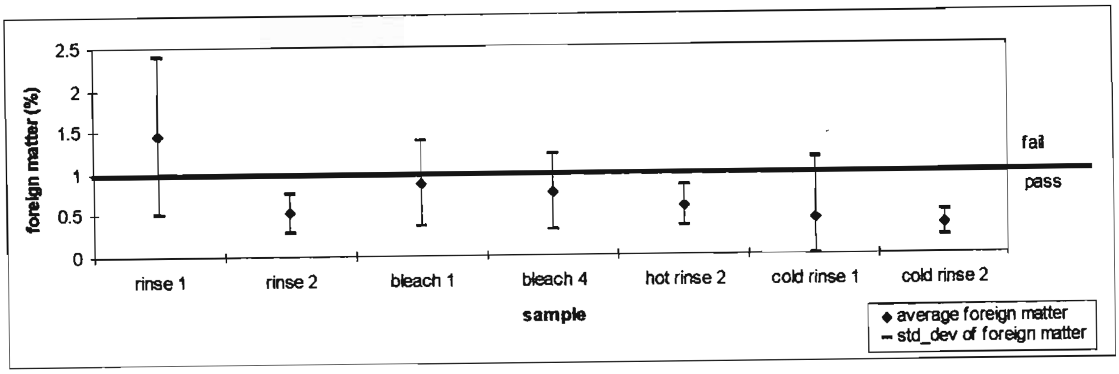

Figure 3.5: Foreign matter of Cloth 223 throughout its processing (n=3 samples).

The average ash content for each of the samples fell within the specification of less than 0.5 % (**Figure 3.6**). Only Bleach 1 varied significantly compared to the others. This was expected as bleaching chemicals were added to this tank and would thus have comparatively different values to the other tanks. Results from the batched cloth were excluded from the graph (1.04 % ± 0.20).

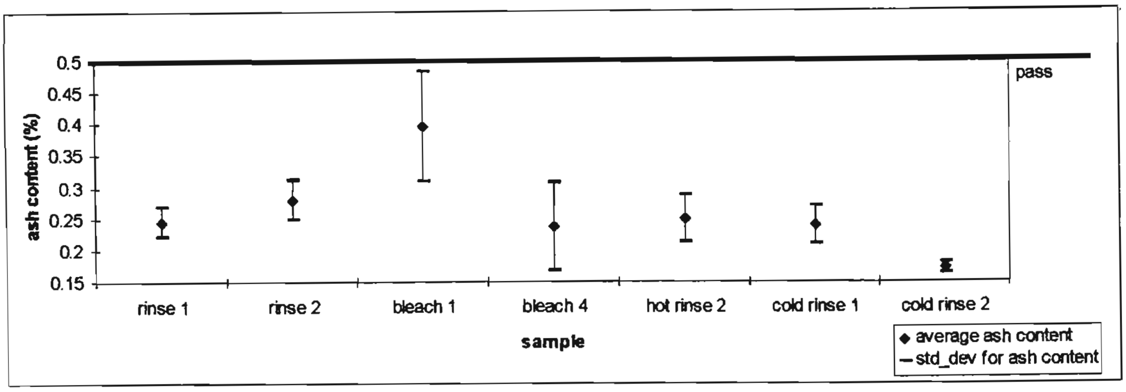

Figure 3.6: Ash content of Cloth 223 throughout its processing (n=3 samples).

3.3.2 Liquid Samples

Three to four liquid samples were taken throughout the run, where S (start) was a sample taken at the early stages of a process, M (middle) during the run and E (end) a final sample at the end. Apart from the bleach samples, all the other samples showed significant COD differences between the start and end of a run (**Figure 3.7**). As cloth was carried through the tank, the water was influenced by added chemicals and cloth components dissolving into solution affecting the COD values. For example, most of the samples had a COD value that increased between the start and middle of the process run. Liquid samples before the bleach tanks had relatively lower COD values than those from the bleach tank, and after the bleach tanks the COD values were again substantially reduced. These values were attributed to the addition of bleaching chemicals such as hydrogen peroxide.

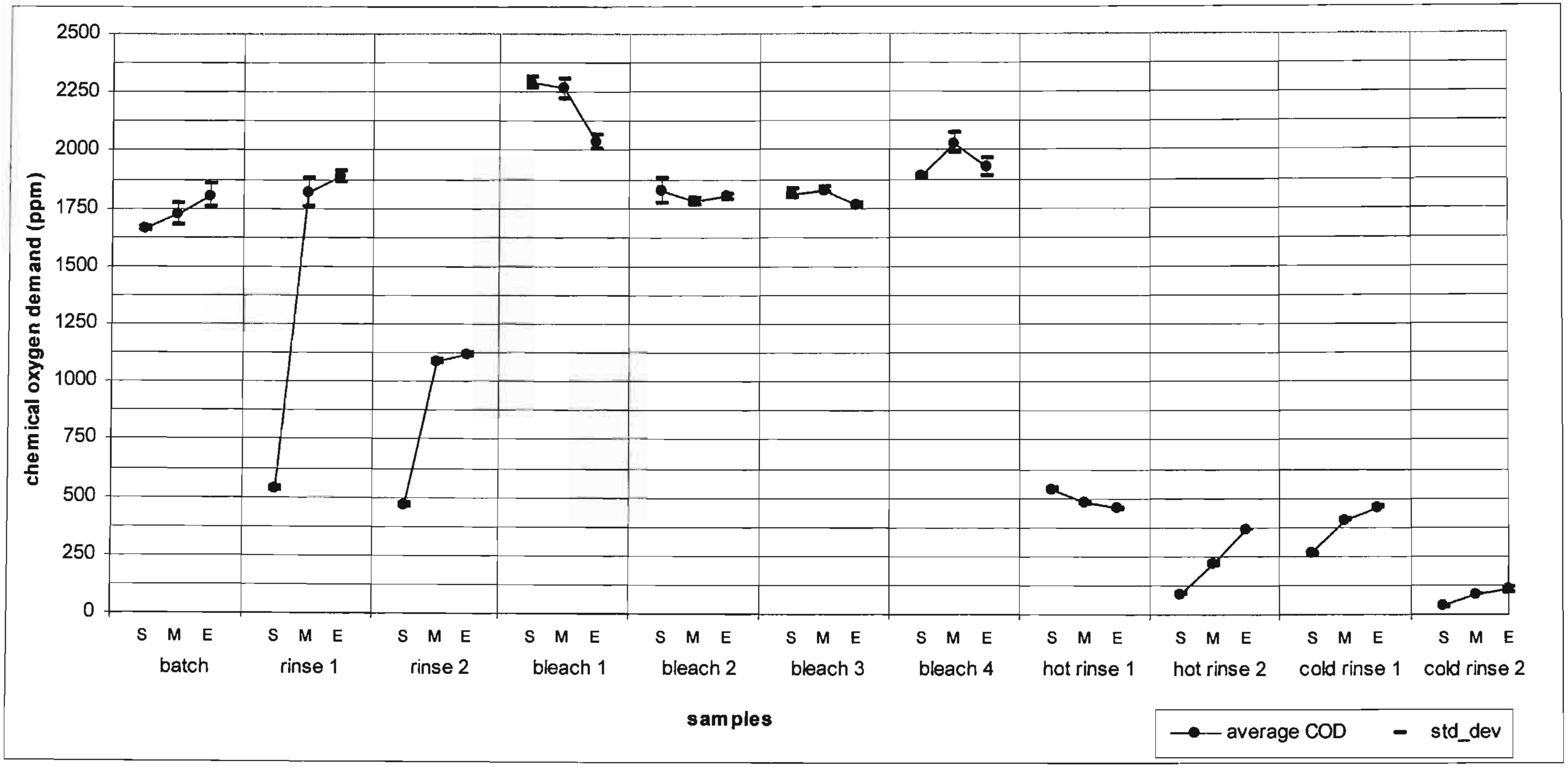

Figure 3.7: COD measurements of various tanks during the bleaching process, where S=start of process, M=middle of process, E= end of process (n=3 samples).

The conductivity results (**Figure 3.8**) followed a similar pattern to that of the COD values (**Figure 3.7**). The conductivity between the start and end of the run varied significantly for most tanks, particularly Rinse 1 and Bleach 1. For Rinse 1, the greige cloth, a batch of six different sources of cloth, carried foreign matter which dissolved in the solution causing an increase in conductivity with time. The inverse trend was evident for Bleach 1 where the initial conductivity was high as chemicals had been added to the tank, and with time the conductivity decreased as chemicals were neutralised, diluted or taken up by the cloth. Bleach samples 2, 3 and 4 remained consistent as there were no external influences to affect the results. The bleach samples had the highest overall conductivity as those tanks had the highest chemical dosing. Conductivity dropped off to a much lower value after the bleaching, since the hot rinse tank consisted solely of water. No significant conductivity variation was detected in Cold rinse 2 between the start and end of the process, meaning that removal of the tank would possibly have negligible or no effects.

The pH results were relatively neutral for samples from the Batch, Rinse 1 and Rinse 2 (**Figure 3.9**). The alkalinity detected in Bleach 1 onwards was due to the chemical addition and the lowered pH into the acidity range for the Cold rinse 1 was due to acetic acid addition. A decrease of only one pH unit was detected from Bleach 4 to Hot rinse 1. Hot rinse 1 and Hot rinse 2 both showed alkaline influences, carry over from the bleaching tanks. Even though the last liquid sample, Cold rinse 2, showed a pH of around 7, the cloth sample from this tank showed a delayed acidic influence from the previous tank solution.

3.3.3 Proposed Removal of Rinsing Processes

The cloth analyses fell within the acceptable SABS specifications for foreign matter and ash content, and there was no significant indication from the liquid analyses that all the rinses were necessary. It was thus deduced that some of the rinsing processes could be removed as a means of reducing water use and wastewater production. However, a trial run was to be conducted by the company to ensure that the cloth still complied with the specifications with the reduced rinses. The following suggestions were made: removal of one of the initial cold rinses before bleaching, removal of the two hot rinses after the bleaching and heating one of the final rinses (**Table 3.7**). A feasibility study was conducted.

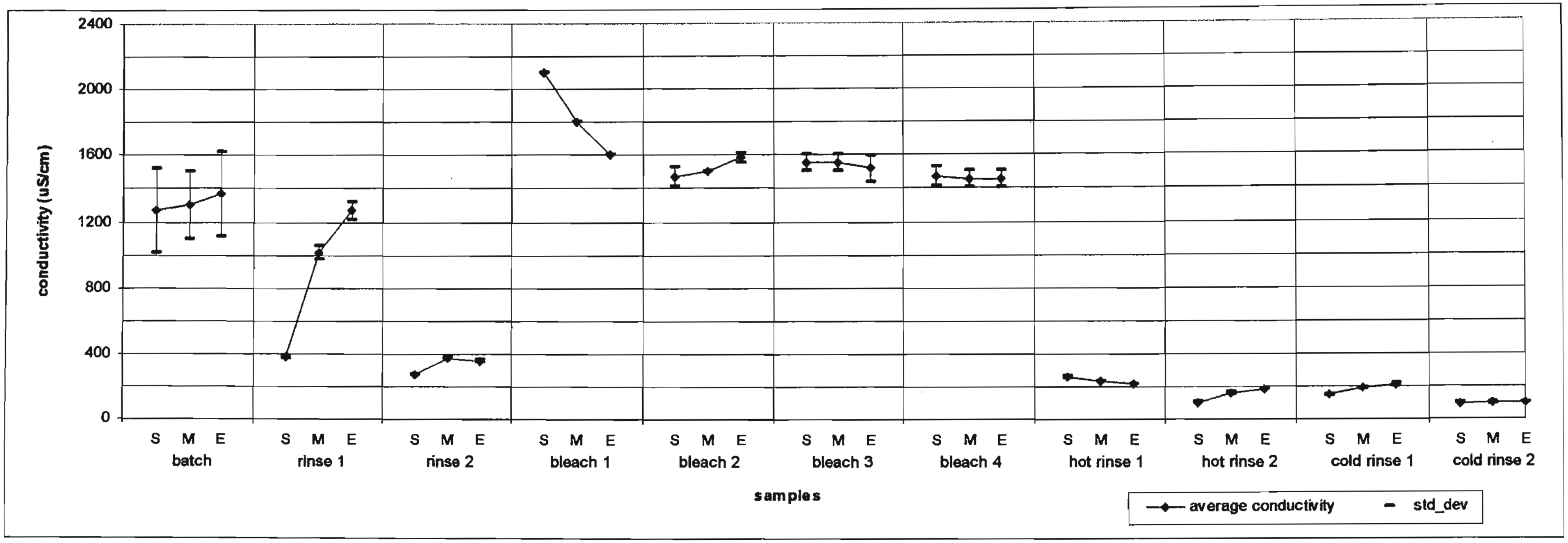

Figure 3.8: Conductivity measurements of various bleach house baths, where S=start of process, M=middle of process, E= end of process (n=3 samples).

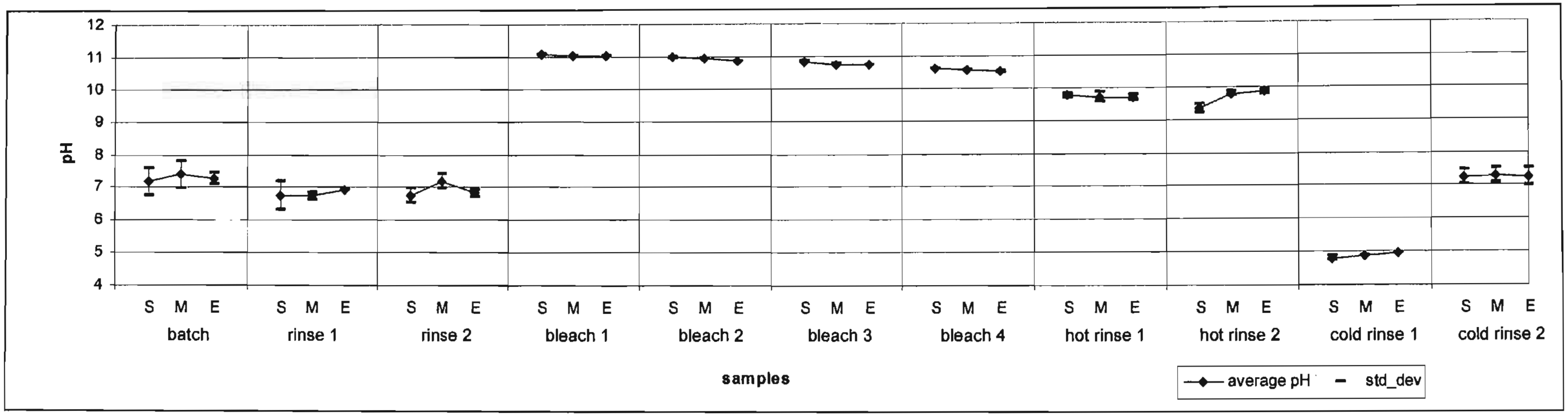

Figure 3.9: pH values of bath solutions from the bleach house, where S=start of process, M=middle of process, E= end of process (n=3 samples).

Table 3.7: Comparison between existing and proposed process with reduced rinse tanks.

Input	Process	Input	Process
cloth water	batch	cloth water	batch
water	rinse 1	water	rinse 1
water	rinse 2		
chemicals water	bleaching	chemicals water	bleaching
water	hot rinse 1		
	double tank		
water	hot rinse 2		
water acetic acid	cold rinse 1	water acetic acid	cold rinse
cloth water	cold rinse 2	cloth water	hot rinse

3.4 FEASIBILITY STUDY

A feasibility study was undertaken to determine potential savings (**Table 3.8**). Each half jig carried 1 200 L of water and cloth was run through a tank twice, thus 2 400 L per tank. At the time of the investigation, Company A paid R2.57 / kL for incoming water, R1.22 / kL for effluent, and R10.00 / kL to heat rinse water.

Table 3.8: Water costing comparing the current water usage and with fewer rinses (1997 prices).

Process	Volumes	Costs Incoming (R)	Effluent (R)	Total (R)
Normal rinses				
Before bleach	2 x rinses (2 x 2 400 L)	12.34	5.86	18.20
After bleach	4 x rinses (4 x 2 400 L)	24.67	11.71	36.38
	TOTAL			**54.58**
Reduced rinses				
Before bleach	1 x rinses (1 x 2 400 L)	6.17	2.93	9.10
After bleach	2 x rinses (2 x 2 400 L)	12.34	5.86	18.20
	TOTAL			**27.30**
	DIFFERENCE			**27.28**

A potential saving of R 27.28 per 1 200 m batch was calculated for the reduced rinses for each run of Cloth 223. The process run lasted about 6 h which equated to about one batch per shift. With the three shifts, two of 6 h and one of 12 h, about 4 batches could be processed per day. Based on the assumption of 4 batches per day, a total water cost saving of about R109.12 per day, or R24 006 per year (5 days, 4 weeks, 11 months) may be expected. Water consumption would be halved resulting in a potential savings of 2 100 L per tank per run, or 5.544 ML per annum (3 rinses, 4 batches). In addition, energy costs associated with the heating of the hot rinse water would result in savings of about R 24 / batch from the reduced rinse tanks.

Time was another potential saving. By removing 3 rinses, with each run for Cloth 223 taking approximately 30 min, about 1,5 h per shift or 1 320 h per annum would be saved increasing production time and thus product output. Associated to time savings were labour costs. Labour was estimated at R9.26 / batch.

Potential environmental benefits included reduced demand on natural resources, such as water and energy. Less effluent related to fewer chemicals needed at the effluent treatment works reducing potential impact of soil and water contamination. Less chemicals meant fewer vapours emitted to atmosphere reducing pollution and health impacts on the employees. During the investigation other issues were noted and should be raised as good house keeping practices. Additional process recommendations were presented.

minimisation opportunities in this investigation, the project team could conduct further initiatives in the future, possibly focusing on other areas of the company. This could then further develop into cleaner production initiatives in the future, but was not the immediate goal for this company.

3.7 CONCLUSION

Waste minimisation in this textile company was based on improving loom operations in the weaving department and reducing water use in the bleach house. In so doing, waste materials, demand on natural resources, water use and energy were reduced. Additionally, less effluent meant lower treatment costs and chemicals with financial benefits (**Table 3.9**). Clearly both economic and environmental savings can be experienced through waste minimisation which leads to better environmental perspectives for the company.

Table 3.9: Potential water savings (1997) from a reduction in rinse tanks.

Saving	Unit	Amount per annum
Economic	R	53 272
Water	L	5 544 000
Time	days	55

CHAPTER 4

CASE STUDY 2: A METAL BEARINGS MANUFACTURER

What you do not measure, you cannot manage

ENDS Report 279 (1998)

The aim of this chapter is to demonstrate that waste minimisation opportunities may be identified at Company B, which relate to better performance, reduced environmental impact and economic savings.

Company B manufactures automotive engine bearings, mainly for aftermarket use, and have been in operation since 1962. As part of a larger international group, the majority of the bearings are sold to sister companies and only a small proportion is sold to companies outside of the group. Company B is a captive-shop, applying finishing processes to bearing products, which they manufacture. Approximately 1 000 bearings are produced per month mainly through small batch processes. The factory manufactures aluminium-tin bearings and the nearby subsidiary manufactures copper-lead bearings. Company B operates an 8 h day shift (Monday to Friday) and a 10 h night shift (Monday to Thursday). About 330 people are employed of which 60 to 70 are managers. Company B can be considered as medium sized enterprise

Details associated with the company's industrial network and its potential to participate within an industrial symbiotic network are appended (**Appendix C1 and C2**). This chapter focuses on identifying potential waste minimisation opportunities on the plating line; investigating likely water savings through leak detection; trichloroethylene replacement in the degreasing unit; and reclamation of used oil and coolants through supplier-buyer symbiosis.

The planning and organisational phase of the investigation was initiated with management commitment. A project team was identified, comprising an engineering manager, a logistics manager and a general site manager. The team actively partook in the waste minimisation analysis and will continue with cleaner production and possible ISO 14000 accreditation in the future. The preassessment phase examined material flows and identified focus areas for waste minimisation. The assessment and feasibility phase identified waste minimisation opportunities and associated benefits.

4.1 PREASSESSMENT

The objective of the preassessment phase was to gain an understanding of the practices at Company B and identify potential waste minimisation focus areas. Company B manufactured lubricated friction bearings, including half-shell engine bearings, full round bushings, flange bearings, and round thrust washers for use in passenger cars, trucks and industrial applications. The production line of the bearings followed alloy melting, billet annealing, manufacturing (cutting and grooving), and treatment. Processes and equipment included an induction furnace, an automated lead-tin overlay plating plant, a deoxyflash unit, a degreasing unit and various metal machining units. Although a predominantly batch process, the production lines remains fairly constant with the only variations being alloy composition, bearing size and grooving detail. The bearing manufacturing and finishing processes were illustrated (**Figure 4.1**) and associated information detailed (**Appendix C3**). Mass balance investigations were conducted on metal flows (**Appendix C4**), but as of yet, no actual waste quantification is conducted at Company B. Estimated waste volumes are based on figures used by a plant in Scotland that uses the same specifications. The highest proportion of waste comes from the bimetal end scrap. This metal also carries with it a high loss value as it consists of two metal components and it is therefore difficult to reclaim both metals. The process is also far along the production line and has involved much labour costs and time. In order to validate actual waste amounts, a waste management system should be developed.

Sources of potential pollution from Company B were identified in a study conducted by Occutech in 1997. Air pollution: mainly trichloroethylene from the degreaser, but also solvents from the various processes and local exhaust ventilation which removes contaminants from the work area and releases them into the atmosphere. Land pollution: poor housekeeping in the waste skip area which stores domestic, timber and metal waste with potential for environmental contamination (e.g. soil). Water pollution: plant washings and spillages, oils and solvents from the machinery areas, and chemical waste from the automated plating unit, the deoxyflash unit, and the laboratory. Waste control measures include the drainage of coolant, oil and plant washings into an oil trap and sumps. Sediment is removed by a tanker from Oil Separation Services. Trichloroethylene is emptied into labelled drums and removed by Enfield Services for recycling. Liquid effluent containing chemicals from various processes is transported to the effluent treatment plant via drains or collected in drums.

To better assess potential focus areas a table was compiled together with the project team which identified the size, nature and cost associated to specific production areas (**Table 4.1**).

Table 4.1: Potential focus areas for waste reduction.

Waste stream	Size	Hazardous nature	Costs	Potential
Foundry	-	-	-	No
Strip line	+	+	+	Yes
Press shop	-	-	+	No
Plating	++	++	++	Yes
Deoxyflash	+	++	+++	Yes
Bearing machining	++	+	+++	Yes

- small + medium ++ large +++ very large

In the foundry, the only waste was scrap metal, labour costs were small and the product was relatively low cost. In the strip line department, hazardous components included trichloroethylene and labour costs were medium. The press shop was small, scrap metal was the major waste component, with medium labour and production costs. The plating shop had a hazardous liquid waste stream. Incorrect plating would result in the bearing being wasted if it could not be reworked and chemicals involved made this a cost intensive process. The automated process was not labour intensive. The deoxyflash unit, though fairly small to medium in size, also required chemical input, and was manually operated. Labour costs were significant and the product carried a high loss value due to the number of processing operations already complete. Bearing machining was cost intensive in terms of machinery and labour required. Oils and coolants were consumed.

The strip line, plating, deoxyflash and bearing machining processes were identified as the priority potential improvement areas. All the processes produced metal waste but the wet processes, plating and deoxyflash, also produced harmful wastewaters. Future plans to automate the deoxyflash process meant that improvement options would become redundant in this area, therefore the automated plating line was the preferred focus area. Since there was minimal manual involvement, another element of betterment had to be identified. Cushnie, 1994, claimed that the most obvious source of pollution in a metal finishing shop is the drag-out of various processing tanks into subsequent rinses. Reducing drag-out not only reduces the volume of pollutants reaching the wastewater stream but also reduces the amount of chemical loss. Drag-out reduction through increased drip times was investigated.

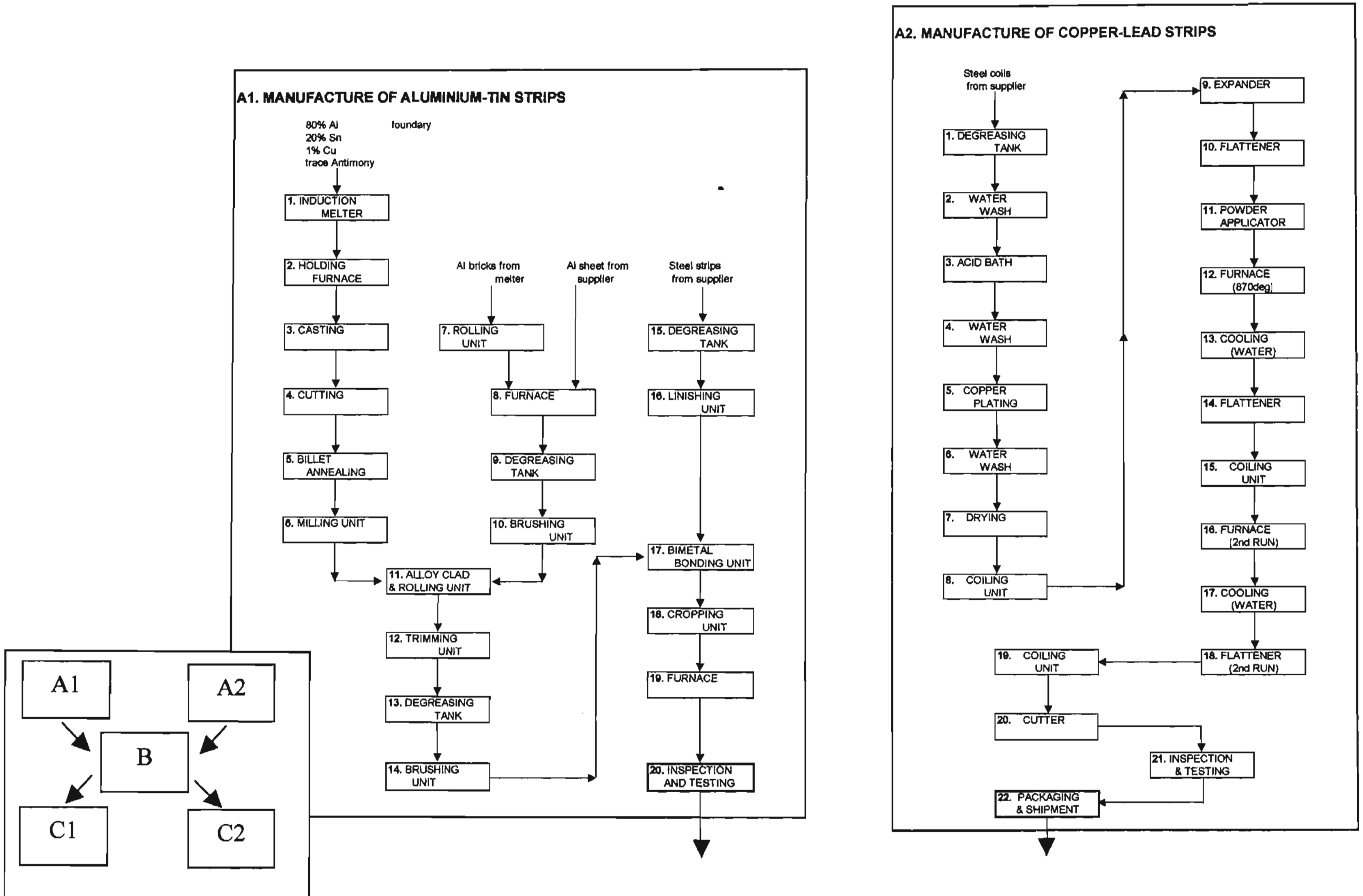

Figure 4.1a: Manufacture of aluminium-tin (A1) and copper-lead strips (A2).

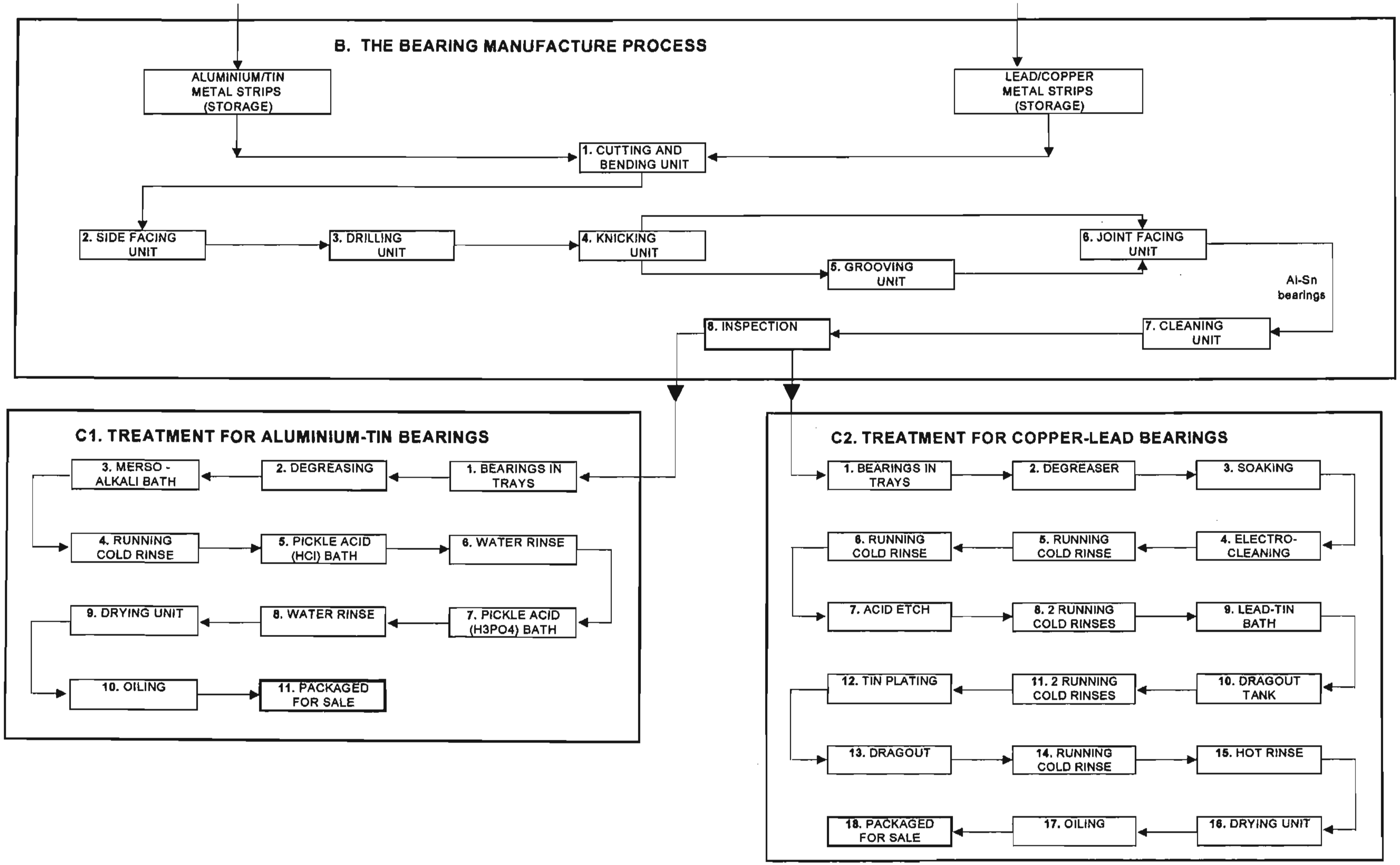

Figure 4.1b: Bearing manufacture (B), deoxyflash treatment (C1) and plating treatment (C2).

4.2 ASSESSMENT PHASE

The objective of the assessment phase was to further investigate potential waste minimisation focus areas identified during the preassessment phase. The assessment phase focused specifically on the copper-lead half-bearings which were plated with lead-tins alloy. In particular, current drip times were analysed and more economical times were calculated.

4.2.1 Introduction: The Plating Process

A bearing consisted of two half-bearings. Half-bearings were stacked onto a jig. Five jigs comprised a flight (**Figure 4.2**). The flight was transferred through a number of tanks containing various solutions.

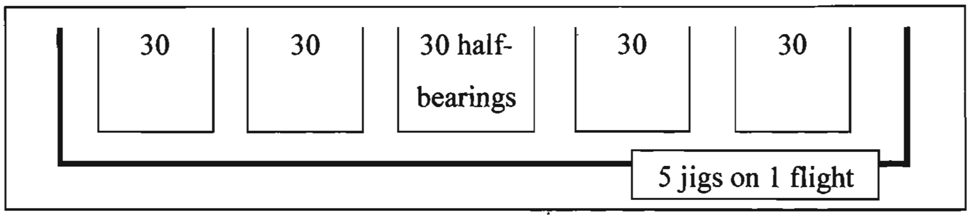

Figure 4.2: The description of a flight which consists of 5 jigs containing 30 half-bearings.

The process flow is given in **Table 4.2**. Tanks are not located in a sequential order that coincides with the process sequence, but rather in an order that facilitates more than one flight to pass through the process concurrently. The process sequence may be understood by following the arrows in **Table 4.2**. At any given time, ten different flights are at different stages of being plated. As such, this is a highly ordered system, one that is computerised in such a manner that drip times and carry over times are precisely controlled.

During the investigation, the flight took approximately 1 h to complete the plating process (**Appendix C5**) based on:

- transfer time from one tank across to another: about 4 s (dependent on tank location)
- the time to lower or raise the flight from the tank: 8 s
- time in the tank: varied depending on the process
- drip time for soak cleaner, electrocleaner, acid, hot rinse, Pb-Sn and Sn plating tanks: 6 s

Table 4.2: Process flow for the plating of copper-lead bearings at Company B.

Stop / Start	Tank No.	Process
UNLOAD ←		drier 2 (40 °C)
		drier 1 (60 °C)
	1	hot rinse (80 °C)
LOAD →	2	soak cleaner (65 °C)
	3	electrocleaner (55 °C)
	4	cold rinse
	5	cold rinse
	6	HCl pickle
	7	cold rinse
	8	cold rinse
	9	cold rinse
	10	tin drag-out
	11	tin plating (75 °C)
	12	cold rinse
	13	cold rinse
	14	lead-tin drag-out
	15	lead-tin plating (75 °C)

It is common practice to have a *drag-out* tank following the plating tank and then 2 or 3 rinse tanks. The purpose of the drag-out and rinse tanks is to reduce contamination of one plating solution carried on the work as it moves into another tank. The more rinse tanks used the better, because eventually the majority of the solution is rinsed off the part and only water is carried into the next plating solution tank. However, too many rinse tanks reduces efficiency in terms of production time and requires a large operating area. At the time of the investigation two rinse tanks followed the drag-out tank with water recycling (**Figure 4.3**). Three and four counterflow rinses have been found profitable (Graham, 1971)

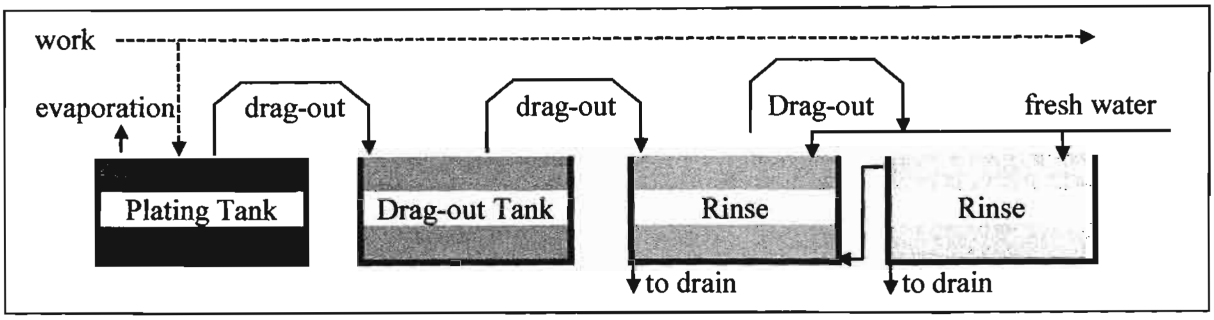

Figure 4.3: The counterflow rinsing process used at Company B.

In counterflow rinsing, fresh water enters the tank furthest from the process tank and overflows into the next tank closer to the process tank, in the opposite direction of the work flow. As work runs through a counterflow 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. Counterflow rinsing reduces water use and effluent, and saves on plating solution. In addition to the flow system used at Company B, rinse water from the first rinse tank may be counter flowed into the drag-out tank; and through adequate evaporation, solution from the drag-out tank may be used to replenish the plating tank solution. Ultimately drag-out tanks are dilute plating tanks and thus carry a high value as solution is lost. By using the solution from the drag-out tank as a make-up solution for the plating tank, consumption of plating chemicals can be reduced. However, it is also wasted effort if too much solution is constantly being dragged out of the plating tank. An inexpensive method to reduce drag-out was investigated by determining optimal drip time.

4.2.2 Drag-out Calculations and Results

The rate that solution drips off the work piece is a function of solution viscosity and surface tension. A tray was positioned under a jig immediately after it had been removed from a tank. The volume of drip-off was measured after 4 s, 10 s, 30 s and 60 s. The collected volume was then extrapolated to calculate the drip volume as a function of time. Two equations fitted the practical data results most closely (**Equation 4-1** and **Equation 4-2**):

Finite draining volume model: $v = k\,(1 - e^{-at})$ (4-1)

where v = volume, t = time,

k = approximate total liquid volume on the drag-out part, a = rate constant

Exponential draining model: $v = bt^c$ (4-2)

where b and c are constants.

The relationship between volume and time was analysed to determine which equation fitted the data best in terms of the respective r^2 values (least square fit). **Figures 4.4a, 4.4b, 4.4c, 4.4f, 4.4h, 4.4i, 4.4j, 4.4k, 4.4l** and **4.4o** (white background graphs) followed the first equation most closely, the remainder followed the second equation. For Equation 4-1, the equation best represented the curve towards the end of the drip time where a low volume of solution was left on the work piece. For Equation 4-2, the equation best represented the beginning of the process and thus for **Figures 4.4d, 4.4e, 4.4g, 4.4m,** and **4.4n** (grey background) no plateau effect was evident. A longer measuring time could be investigated in the future such that the first equation may be applied to these curves.

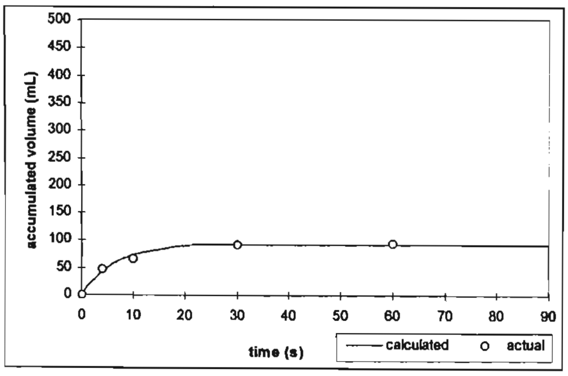

Figure 4.4a: Drip rate from the soak cleaner tank (65 °C) (Tank2).

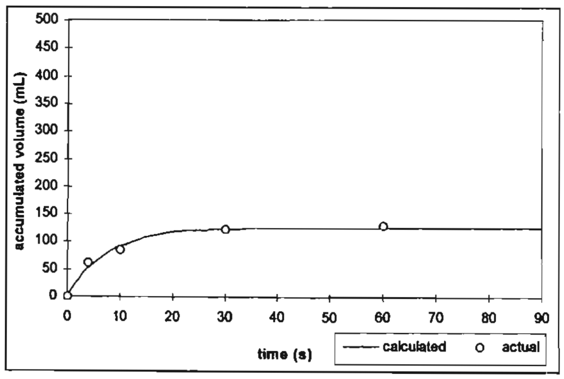

Figure 4.4b: Drip rate from electrocleaner tank (55 °C) (Tank 3).

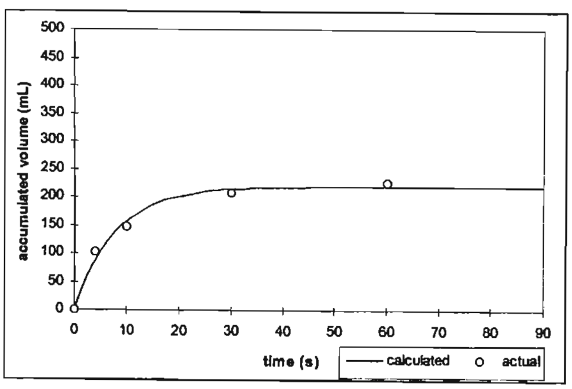

Figure 4.4c: Drip rate from the 1st rinse tank (Tank 4).

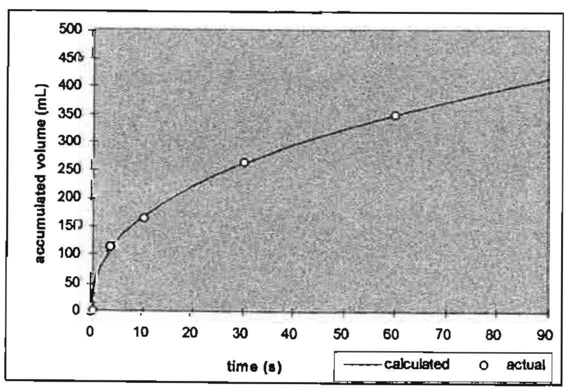

Figure 4.4d: Drip rate from the 2nd rinse tank (Tank 5).

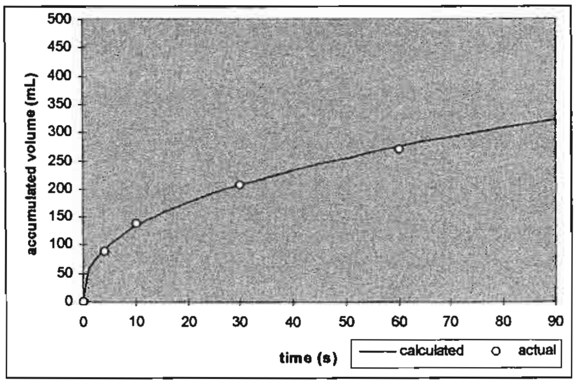

Figure 4.4e: Drip rate from the acid tank (Tank 6).

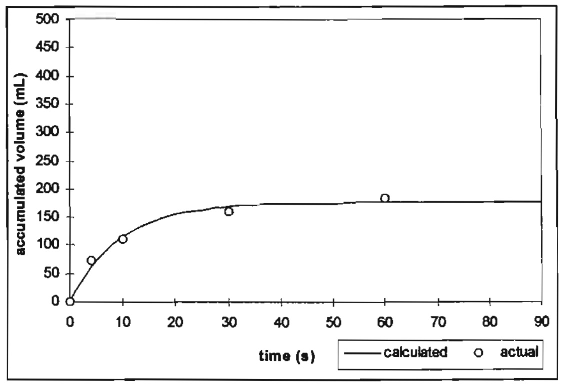

Figure 4.4f: Drip rate from the 3rd rinse tank (Tank 7).

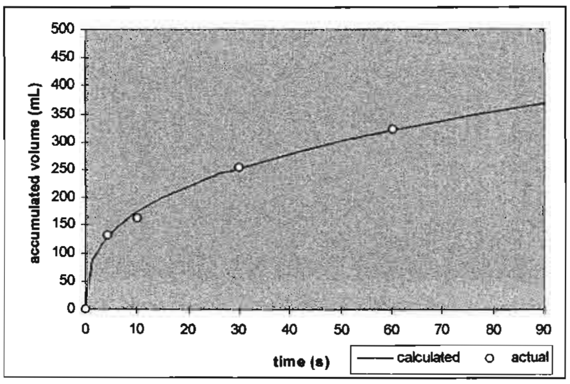

Figure 4.4g: Drip rate from 4th rinse tank (Tank 8).

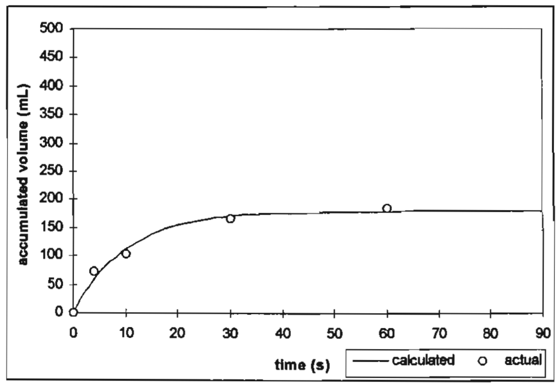

Figure 4.4h: Drip rate from the lead-tin plating tank (75 °C) (Tank 15).

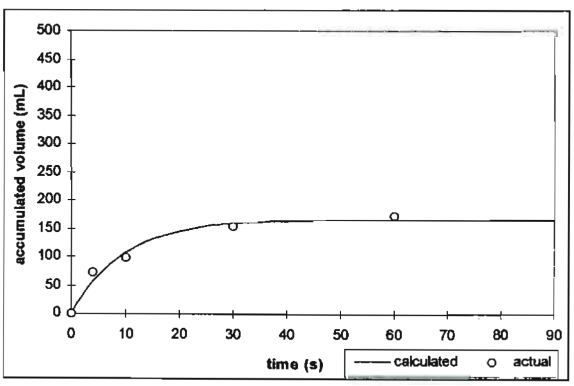

Figure 4.4i: Drip rate from the lead-tin dragout tank (Tank 14).

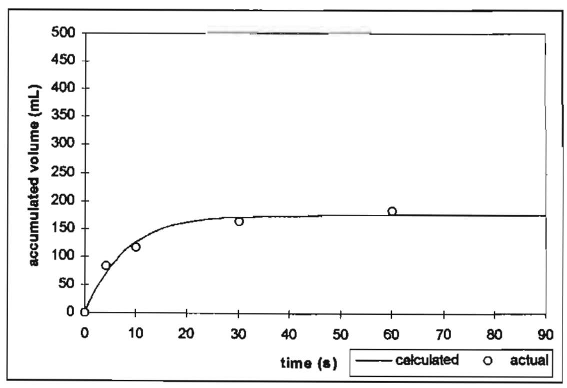

Figure 4.4j: Drip rate from the 5th rinse tank (Tank 13).

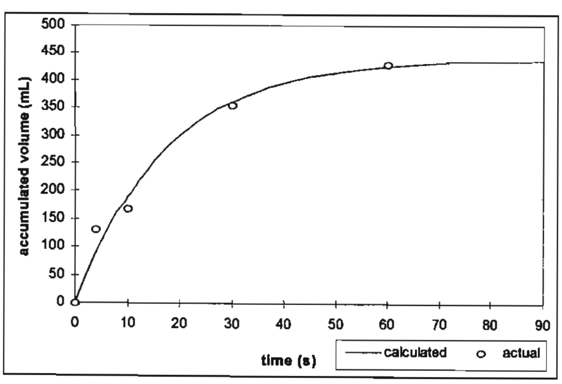

Figure 4.4k: Drip rate from the 6th rinse tank (Tank 12).

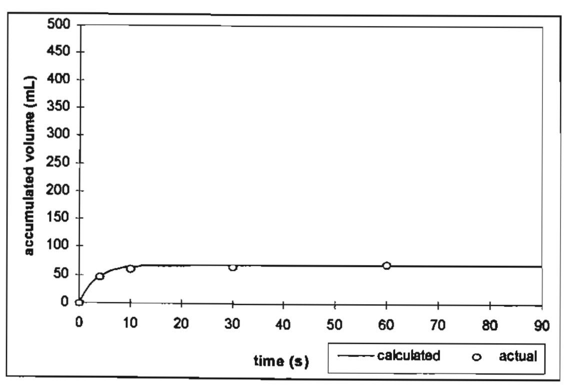

Figure 4.4l: Drip rate from the tin plating tank (75 °C) (Tank 11).

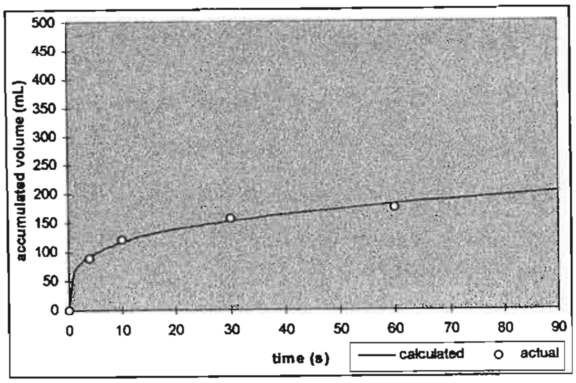

Figure 4.4m: Drip rate from the tin dragout tank (Tank 10).

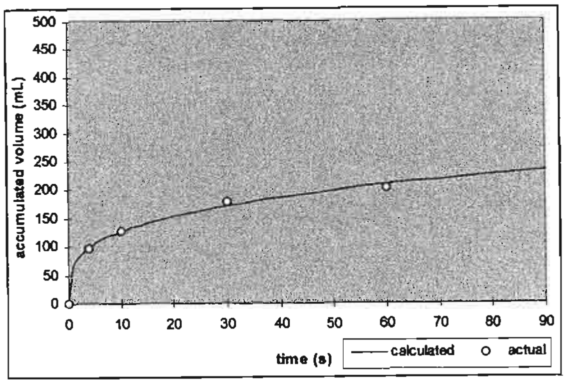

Figure 4.4n: Drip rate from 7th rinse tank (Tank 9).

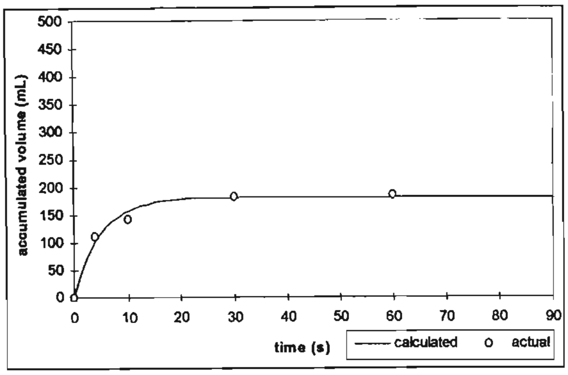

Figure 4.4o: Drip rate from hot water rinse tank (Tank 1).

Gradients were calculated and the assumption was made that where the gradient tended to zero the drip rate was minimal, i.e. where $dv / dt \rightarrow 0$. Gradients that are bordered in **Table 4.3** represent the first flow rate of less than 1 mL / s. This point varied for each tank due to variations in solvent viscosity and tank temperature. Some of the tanks did not reach a flow rate of 1 mL / s within the time analysed (90 s) and for these tanks longer drip times should be investigated.

Table 4.3: Calculated gradients of the tanks at different time intervals.

Tank	2	3	4	5	6	7	8	15	14	13	12	11	10	9	1
Time (s)	Soak	Elec	Rinse	Rinse	Acid	Rinse	Rinse	Pb-Sn	Drag	Rinse	Rinse	Sn	Drag	Rinse	Hot
10	3.08	4.08	6.92	8.30	6.48	5.58	7.32	4.95	3.85	4.79	7.07	2.05	3.72	4.41	5.31
15	2.54	3.61	6.39	6.08	4.71	5.28	5.16	5.44	5.05	5.21	12.08	1.04	2.49	3.00	4.43
20	1.38	2.10	3.80	4.98	3.84	3.39	4.12	3.63	3.35	3.18	9.50	0.35	1.93	2.35	2.11
25	0.75	1.22	2.27	4.30	3.30	2.17	3.48	2.42	2.23	1.94	7.48	0.12	1.59	1.95	1.01
30	0.40	0.71	1.35	3.82	2.92	1.39	3.05	1.62	1.48	1.18	5.88	0.04	1.37	1.69	0.48
40	0.17	0.33	0.64	3.32	2.53	0.73	2.61	0.90	0.82	0.58	4.13	0.01	1.15	1.42	0.17
50	0.05	0.11	0.23	2.87	2.17	0.30	2.21	0.40	0.36	0.22	2.56	0.00	0.95	1.18	0.04
60	0.01	0.04	0.08	2.55	1.93	0.12	1.93	0.18	0.16	0.08	1.58	0.00	0.81	1.02	0.01
70	0.00	0.01	0.03	2.31	1.74	0.05	1.73	0.08	0.07	0.03	0.98	0.00	0.72	0.91	0.00
80	0.00	0.00	0.01	2.12	1.60	0.02	1.57	0.04	0.03	0.01	0.61	0.00	0.64	0.82	0.00
90	0.00	0.00	0.00	1.97	1.48	0.01	1.45	0.02	0.01	0.00	0.37	0.00	0.59	0.75	0.00

It was evident that in order to reduce carry over, the drip times should be extended from 6 s to a minimum of 20 s for the tin tank, 30 s for the soak clean and hot rinse tanks, 40 s for the first, third, and fifth rinses, lead-tin plating and lead-tin drag-out tank, about 50 s for the tin drag-out tank and about 1 m 20 s for the sixth and seventh rinse tanks. Since this is an automated process with flights positioned in almost every tank, different drip times for different tanks are not possible; one overall optimum drip time had to be calculated.

4.3 FEASIBILITY ANALYSIS

A feasibility table (**Appendix C5**) was compiled based on savings in water and chemicals from the extended drip time less the cost of time resulting in a potential profit. Values have been summarised between 20 - 30 s (**Table 4.4**). The results followed a parabolic curve and an optimal drip-time was identified at ***26 seconds***.

Table 4.4: Economic savings (1998) of solution with extended drip time.

Time (s)	Solution savings (R)	Cost of time (R)	Profit (R)
20	75.81	23.33	52.47
21	78.56	25.00	53.56
22	81.07	26.67	54.41
23	83.37	28.33	55.04
24	85.47	30.00	55.47
25	87.39	31.67	55.73
26	89.16	33.33	**55.82**
27	90.78	35.00	55.78
28	92.26	36.67	55.59
29	93.62	38.33	55.29
30	94.88	40.00	54.88

The R55.82 saving per day, based on the difference between current drip time of 6 s and optimal drip time of 26 s, equates to R13 201.43 (5 days, 4.3 weeks, 11 months) per year. Apart from the economic benefit there would also be environmental benefits. Less drag-out means less contamination of successive tanks, thus less wastage and need for replacement of chemicals and water, reducing unnecessary harmful impact on the environment and saving on resources. In addition to extending drip time to reduce solution drag-out, other simple savings may be achieved. Recommendations have been presented (based on the EPA's *International Waste Minimisation Approaches & Policies to Metal Plating*) and three aspects were further discussed: pipe leaks, trichloroethylene replacement and enhancement of oil supplier relationship.

4.4 OTHER RECOMMENDATIONS

In reviewing the processes and practices at Company B, observations lead to the identification of further waste minimisation options. Some recommendations are presented.

By positioning the bearings properly on the rack, plating quality could be improved and drag-out reduced. Parts should be positioned to consolidate the run-off streams and so that the lowest profile emerges from the fluid as the rack is removed. The best position is determined through experimentation:

Where possible, plating solution tanks should be kept covered to reduce contamination and improve performance. High purity electrodes should be used to reduce impurities from falling out and contaminating the solution. Plating solution carry over may be reduced by reducing the solution viscosity by lowering the concentration, or increasing temperature. Adding wetting agents also reduces surface tension. Carry over may be also be reduced by controlling withdrawal rates and drainage. This may be achieved by maximising drip time (**Section 4.2.2**), using drip shields to capture and return drag-out as a rack is transported from the process, or using air blow-off during drip time.

Fog or spray rinsing may be used over the process tank where heated processes provide enough evaporative headroom to accept additional fluid. Inlet and outlet points of the rinsing tanks should be at opposite sides of the tank and the flow into the tank should be distributed. Agitation may be achieved through air spraying or other methods.

Flow restrictors may be installed to regulate flow, such as conductivity based controllers on rinse water. When the conductivity reaches a set level, the valve is opened and water flows through the tank. An alternative is timer release controls, either manually activated or maybe activated by the action of racks and hoists. The valve is opened for a pre-determined length of time and then shuts automatically.

Evaporative losses may be controlled through hooded work pieces, extractor fans located above the tanks which collect and condense evaporated solution back into the tank, or adding surfactant foams. Energy savings in heating the tank solution may be achieved by pumping the water around the dryer tanks (which are air blown with hot air); since the dryer tanks are warm the water passing to the heated tanks will be heated. One essential saving, that commonly goes unmonitored, is repairing of leaking pipes. Unaccounted water losses were investigated over the 1998 Christmas period.

4.5 PIPE LEAKS

Three industries, manufacturing similar products, were situated on the property, sharing certain utilities, such as water supply, wastewater runoff and an underground storage sump. Three water meters located outside the main entrance gate were inspected. One meter measured water use for Company B, the other for the adjacent company and the third, older meter for both companies. Data analysis was focused on the time period 00:00 to 07:00 during which time there should have been no demand on water use. An unaccounted loss of 0.72 kL / h (±0.19) was detected. At a charge of R2.52 / kL, the money lost through pipe leaks equated to R1.81 / h or approximately R16 438 / annum (24 h, 8 days, 4.3 weeks, 11 months). Leakage sources must be identified and repaired. Further investigations should be conducted to identify leakages that may occur during process operations which could result in an even greater economic loss.

4.6 TRICHLOROETHYLENE REPLACEMENT

Reducing waste by implementing material changes was investigated, in particular substituting chlorinated solvents for less hazardous compounds. Trichloroethylene was the degreasing agent used at Company B. Acute and chronic inhalation exposure of this colourless solvent results in central nervous system effects, such as dizziness, headaches, confusion and weakness, and may affect the gastrointestinal system, liver, kidneys and skin (from Material Safety Data Sheets). Due to the company's international associations, there have been pressures to move away from the use of this solvent. In this regard, producers of biological degreasers were approached and a replacement suggested. Lemsolv Plus (approximately R22 / L), is applicable to electrical-mechanical precision engineering, industrial wipes, heavy oil and grease removal, and for tank dips in immersion cleaning. Lemsolv has been formulated from d-Limonene, a naturally occurring citrus oil. The compound has a performance enhancing cleaning agent added to speed the removal of oil and greases and has the following properties:

- film free drying in less than 60 s
- flash point greater than 61 °C
- good solvency
- an Occupational Exposure Standard of 200 ppm over 8 h, i.e. repeated exposure without adverse effects (Lemsolv Plus has the same Occupational Exposure Standard as III Trichloroethane but formulation requires no hazardous labelling).

Company B had already initiated experiments with another solvent substitute, and only once the trial runs had been completed could further investigations be conducted by the company to determine whether the biological solvent was adequate to replace trichloroethylene.

Other substitutions of the chlorinated degreasing solvent may include using:

- non-ozone depleting solvents that are used as drop-in replacements in conventional chlorinated solvent equipment
- perfluorocarbons which are used in new vapour degreasing tanks for cleaning heavily soiled parts or parts requiring a high quality cleaning process
- use of supercritical fluids, for example, carbon dioxide, an emerging technology with limited application
- molten salt baths, also with limited application

The release of chlorinated solvents can be reduced through design changes to degreasing equipment and good operating practices. Examples of design changes include increased freeboard, automatic rolltop, hoist speed control, and refrigeration zone. An example of good operating practice includes covering unused degreasing.

4.7 ENHANCEMENT OF OIL SUPPLIER RELATIONSHIP

In addition to improving operations within the company, Company B can enhance its relationship with its suppliers and buyers. In particular, the relationship between Company B and its oil supplier were further analysed. The oil supplier company could be encouraged to take back spent oil/coolant, an unavoidable process waste, and reclaim this where possible. Alternatively, the supplier and buyer could, through mutual interests, initiate a recycling plant on-site. Ultimately, the buyer buys less expensive recycled oil/coolant from the supplier, reducing environmental impacts and the supplier becomes more of a service provider.

In reviewing the supplier-buyer relationship, two aspects were identified as having scope for improvement. The first was product reduction and the second was on-site recycling. Company B stocked numerous different oil and coolant products, many of which performed similar functions and which were only used in small volumes (25 L or less). The potential existed to use fewer, more general purpose products by consulting with the supplier. Oils and coolants used in excess of 200 L per annum were tabulated (**Table 4.5**).

Table 4.5: Coolant and oil products supplied to Company B.

Currently in use	Volume (1997) (L)	Cost (1998) (R / L)
Biocut CE (coolant)	4 620	10.10
Cooledge A (coolant)	630	9.16
Rustillo DWX 31	4 460	7.77
Hyspin AWS 68	(7 mnths) 4 410	7.27
Hyspin AWS 32	(7 mnths) 420	6.19
Magna BD 68	(7 mnths) 630	5.94
Magnaglide D220	210	8.53
Alpha SP 320	210	6.89

Using the expertise from the supplier, some potential product replacements were identified. Biocut CE could be used in place of Cooledge A (which deteriorates with time), and multigrade Vario HDX (R7.22 / L) could be used to replace Hyspin AWS 68 and Hyspin AWS 32. Although more costly, the suggested products were of a higher quality, would have a wider application, and could benefit the company by:

- reducing capital outlay of numerous different products, contamination and stock control that would be required if numerous different products were used
- reducing storage space, 1 x 210 L multipurpose product could replace 5 x 20 L drums of various constituents
- reducing manual errors that may arise from an (illiterate) labourer that may mistake one product for another, which may negatively affect the process.
- reducing wastage, for example those products used in small volumes may eventually become too contaminated or old to use

Spent oil may be recycled externally but there is no current means of external coolant recycling. For this reason, the supplier suggested an on-site cooling recycling unit, the HM4 (**Figure 4.5**). Current infrastructure would allow for a small recycling unit to be set up, recycling spent coolant for re-use. Already on-site is a vacuum cleaner and a sump which would contribute to some of the operations of the recycling unit. A similar recycling unit exists in Johannesburg, but this project would be the first of its kind in Durban.

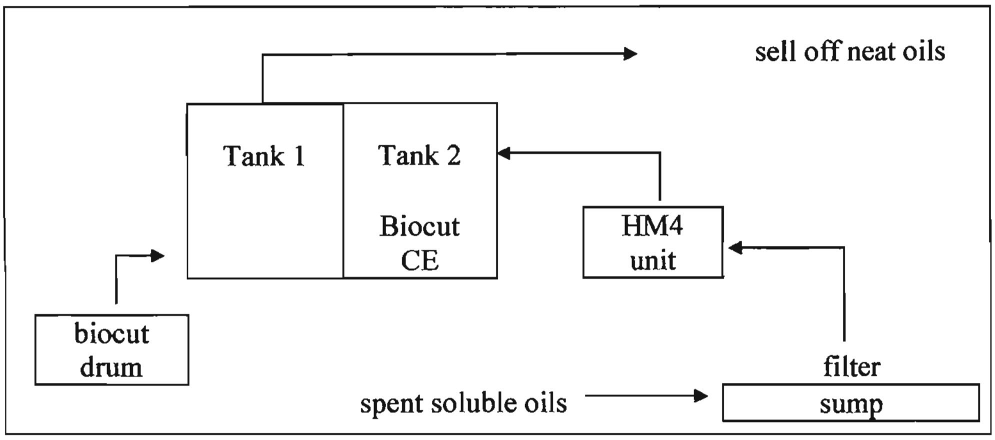

Figure 4.5: Recycling unit suggested for Company B.

Recycling modifications would be incorporated into the current system. Fresh biocut is used to refill the biocut tank, fitted with a mixer to ensure a homogenous solution. Used soluble oils are discharged into a sump with a pump to recirculate the coolants through a filter. Additive additions are necessary to restore losses during the processes. Sludge from the sump must be cleaned out at least once a month. The mobile HM4 unit is powered by an electrical motor, removes trampoil, even when emulsified in the coolant. Spent neat oil removed from the tanks can be sold off to an oil recycling company.

To maintain efficient operation of the unit, filters must be rinsed frequently. The additives are costly and must thus be stored in a locked room with suitable monitoring. Separation of used products on the working floor was recommended as follows:

- neat oils
- soluble oils + waste
- others (soaps/floorcleaners)

According to the supplier, a 20 % saving of the current operations may be experienced in using the unit, since labour costs are lowered as is wastage. Should the neighbouring two companies participate in the purchasing of the unit, a pay off period of 1 year was predicted by the supplier. The unit could be paid off by a minimal additional charge (from 40c / L) added onto the existing price for the purchase of oil and coolants. Thus the higher the purchasing stock the faster the unit is paid off. The supplier will take responsibility for the maintenance of the unit until the unit is paid off, the price of which is also included in the stock prices.

4.8 DISCUSSION

Company B was a smaller scale company compared to Company A, but it had a proactive attitude due to international pressures. This company was eager to reduce their waste in any aspect that could be identified. Although commitment was given by top management, and a project team was established, dedication to the project investigation was only evident from one or two members. The company was small and thus production results were far more relevant than waste minimisation. Data to complete any sort of material balances were not available. Thus identifying potential waste minimisation areas was achieved through discussions with the project team and the development of a size, nature and cost driven table, and not through the conventional method of analysing mass balancing calculations. Nevertheless, positive results were still achievable.

The plating plant was identified as a potential waste minimisation area. Even though equipment was relatively new, automated and custom designed, it was a challenge to identify improvement opportunities. This also proved that continual improvements could be achieved by reassessing any old or new process. Waste minimisation is an ongoing process and should be conducted on a regular basis. In particular, the length of drip time was investigated to assess optimum drip time for minimal solution carry over into the drag-out tank following the plating tank. In addition, a simple but effective waste minimisation investigation to determine how much water was lost through leaking pipes was investigated. This proved a successful investigation as there were indeed leaks detected.

Other aspects that were discussed were the potential replacement of trichloroethylene with a less harmful solvent and further establishing the relationship with the company's oil supplier. Again this company was solely interested in waste minimisation, and cleaner production and industrial symbiosis were not evidently important. Inadvertently, the company enhanced its relationship with its supplier and in this manner demonstrated industrial symbiosis.

4.9 CONCLUSION

The waste minimisation investigation at Company B proved to have financial savings both through extending the drip time and by fixing leaks (**Table 4.6**):

Table 4.6: Opportunities for economic benefit identified.

Area	**Amount (R / annum)**
Extended drip time to 26 s	13 201
Fix leaks	16 438
TOTAL	29 639

Other areas have been identified for possible economic savings but further investigations are to be conducted by the company if the interest arises. These benefits identified will greatly benefit the environment in terms of preserving water use with lower wastewater requiring treatment. Alongside the financial savings, there are obvious benefits to the environment. These include a reduction in the demand for water and energy, less chemicals, metals and dyes being discharged to drain and a reduction in the mass of solid waste disposed of to landfill. Quantification of the savings to the environment is complex and problematic and was not included in this investigation.

CHAPTER 5

DISCUSSION AND CONCLUSIONS

Measure, compare, see how to improve and then change

P. Pybus (2001)

South Africa has been identified as a water deficient country. Any opportunities to reduce industrial water use and wastewater production will prove beneficial for future developments. Future generations are dependent on present development that should be sustainable. As such, many countries have developed cleaner production initiatives. Concepts that have been used to demonstrate cleaner production include industrial symbiosis and waste minimisation. Two sectors that were identified as having significant potential to impact on the environment were the textile and metal finishing sectors. In both these sectors water is a primary raw material and the discharges of wastewater are contaminated with chemicals or heavy metals. A case study from each sector was used to investigate the scope for waste minimisation. Valuable lessons learnt in these case studies can be used to ensure the success of similar waste minimisation initiatives in these and other sectors.

5.1 COMPANY PARTICIPATION

Identification of a company that would partake in such an investigation proved challenging. It was noted that the smaller the company, the higher the competition and therefore company and process information was more guarded. As access to quantitative data was requested, so the companies withdrew from the project. This will not only pose a significant barrier in terms of participating in an industrial symbiotic network in the future, but also hinders a transparent and open relationship that should exist between suppliers and buyers for effective communication. Other challenges during the investigation were a lack of commitment and interest from the companies. The benefits of waste minimisation were largely under-estimated, while the perceived cost were over-estimated. As such valuable time was not offered during the investigation. The two companies that agreed to participate in the study were open to the potential benefits of waste minimisation. Both companies had strong international influences, and thus the waste minimisation investigation was welcomed. These companies understood current and future legislative pressures. The companies understood that simple no- or low-cost measures could reduce the costs of treating waste, and minimise unnecessary loss of raw materials, chemicals and energy.

A positive attitude from both the companies was driven by top management commitment. Such commitment is paramount if any achievements are to be expected. An added driver in the investigation was the development of a project team. This team would be responsible for the success of the project and so project ownership was noted. It was important for the researcher to provide support in the form of facilitating the process rather than conducting the entire process as in the traditional consultant-client relationship. In so doing, the project team, comprising people who understood company processes, drove for improvement opportunities with potential savings. In Company A, a far greater degree of commitment was noted from the project team as opposed to Company B. In Company A, each member played a specific role. Whereas in the smaller, Company B, one person held a number of different responsibilities and towards the end of the project only one member was still evidently participating in the investigation.

5.2 COMPANY NETWORKS AND INDUSTRIAL SYMBIOSIS

Each company co-existed in an industrial network. A network map of the company was established for future symbiotic development. Suppliers and buyers, up and down the production line, were identified. Efforts to foster symbiotic relationships within the network would form an essential part of any strategy to improve the environmental profile of these companies in terms of increasing production efficiency, and reducing environmental impact, resource use and waste production. It was easier to interpret the supplier-buyer relationships in Company B. This was largely attributed to the fact that due to the size of Company A different people managed different aspects of buying and selling, whereas at Company B one or two people were tasked with interacting with all the suppliers and buyers. Furthermore, in communicating with the oil supplier of Company B, it was evident that new initiatives to establish a mutually beneficial partnership was welcomed.

The potential of the companies to participate in an industrial symbiotic network was investigated. Employees were aware and focused in terms of the company's performance in isolation, but less responsive in terms of the company's position within any larger network. The companies had a low level of understanding in terms of changing operational performance in line with cleaner production but were unable to understand the benefits of more sophisticated approaches, such as industrial symbiosis. Such concepts proved to be premature.

Both companies were identified as being partially suited to participation in an industrial symbiosis network and some of the issues that needed to be addressed were highlighted, including:

- ineffective or hindered internal communication;
- reluctance to alter practices for fear of damaging the specific product brand reputation;
- product confidentiality;
- budgeting and resource allocation practices which may constrain innovation and increase the time for resolution of problems;
- a somewhat politicised decision making process within the company;
- the general lack of awareness regarding environmental issues or opportunities;
- uncertainty established due to ownership changes and staff downsizing;
- non-participatory decision-making and racial boundaries; and
- license agreements which could limit the capacity for innovation.

Undertones of internal politics with regards to how the company operated were evident at Company A. Although members of the project team were eager to drive certain initiatives, higher management could prove to inhibit ideas or projects. The inverse was true for Company B, where the project team diminished to one member. This person had the power to initiate or run with practically any project within certain limits. An important aspect that was highlighted at Company A was that workers on the shop floor often had interesting and useful ideas. Although this was the case, no shop floor members were included in either project teams. It must be stressed that shop floor staff are the people that deal with the machinery and processes every day, and their input into any waste minimisation investigation could prove valuable.

5.3 WASTE MINIMISATION OPPORTUNITIES

The bulk of the investigation focused on the identification of potential waste minimisation opportunities following a waste minimisation technique of preassessment, assessment and feasibility analysis. Processes and practices were reviewed and analytical testing was conducted, where necessary. Although the initial waste minimisation procedure was established in **Chapter 2**, this was adapted to each company accordingly.

Although team members from the companies were open to data sharing, access to this data often proved difficult due to ineffective management (Company A) or no or inadequate data collection (Company B). An information management system is recommended to systematically collate data so that it is easily accessible for future investigations. A lack of financial resources proved to be a barrier in Company A in terms of replacing older equipment. However, in this initial waste minimisation study new equipment was not the only resolution. By identifying operating improvements, older equipment could be run more effectively without the need for newer equipment. Opportunities that were identified in this study were to be simple and no- or low cost.

Emphasis of the waste minimisation investigation was directed at reducing waste at source and improving operational processes. Waste minimisation opportunities existed for both companies and investigation of further improvement options by the company in the future will be a driver towards sustainable development. Opportunities were identified to reduce the use of raw materials, thus saving costs as well as treatment requirements, but maintaining or improving product output. Results from the case studies may be used to guide other industries, such as to promote good housekeeping, efficient use of materials, and policy developments such as extending producer responsibilities. Information dissemination is fundamental.

A lack of basic housekeeping was noted in both companies. In particular, insufficient control of drips, leaks, spills and worker operations, and infrequent machinery maintenance was noted. Simple recommendations for improved house keeping included installing water meters, improving stock takes and maintaining process records. Such records may include chemical purchases, inventory, bath analyses, dumps and additions, water usage, wastewater treatment chemical usage, and spent process bath and sludge analyses and are beneficial in the development of the company's material balances and in the waste minimisation process.

Staff awareness and attitude regarding waste minimisation was low and long term training was required. Training should cover waste minimisation and prevention at source, process chemistry additions and sample taking, handling of spills and leaks, and operation of pollution prevention and control technologies. Other topics that should be demonstrated to employees include background information regarding regulations, overall health and safety effects in the work place, and overall costs of waste treatment before and after the implementation of waste minimisation procedures. Moreover, worker awareness regarding environmental issues must be driven and motivated by top management. Waste minimisation opportunities are best identified when all employees of the company are involved in the process, presenting multiple and varied inputs.

The aspect of waste minimisation was based on productivity and water reduction. The investigation detailed removal of rinse tanks in the bleach house for the textile company, thereby also reducing labour costs and time, and extending drip times of the jigs during the plating process and reducing pipe leaks in the metal finishing company. Potential benefits were calculated and amounted to over R80 000 savings per annum. The potential waste minimisation opportunities could reduce raw material consumption such as water, chemicals, and electricity.

The burden on the environment would be reduced in that fewer raw materials would be used and less waste produced, in terms of chemicals, metals and dyes being discharged to drain and solid waste disposed of to landfill. Quantification of the savings to the environment was complex and problematic and was not included in this investigation. The companies were driven by money, not environmental benefits, but the need to quantify, record and disseminate such information will prove beneficial in the future as more people become environmentally conscious. Company morale improved throughout the investigation as employees became more aware of potential savings through improved performances. As such, the whole company image was enhanced and marketability of products could increase.

Other potential areas for improvement that were identified included purchasing of newer looms or conversion into more efficient looms in the weaving department, possible elimination of week-end shifts, increasing the thread length wound onto pirns and effective winding to allow for head-to-tail attachments for more continual machine runs, and selling of reject cloth as low quality cloth. In the metal finishing company other opportunities included making changes to input materials, such as replacing the degreasing agent, trichloroethylene, with a less harmful solvent, standardisation of some of the oil and coolant materials used thereby reducing chemical inventory, and internal reclamation of coolants through enhanced interaction with the supplier.

By focusing on waste minimisation, a basic tool for achieving cleaner production, a company can operate more efficiently. Waste minimisation benefits the company's triple bottom line. The waste minimisation options identified will benefit the company financially, by reducing material wastage and environment impacts, such that development in the future tends towards sustainability, presenting the company as more socially acceptable, and encouraging prospects for global trading. Great potential for improvement in terms of future sustainable developments exists for the textile and metal finishing sectors, and other sectors which proactively take the initiative to improve their operations.

5.4 CONCLUSION

A number of barriers were encountered throughout this waste minimisation investigation. With the valuable lessons learnt from this study, future investigations may prove easier to manage. Common barriers that need to be addressed in future initiatives include:

- a reluctance to share information
- withdrawal of the company from the investigation due to the nature of information requested

- inadequate / lack of data collection necessary for investigation
- a lack of / no commitment from management or senior staff
- financial and time barriers
- uncertainty regarding the project and potential costs/success

In the longer term, waste minimisation will gradually become integrated in new / future developments. However, it is likely that the term *waste minimisation* will slowly be absorbed into the concepts of cleaner development as industrial development strives towards an ideal situation of *zero waste*. No longer will the term *waste minimisation* be used but rather cleaner production in a drive for sustainable development.

5.5 RECOMMENDATIONS

Key recommendations for future waste minimisation investigations are given:

- Ensure company and top management commitment
- Establish a project team that can assist with the initial investigation and thereafter continue with waste minimisation initiatives for the company
- Use previous cost savings from similar case studies to highlight the benefits of waste minimisation
- Assist / guide the company with data capturing and recording for use in mass balance investigations
- Ensure that parameters that need to be monitored are monitored, and if not encourage the company to initiate such relevant monitoring
- Target smaller, no-cost or low cost opportunities before larger / financially intensive projects so that the success of the smaller objectives may encourage further progress
- Have regular feedback / update meetings to keep momentum in the project
- Waste minimisation opportunities always exist; on completion of a waste minimisation investigation, processes and practices should again be reviewed in a cyclical, ongoing loop of improvement.

Post Script

This waste minimisation investigation was the first of its kind in the School for Chemical Engineering at the University of Natal, Durban. The field work was undertaken between March 1997 and December 1998. At the same time, or shortly after this research, a number of other waste minimisation and related initiatives, tours and legislation followed. Events that occurred between the undertaking of the research and submission of the dissertation are tabulated (**Table PS.1**) and discussed below. Valuable lessons learnt from this waste minimisation study were used by the Pollution Research Group in later studies and projects.

1.1 The author participated in a DANCED funded mission in Lesotho in 1998. The mission was to provide technical assistance to the Lesotho National Development Corporation for the effluent treatment from Thetsane Industrial Estate. Specific focus was given to textile processes of polluting companies in the Thetsane area and waste minimisation options available for the companies to reduce their environmental impacts.

1.2 The author conducted a technical tour in 1998 to the Institute of Product Development, in Denmark, where a number of textile and metal finishing companies were visited as part of Cleaner Technology Transfer to South African Industries. The Industrial Symbiotic Network at Kalundborg was also visited and experiences discussed.

The author assisted and presented at a workshop and a number of conferences held in 1998.

1.3 The author was on the organising committee for the workshop, An Industrial Symbiosis View of Small & Medium Enterprises, held in Cape Town.

1.4 The author was a facilitator at the Southern African Regional Conference on Cleaner Production held in Midrand.

1.5 The author presented at the WISA Biennial Conference and Exhibition held in Cape Town: *Industrial symbiosis in small and medium sized enterprises following Waste Minimisation.*

1.6 The author presented at the 2nd International Conference on Advanced Wastewater Treatment, Recycling and Reuse, held in Milano, Italy where further information sharing and international experiences were learnt: *Industrial symbiosis and eco-efficiency in the textile industry: A South African case study.*

Table PS.1: Time line of Waste Minimisation events in South Africa.

Events	Year 1997	1998	1999	2000	2001	2002
1. Activity by Author						
Author's Waste Minimisation Investigation	X	X				
1.1 DANCED support to Lesotho National Development Corporation	X					
1.2 Technical Visit to Denmark on Cleaner Technology		X				
1.3 Workshop on Industrial Symbiosis in Cape Town		X				
1.4 SA Regional Cleaner Production Conference in Midrand		X				
1.5 Presentation at WISA biannual Conference in Cape Town		X				
1.6 Presentation at IAWQ in Italy		X				
Write-up of dissertation						X
2. Legislation						
2.1 White Paper on Environmental Management Policy for South Africa	X					
2.2 National Water Act		X				
2.3 National Environmental Management Act		X				
2.4 White Paper on Integrated Pollution and Waste Management		X	X			
2.5 National Waste Management Strategy and Implementation Plan				X		
3. Waste Minimisation Clubs and Associations						
3.1 WRC project I: Durban Metal Finishing		X	X	X		
3.2 WRC project I: Hammarsdale Club			X	X		
3.3 Western Cape Metal Finishing				X	X	X
3.4 Gauteng Surface Finishers Association				X		
3.5 Western Cape Club for Large Industries				X		
3.6 Port Elizabeth Metal Finishing Waste Minimisation Club				X		
3.7 Pietermaritzburg Waste Minimisation Club					X	
3.8 First National Cleaner Production Centre in South Africa						X
3.9 WRC project II				X	X	X
3.10 DANCED Cleaner Production						X

A number of environmental white papers were drafted and legislation promulgated in and around the time of the dissertation, namely:

2.1 The White Paper on Environmental Management Policy for South Africa (GN 18894 Notice 749 of 15 May 1998).

2.2 The National Water Act (Act 36, 26 August 1998).

2.3 The National Environmental Management Act (Act 107 of 27 November 1998).

2.4 The White Paper on Integrated Pollution and Waste Management for South Africa (GN 20978 Notice 227 of 17 March 2000).

2.5 The National Waste Management Strategy (1998 – 1999).
In 1998, the Pollution Research Group were appointed as local Waste Minimisation consultants for the development of the National Waste Management Strategy and Implementation Plan, which was adopted by national government at the end of 1999. Experiences learnt from this dissertation enabled valuable input by the Pollution Research Group to this initiative.

In 2002, Prof. Chris Buckley, Head of the Pollution Research Group, was nominated as a member of the Minister's National Water Advisory Council. The development of this Council is in fulfilment of the requirements of the National Water Act 36 of 1998.

Other waste minimisation projects in the form of clubs and associations that were undertaken using knowledge gained from the Waste Minimisation dissertation include the following:

A three-year project, *Initial Assessment and Pilot Study*, funded by the Water Research Commission was initiated at the beginning of 1998 which resulted in the development of:

3.1 a sector-specific waste minimisation club in the Durban Metro region targeting the metal finishing sector.

3.2 a cross sectional waste minimisation club in the Hammarsdale region targeting the textile sector and associated industries.

The activities of the such pilot clubs continue as associations, such as the KwaZulu-Natal Metal Finishing Association and the Hammarsdale Industrial Conservancy.

Other initiatives specifically associated to metal finishing that stemmed from the success of the pilot waste minimisation clubs include the:

3.3 the Western Cape Metal Finishing Association and

3.4 the Gauteng Surface Finishers Association which are run as Waste Minimisation Clubs.

Other clubs that developed throughout South Africa were then initiated, such as the:

3.5 Waste Minimisation Club for Large Industries in the Western Cape.

3.6 Port Elizabeth Metal Finishing Waste Minimisation Club.

3.7 Pietermaritzburg Waste Minimisation Club.

3.8 In addition to other African countries, South Africa developed its first National Cleaner Production Centre in 2002.

3.9 Based on the initial Water Research Commission project, a further three year project, *The Establishment of a Methodology for Initiating and Developing Waste Minimisation Clubs*, was initiated in the textile and metal finishing sectors.

3.10 A further DANCED funded project on Cleaner Production has been initiated. The author provided input to the project design in 1998 (textiles and metal finishing) and inception meeting in 2000 (metal finishing).

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APPENDICES

APPENDIX A: QUESTIONNAIRES

A1 NETWORKING PARTNERS

GENERAL INFORMATION		UPDATE:	
Company: Address: Tel.number: Fax number:			

BLACK-BOX:	CONTACT PERSON:	FUNCTION	REMARKS:

UTILITY PROVIDING ORGANISATIONS

UPDATE:

QUESTIONS:	ELECTRICITY PROVIDING COMPANY:	WATER PROVIDING COMPANY:
Name and address of utility providing organisation:		
Name contact person:		
Costs per year for company:		
Consumption rate of company relative to the area: * high * normal * low		
Intensity of association: * high * normal * low		
What water- or electricity-saving techniques have been implemented, if any: What recommendations can be made?		
What contacts (problems, co-operation) between company and the Council have there been in the past, are there presently and are foreseen in the future - i.t.o materials, finance and information ?		
Remarks:		

SUPPLIERS

UPDATE:

NAME	AREA	CATEGORIE	AID / POP *	AMOUNTS OF PRODUCTS PER YEAR * HIGH * MEDIUM * LOW	INTENSITY OF SUPPLY (RELATION) * HIGH * MEDIUM * LOW	RATE OF IMPORTANCE OF SUPPLIER * HIGH * MEDIUM * LOW	TRANSPORT (MEANS, WHEN HOW MUCH)	REMARKS
Local suppliers:								
National suppliers:								
International Suppliers:								

General remarks:

* AID = Aiding material (not part of product)
POP = Part of Product-material

WASTE TREATMENT COMPANIES

UPDATE:

1) HAZARDOUS WASTE STREAMS

HAZARDOUS WASTE STREAM	AMOUNTS PER YEAR	WASTE TREATMENT COMPANY (NAME, ADDRESS AND CONTACT PERSON)	COLLECTION BY WASTE TREATMENT COMPANY (HOW OFTEN, WHERE)	WASTE TREATMENT PROCESS BY WASTE TREATMENT COMPANY	INTENSITY OF ASSOCIATION (RELATION) * HIGH * MEDIUM * LOW	REMARKS (OTHER INFORMATION SOURCES)

2) NON HAZARDOUS WASTE STREAMS

NON HAZARDOUS WASTE STREAM	AMOUNTS PER YEAR	WASTE TREATMENT COMPANY (NAME, ADDRESS CONTACT PERSON)	COLLECTION BY WASTE TREATMENT COMPANY (HOW OFTEN, WHERE)	WASTE TREATMENT PROCESS BY WASTE TREATMENT COMPANY	INTENSITY OF ASSOCIATION (RELATION) * HIGH * MEDIUM * LOW	REMARKS (OTHER INFORMATION RESOURCES)

MAJOR COMPETITORS

UPDATE:

NAME	ADDRESS	COMPETITION REGION * INTERNATIONAL * NATIONAL * LOCAL	PRODUCTS MANUFACTURED	COMPETITION TO COMPANY * HIGH * MEDIUM * LOW	AREA OF STRENGTH/ WEAKNESS COMPETITOR	INFORMATION EXCHANGES	REMARKS

MAJOR CLIENTS

UPDATE:

NAME, REGION, DURATION OF RELATIONSHIP IN YEARS	SIZE OF COMPANY * LARGE * MEDIUM * SMALL	SECOND-TIER CLIENTS	PRODUCTS PURCHASED	INTENSITY OF ASSOCIATION (RELATION) * HIGH * MEDIUM * LOW	YEARLY PURCHASE OF PRODUCTS (% - PROFITS)	TRANSPORT (MEANS, WHEN HOW MUCH)	REMARKS
							GENERAL REMARKS:

SUPPORT ORGANISATIONS

UPDATE:

NAME AND ADDRESS	PURPOSE OF ASSOCIATION	INTENSITY OF ASSOCIATION * HIGH * MEDIUM * LOW	COST PER YEAR / PROJECT	INFORMATION EXCHANGES	REMARKS

Think of:
* Research Institutions
* Knowledge Providing Organisations
* Industry / Employer Organisations
* Employee Organisations /Trade Unions

LOCAL GOVERNMENT & COMMUNITY ORGANISATIONS

UPDATE:

NAME AND ADDRESS	PURPOSE OF ASSOCIATION	INTENSITY OF ASSOCIATION * HIGH * MEDIUM * LOW	COST PER YEAR / PROJECT	INFORMATION EXCHANGES	REMARKS

Think of:
* environmental legislation
* sponsoring
* Non Governmental Organisations (Greenpeace etc)
* Day-care children (Chreche)

A2 POTENTIAL FOR INDUSTRIAL SYMBIOSIS

Name: ____________________________

Company: ________________________

PERSONAL INFORMATION

1. Position: _____________________

   Responsibilities?

2. How long in present position? ________ How long with the company?________

BACKGROUND INFORMATION

3. What is your core product line?

Values	cohesiveness within the company	communication, sense of direction, vision, stability, working together

4. Who and where are your customers? Your competitors?

Values	seek out new possibilities (outward looking)	liaisons, new products, new markets, recent changes, benchmarking against others
Intent	form informal partnerships and alliances	alliance, partnership, work together, groups, associations, sharing, membership
Capacity	deal with external pressures/constraints	relations with customers and suppliers, neighbours, typical practice in industry, proactive or reactive, leader or follower, contacts with others in the same business

5. What is the state of your industry sector right now (i.e. not just your company)? Are there any additional key issues facing your company right now?

Values	cohesiveness within the company	communication, sense of direction, vision, stability, working together
Intent and Capacity	disclose information about company to external parties	relationship with community, competitors, trade secrets, public relations, things to hide
Intent and Capacity	commit human and financial resources	time, people, money, profit or loss, consultants, training, commitment
Intent	form informal partnerships and alliances	alliance, partnership, work together, groups, associations, sharing, memberships
Capacity	deal with the change (e.g. morale, 'saturation level')	other initiatives, legal compliance, stress, satisfaction, capacity, slack, overtime, motivation
Capacity	deal with external pressures/constraints	relations with customers and suppliers, neighbours, typical practice in industry, proactive or reactive, leader or follower, contacts with others in the same business

6. Are you a public or private company? Part of a larger corporation? If so, what kind of interactions happen between the company and head office / other subsidiaries?

Values	cohesiveness within the company	communication, sense of direction, vision, stability, working together

Intent	form informal partnerships and alliances	alliance, partnership, work together, groups, associations, sharing, memberships
Capacity	deal with external pressures/constraints	relations with customers and suppliers, neighbours, typical practice in industry, proactive or reactive, leader or follower, contacts with others in the same business

7. How many people work here? (including managerial, excluding contractors). Within the past two years, have there been any major changes in number of personnel?

Intent and Capacity	commit human and financial resources	time, people, money, profit or loss, consultants, training, commitment
Capacity	deal with the change (e.g. morale, 'saturation level')	other initiatives, legal compliance, stress, satisfaction, capacity, slack, overtime, motivation

8. Is there a management model that is applied throughout the organisation (e.g. MBO, TQM)? Does the company participate in management systems such as NOSA and ISO 9002? How, for example, are environmental issues / problems managed?

Values	responsibility towards the environment	recycling, waste, community, place on 'evolutionary ladder'
Values	wanting to learn	training, mistakes, failures, successes, information, keeping current, best practices
Intent and Capacity	commit human and financial resources	time, people, money, profit or loss, consultants, training, commitment
Capacity	know techniques for improving environmental performance	waste minimisation, EMS, cleaner production, recycling, substitution, monitoring, planning, EM
Capacity	deal with the change (e.g. morale, 'saturation level')	other initiatives, legal compliance, stress, satisfaction, capacity, slack, overtime, motivation

9. How does communication occur within the organisation, both top-down and bottom-up within the company? For example, how are decisions made and communicated to the relevant people?

Values	wanting to learn	training, mistakes, failures, successes, information, keeping current, best practices
Values	cohesiveness within the company	communication, sense of direction, vision, stability, working together
Intent	form informal partnerships and alliances	alliance, partnership, work together, groups, associations, sharing, memberships
Capacity	get the 'key people' on board	communicate, agree, delegate, harmony, 'old-timers', sell

VALUES

10. How long has the company been in business? Describe the history of the company to the present day. Can you recall any stories/myths around your historical figures?

Values	think of the long term	history, company myths, planning, strategy
Values	cohesiveness within the company	communication, sense of direction, vision, stability, working together

11. Describe your longest serving employee. What is he/she like? Does this employee's seniority afford them any special status / privileges / respect in the company? Are there others within the company which are afforded special status / respect by peers or management? Why do they have this status?

If you really need to 'get something done' or 'get someone on-side', who do you go to? What makes this person effective for you? Are there other such 'key' people in the company? How well do these 'key' people relate to and communicate with one another?

Values	think of the long term	history, company myths, planning, strategy
Values	cohesiveness within the company	communication, sense of direction, vision, stability, working together
Intent	form informal partnerships and alliances	alliance, partnership, work together, groups, associations, sharing, memberships
Capacity	get the 'key people' on board	communicate, agree, delegate, harmony, 'old-timers', sell

12. How well do the words "above and beyond the call of duty" describe your company and its employees? Is the stress level of you and your peers manageable? Is excessive 'sick leave' a problem? Does overtime in the company tend to be periodic or chronic? What does the company do to keep its staff happy?

Do people in the company socialise as a group outside of work? Is this done through the company, or informally?

Values	go the 'extra mile'	overtime, donations, involvement, dedication, loyalty
Values	seek out new possibilities (outward looking)	liaisons, new products, new markets, recent changes, benchmarking against others
Values	think of the long term	history, company myths, planning, strategy
Values	cohesiveness within the company	communication, sense of direction, vision, stability, working together
Intent	form informal partnerships and alliances	alliance, partnership, work together, groups, associations, sharing, memberships
Capacity	deal with the change (e.g. morale, 'saturation level')	other initiatives, legal compliance, stress, satisfaction, capacity, slack, overtime, motivation

13. Describe the company's relationship with its neighbours / the community (e.g. friendly/unfriendly/indifferent). What kinds of communication go on? What other forms of interaction go on - e.g. programmes, sponsorships, lawsuits? What is the attitude within the company towards neighbours and the community?

What is the attitude/awareness within the company towards the environment? (e.g. inconvenience, constraint, business opportunity)?

Values	responsibility towards the environment	recycling, waste, community, place on 'evolutionary ladder'
Values	go the 'extra mile'	overtime, donations, involvement, dedication, loyalty
Values	think of the long term	history, company myths, planning, strategy
Intent and Capacity	disclose information about company to external parties	relationship with community, competitors, trade secrets, public relations, things to hide
Capacity	know techniques for improving environmental performance	waste minimisation, EMS, cleaner production, recycling, substitution, monitoring, planning, EM
Capacity	deal with external pressures/constraints	relations with customers & suppliers, neighbours, typical practice in industry, proactive / reactive, leader or follower, contacts with others in the same business

14. What kinds of training and development happen within the company? More generally, how does learning happen within the organisation? (For example, what happens to ensure mistakes are not repeated?). How are problem areas identified, and what steps are taken to solve them? Do the same problems reappear over and over again?

Values	seek out new possibilities (outward looking)	liaisons, new products, new markets, recent changes, benchmarking against others
Values	think of the long term	history, company myths, planning, strategy
Values	wanting to learn	training, mistakes, failures, successes, information, keeping current, best practices
Values	cohesiveness within the company	communication, sense of direction, vision, stability, working together
Intent	take risks	chance, change, pressure, uncertainty, unknown, opportunity

15. Are there any 'longer-term' projects, programmes or initiatives underway? (could be technical, administrative, human resources, marketing or otherwise) i.e. will probably take more than one year / five years / ten years to complete.

Within the past two years, have any major changes happened in the company? (could be technical, administrative, human resources, marketing or otherwise). How often do such changes happen?

How are people in the company coping with these long term programmes / recent changes? Was there resistance from the company, and if so, how has it been overcome?

Values	seek out new possibilities (outward looking)	liaisons, new products, new markets, recent changes, benchmarking against others
Values	think of the long term	history, company myths, planning, strategy
Values	wanting to learn	training, mistakes, failures, successes, information, keeping current, best practices
Values	cohesiveness within the company	communication, sense of direction, vision, stability, working together
Intent	take risks	chance, change, pressure, uncertainty, unknown, opportunity
Intent and Capacity	commit human and financial resources	time, people, money, profit or loss, consultants, training, commitment
Intent and Capacity	innovate / experiment (with production processes as well as systems)	changes to process, age of equipment, number of different products, markets, deadlines, stock, expert, foreman, engineer
Capacity	deal with the change (e.g. morale, 'saturation level')	other initiatives, legal compliance, stress, satisfaction, capacity, slack, overtime, motivation

16. Are you aware of any potential long-term environmental, health or safety liability or risk arising out of your operation? If so, can the risks be minimised, and how may this / is this being done?

At present, what are your key environmental problems, and how are they dealt with (both now and plans for the future)?

Values	responsibility towards the environment	recycling, waste, community, place on 'evolutionary ladder'
Values	go the 'extra mile'	overtime, donations, involvement, dedication, loyalty
Values	think of the long term	history, company myths, planning, strategy

Intent and Capacity	commit human and financial resources	time, people, money, profit or loss, consultants, training, commitment
Capacity	know techniques for improving environmental performance	waste minimisation, EMS, cleaner production, recycling, substitution, monitoring, planning, EM
Capacity	know / understand the production process: key parameters and influence thereof quantity and quality of material and energy inputs/outputs	technical ' know-how', modify, consequences, back-up, information, search, benchmark, common practice, amounts, type, contaminants, values, measurement, monitoring, checking
Capacity	deal with external pressures/constraints	relations with customers & suppliers, neighbours, typical practice in industry, proactive / reactive, leader / follower, contacts with others in the same business

INTENT / CAPACITY

How flexible are the company's production equipment and processes? Where is a change / substitution of materials possible? What would the costs of doing so?

Are there parts of your process particularly troublesome that you'd like to see modified? Is your process essentially static, or are modifications and variations sometimes tried? How difficult is it to get something like this changed? How are proposals for changes judge?

Is the company's expertise in its process 'in-house' or does it depend on outside (head office, overseas) specialists? What sort of technical 'know-how'/RD is available in the company?

Values	seek out new possibilities (outward looking)	liaisons, new products, new markets, recent changes, benchmarking against others
Values	wanting to learn	training, mistakes, failures, successes, information, keeping current, best practices
Intent	take risks	chance, change, pressure, uncertainty, unknown, opportunity
Intent and Capacity	innovate / experiment (with production processes as well as systems)	changes to process, age of equipment, number of different products, markets, deadlines, stock, expert, foreman, engineer
Capacity	know / understand the production process: key parameters and influence thereof quantity and quality of material and energy inputs/outputs	technical ' know-how', modify, consequences, back-up, information, search, benchmark, common practice, amounts, type, contaminants, values, measurement, monitoring, checking
Capacity	get the 'key people' on board	communicate, agree, delegate, harmony, 'old-timers', sell
Capacity	deal with the change (e.g. morale, 'saturation level')	other initiatives, legal compliance, stress, satisfaction, capacity, slack, overtime, motivation

18. What sorts of things place limits on product quality i.e. Which is the limiting factor – customer specifications, process constraints or supply restrictions? What are the critical things that 'make-or-break' out of specification products? How tight must be your production / delivery schedules and stock control?

Values	seek out new possibilities (outward looking)	liaisons, new products, new markets, recent changes, benchmarking against others

Intent and Capacity	innovate / experiment (with production processes as well as systems)	changes to process, age of equipment, number of different products, markets, deadlines, stock, expert, foreman, engineer
Capacity	know / understand the production process: key parameters and influence thereof quantity and quality of material and energy inputs/outputs	technical ' know-how', modify, consequences, back-up, information, search, benchmark, common practice, amounts, type, contaminants, values, measurement, monitoring, checking
Capacity	deal with external pressures/constraints	relations with customers and suppliers, neighbours, typical practice in industry, proactive or reactive, leader or follower, contacts with others in the same business

19. Has the company ever taken a chance on something 'out of the ordinary' and seen a benefit? A loss? How big was the element of risk in the 'chance'?

How well do the words 'innovative' and 'cutting edge' describe this company?

Values	seek out new possibilities (outward looking)	liaisons, new products, new markets, recent changes, benchmarking against others
Values	wanting to learn	training, mistakes, failures, successes, information, keeping current, best practices
Intent	take risks	chance, change, pressure, uncertainty, unknown, opportunity
Intent and Capacity	innovate / experiment (with production processes as well as systems)	changes to process, age of equipment, number of different products, markets, deadlines, stock, expert, foreman, engineer

20. Does the company undertake to talk to / negotiate with outside parties (authorities, community, customers, suppliers)? What is the driver for these discussions? Is any part of the operation possibly a 'trade secret'? Does the company need to 'obtain permission' from a Head Office or other external party for such negotiations?

Does the company belong to a trade, business or similar organisation with common aims? If so, what role does the company play?

Values	seek out new possibilities (outward looking)	liaisons, new products, new markets, recent changes, benchmarking against others
Intent	form informal partnerships and alliances	alliance, partnership, work together, groups, associations, sharing, memberships
Intent and Capacity	disclose information about company to external parties	relationship with community, competitors, trade secrets, public relations, things to hide
Capacity	deal with external pressures/constraints	relations with customers and suppliers, neighbours, typical practice in industry, proactive or reactive, leader or follower, contacts with others in the same business

WRAP-UP

21. If you could change one thing within the company, what would you change?

22. Are there any things which we didn't talk about that you think we should have asked?

APPENDIX B: CASE STUDY 1

B1 NETWORK ANALYSIS

All companies form part of a network, interacting with suppliers and buyers up and down the production line. Company A interacts with cotton and chemical suppliers, clothing stores and competitors, for instance. The main or level 1 networking partners have been illustrated in **Figure B1.1**. Each organisation contributes to the life cycle of the product.

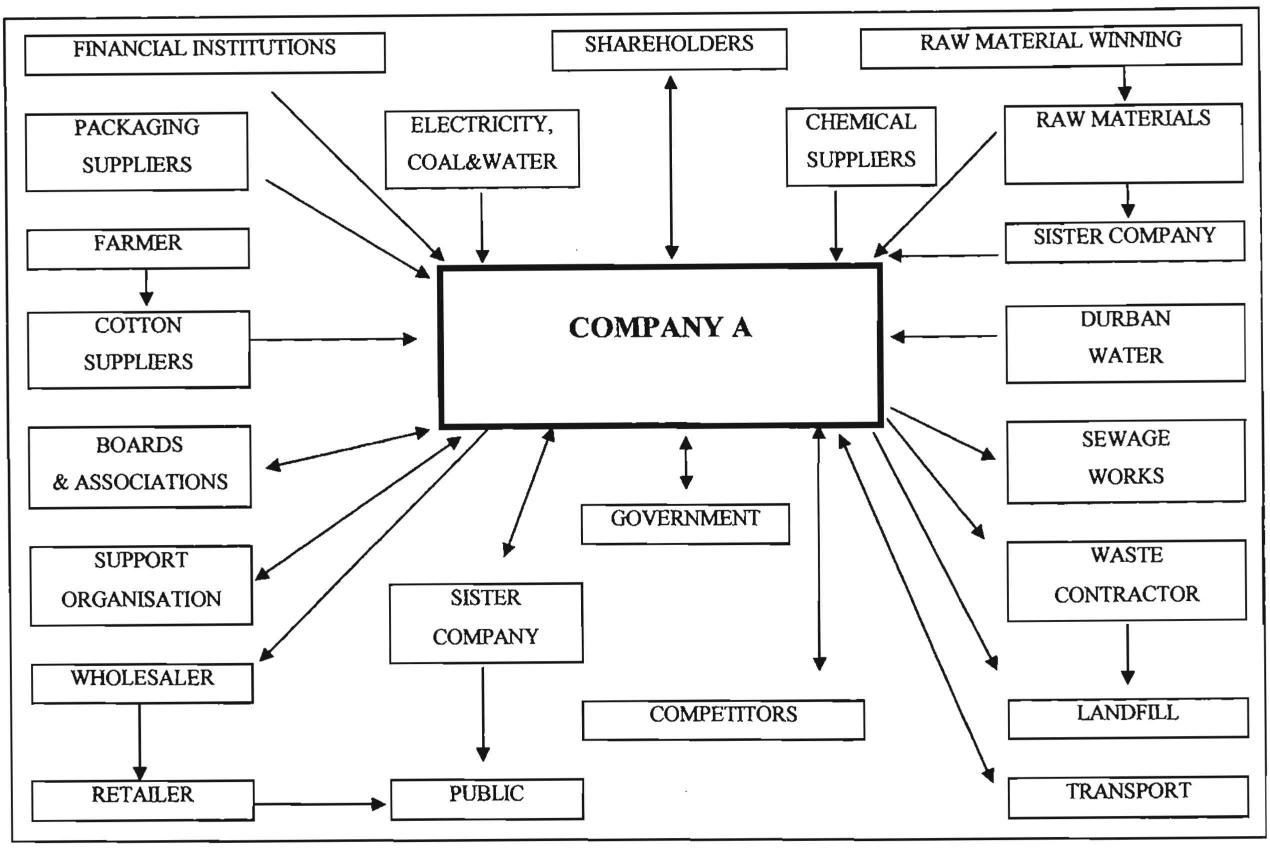

Figure B1.1: Level 1 stakeholder relationships of Company A, a textile manufacturer.

Networking interactions may involve product, information or money exchange; the frequency is dependent on the type of relationship and demand. A more detailed assessment of relationship intensities was conducted by a Cape Town University student, van Beers, 2000, a general network map has been illustrated (**Figure B1.2**).

The main material suppliers, buyers and waste contractors associated with Company A were identified. Waste contractors have been tabulated (**Table B1.1**). In developing good network relationships, Company A wants to be in a position where it can demand that no pesticides be used during cotton growth, for example, or that the packaging comprises only recyclable wrappings.

Symbiotic relationships, mean that cleaner production ideas and waste minimisation principles are diffused throughout the network. The company's potential to participate in an industrial symbiotic network was investigated.

Table B1.1: Waste contractors that interact with Company A.

Waste contractor	Waste stream	Financial effect
Drum Trading	drums tampons sanitary bags / waste sacking textile waste redundant machine scrap metal sliver / pneumofill cloth/thread waste droppings cotton crepe / gauze elastoform	benefit
Durban Metro	sewage	expense
EDB Packaging	re-usable cartons cotton crepe cloth waste	benefit
Intercloth	cotton crepe / gauze	benefit
Lynx Exchange	cotton crepe / gauze re-usable cartons scrap plastic, paper & cardboard	benefit
Phoenix Concrete Fencing	scrap baling wire	benefit
Wastetech	unrecyclable waste chemicals	expense

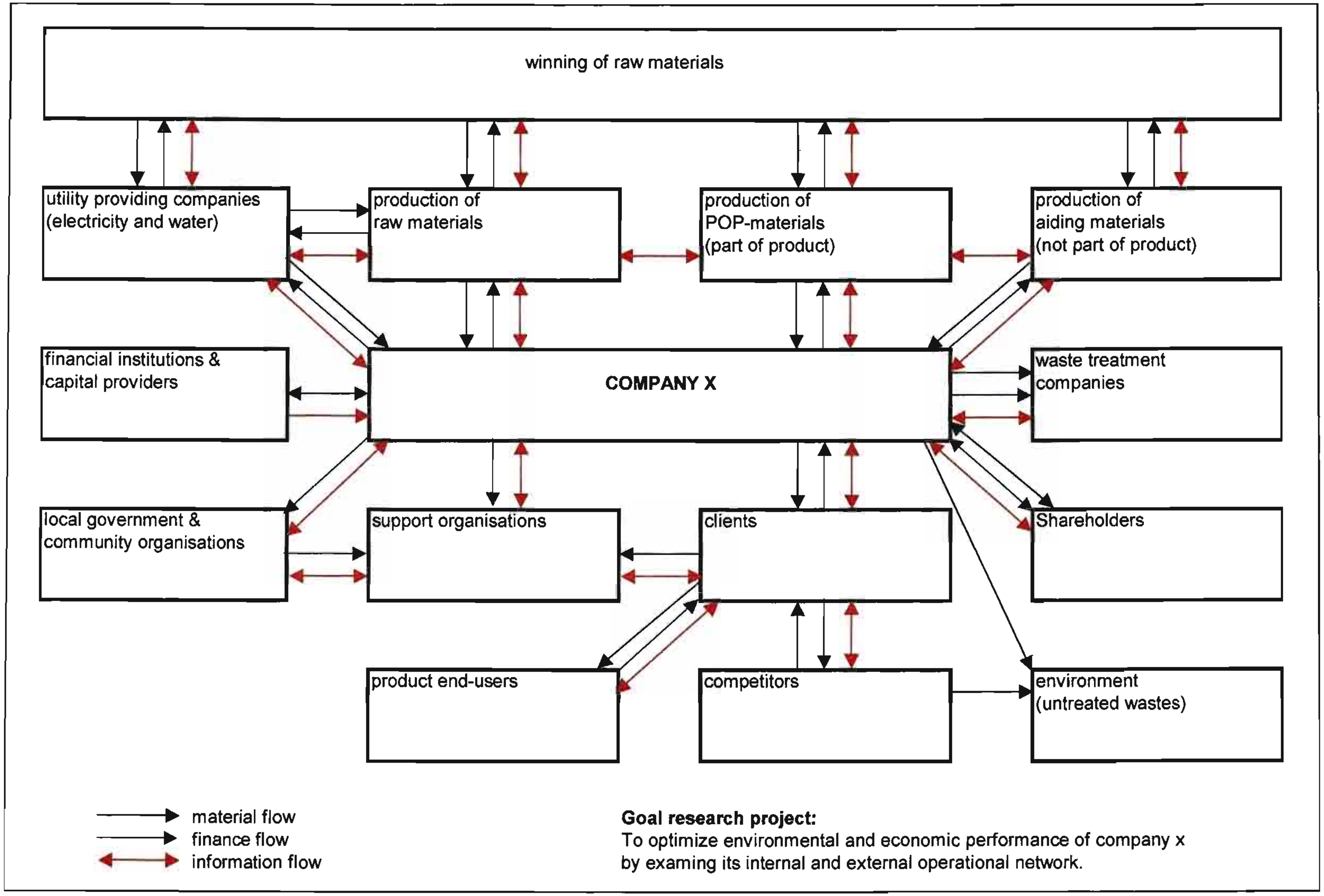

Figure B1.2: A generalised network map.

B2 POTENTIAL FOR INDUSTRIAL SYMBIOSIS

Three employees were interviewed in March 1998, using a detailed questionnaire compiled by African Environmental Solutions (**Appendix A2**). Key aspects from the interviews established that Company A was partially suited to participation in an industrial symbiosis network. The company had a high degree of technical knowledge, taking long term views in its planning and strategy, and demonstrating innovation with the equipment at its disposal. Company constraints included internal communication barriers; reluctance to alter practices for fear of damaging the specific product brand reputation; confidentiality regarding products; budgeting and resource allocation practices which may constrain innovation and increase the time for resolution of problems; a somewhat politicised decision making process within the company; and the general lack of awareness regarding environmental issues or opportunities. Such issues need to be improved in order to obtain maximum benefit from participating in an industrial symbiosis network. Success of symbiotic networks is based on each company promoting clean operations, by minimising waste at source as one important aspect of waste minimisation.

B3 WASTE MINIMISATION PREASSESSMENT

Table B3.1: Members comprising the project team.

ROLE PLAYERS
Process manager
Opening, Blending, Spinning & Preparation Manager
Weaving Manager
Bleach House Manager
Water & Steam Manager
Project Development Manager
Technical Production Planner
Surgical Dressing Manager
Chemical Engineer

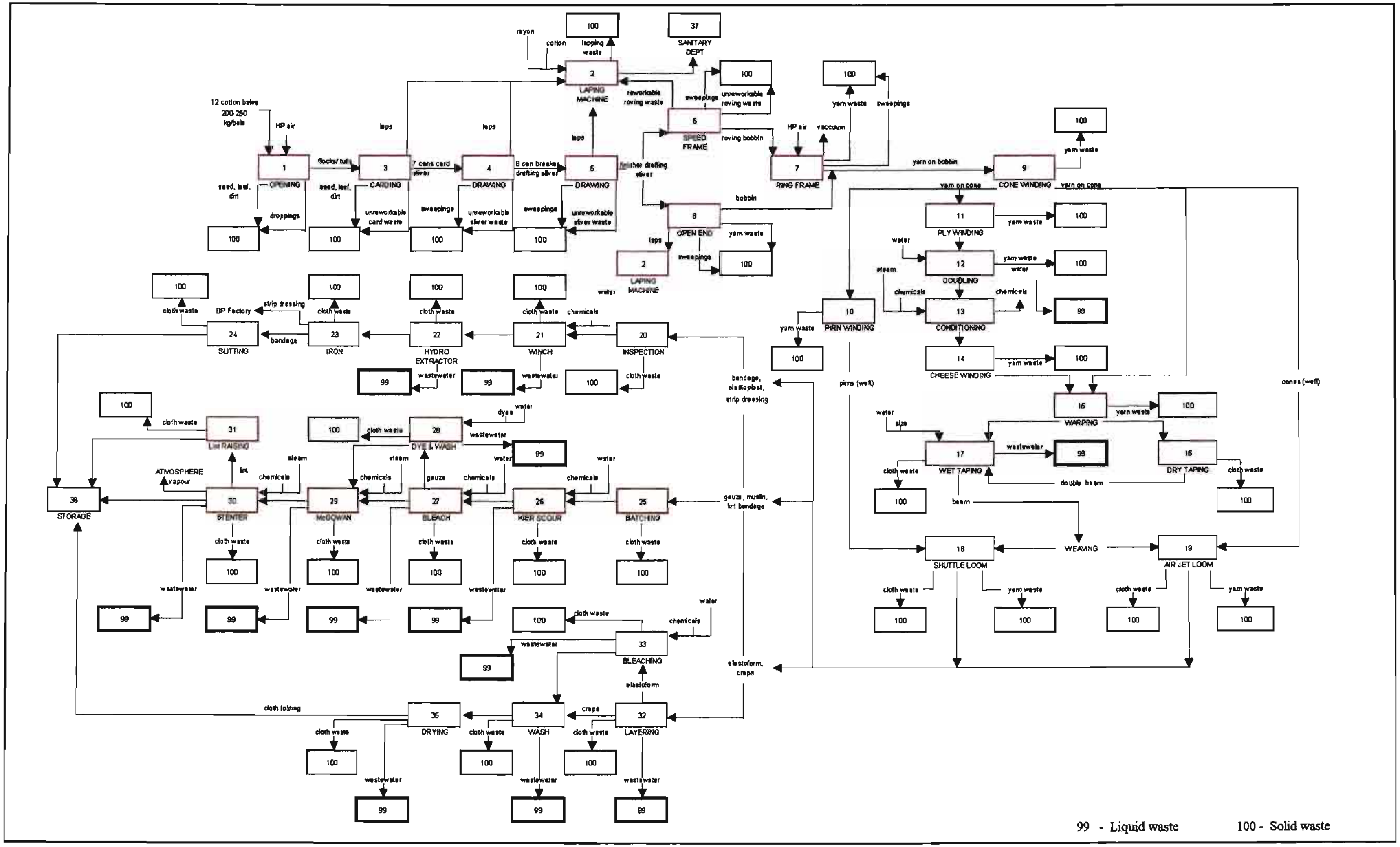

Figure B3.1: Overview of textile processes at Company A.

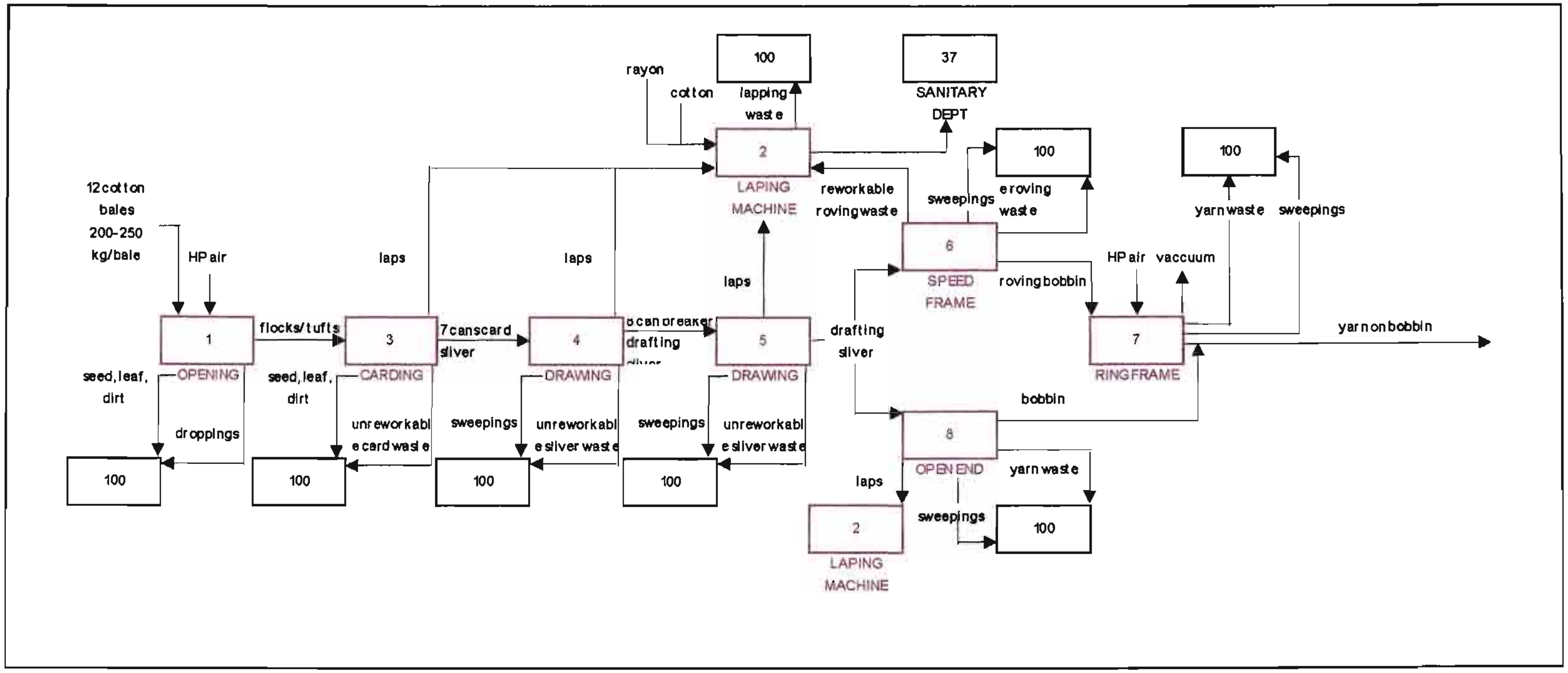

Figure B3.1a: Opening of cotton through to ring framing.

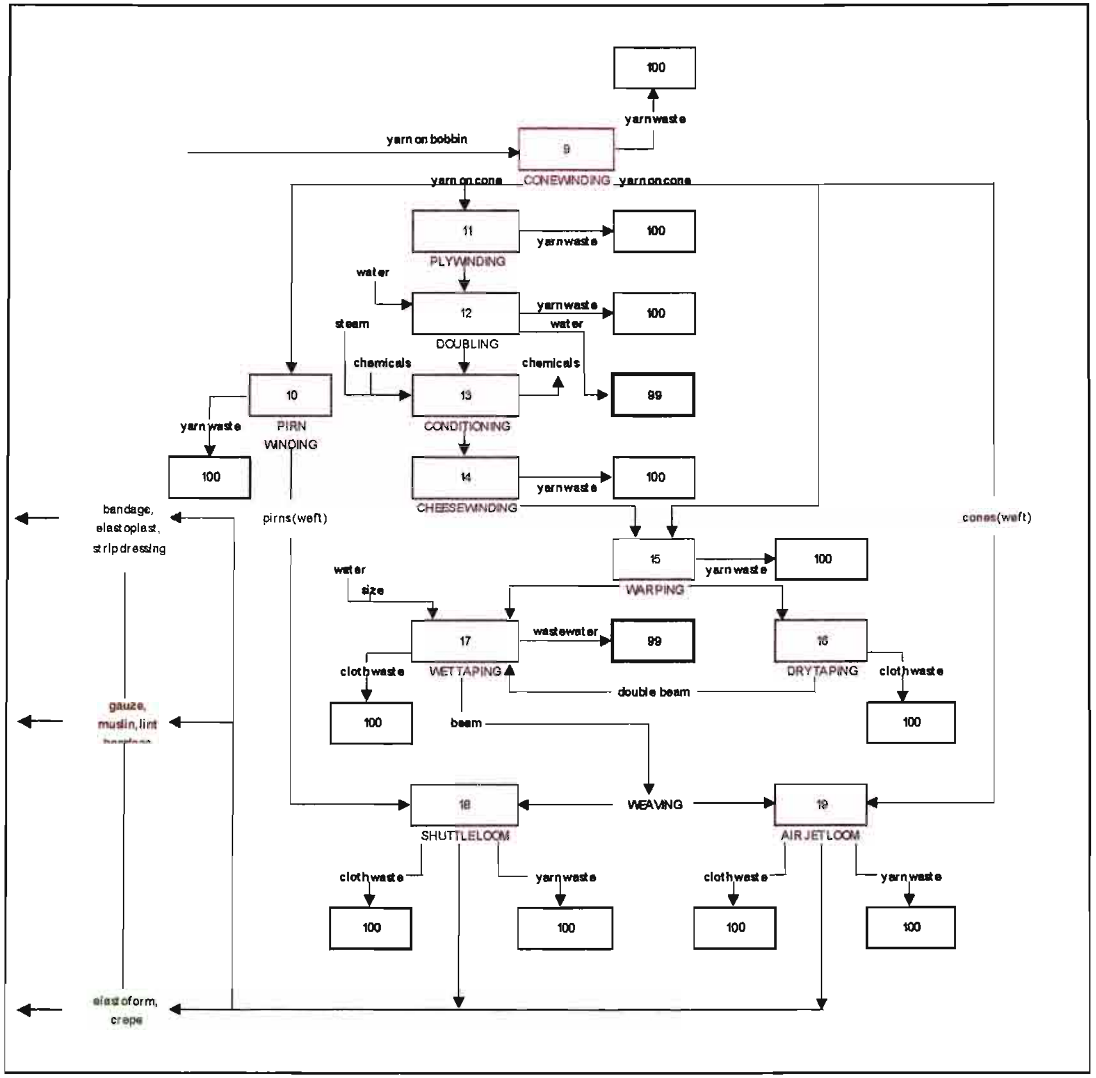

Figure B3.1b: Cone winding through to weaving.

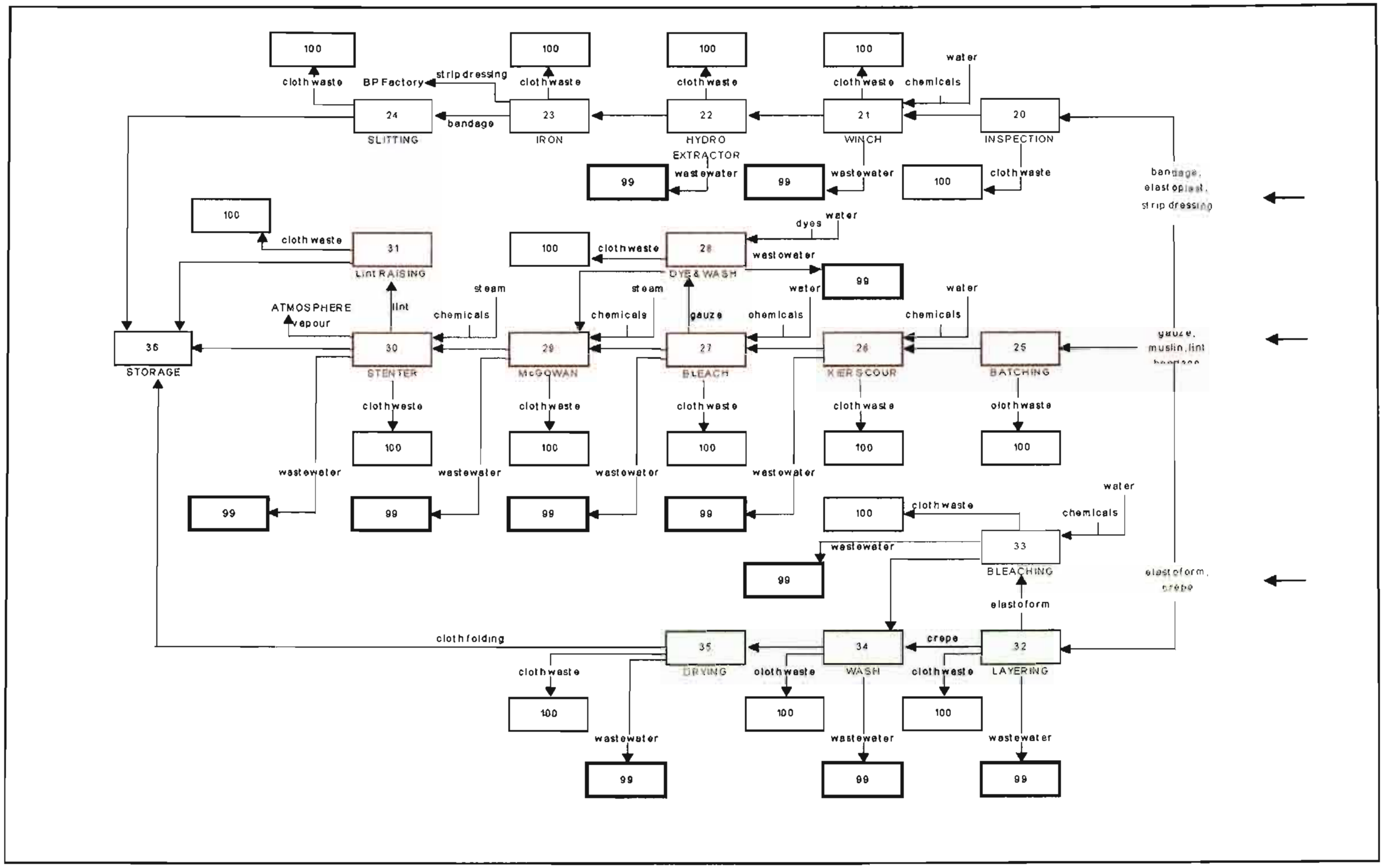

Figure B3.1c: Bleach house processes.

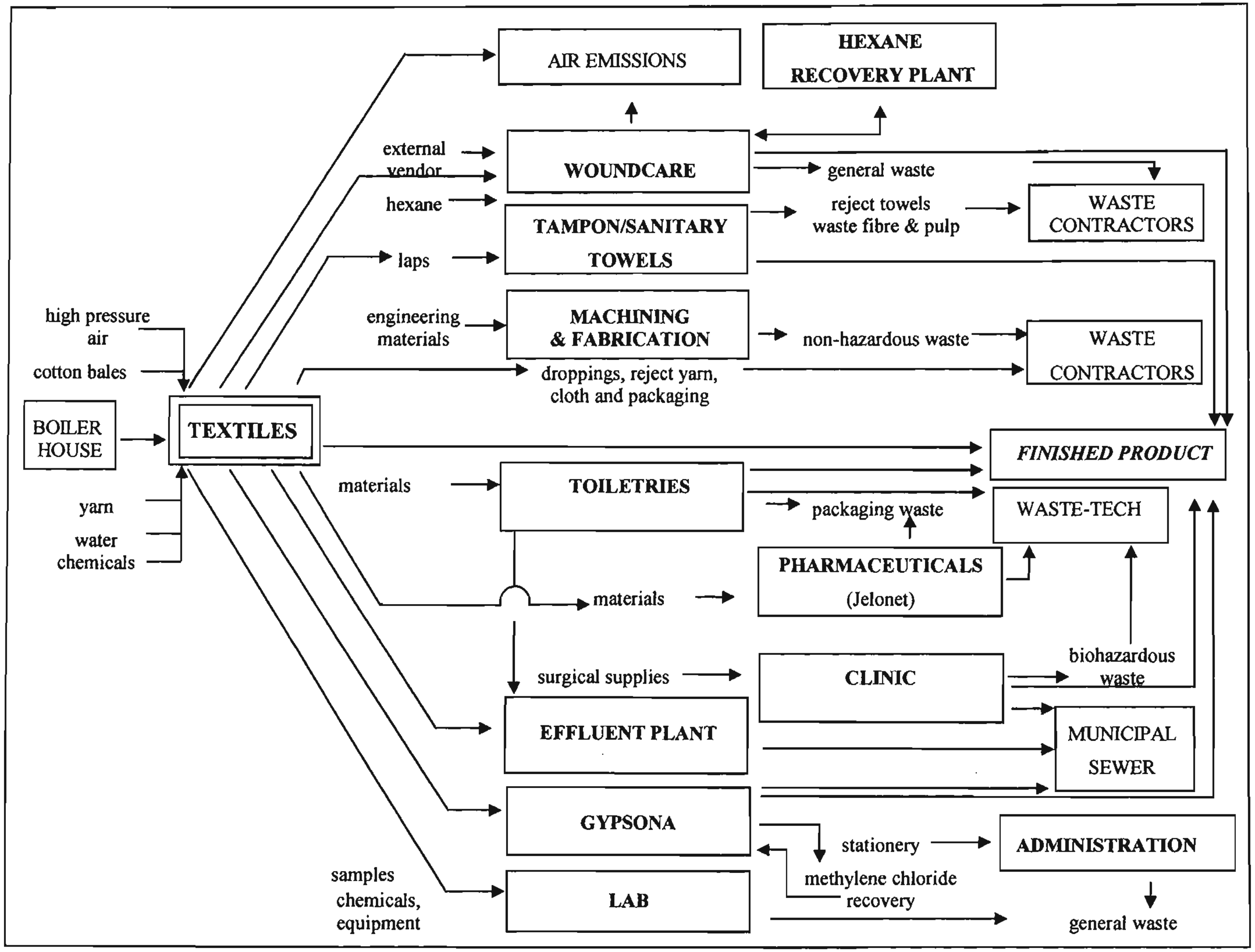

Figure B3.2: Interrelation of textile manufacture in Company A, with product and effluent flows.

B4 MASS BALANCES

Combined into an overall textile processing equation, mass balances of material flows are depicted in **Figure B4.1**. Mass balances of cloth and water have been further detailed.

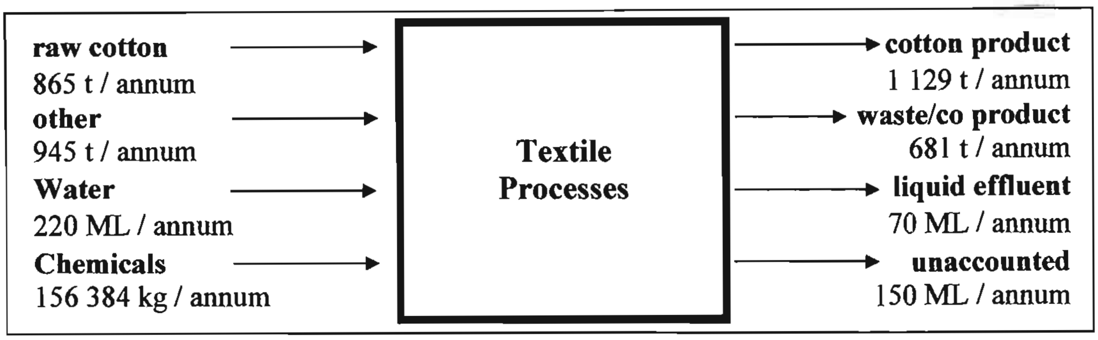

Figure B4.1: Overall inputs and outputs into the textile process (1997).

Cloth Production

Detailed mass balances of cotton inputs and outputs were tabulated (**Table B4.1**) based on raw data and employee estimates received from the company. Additional cotton products were brought into the company and sold during the manufacturing process which, for simplicity, were not included.

Approximately 865 t / annum of raw cotton bales are brought onto site. Approximately 455 t / annum of cotton is reworkable waste and measured waste for which allowances are made. A further 144 t / annum of cotton products are used for sampling and 82 t / annum is lost during the various processes via wash away, fly or other related factors. Fly and wash away of fabric are difficult parameters to monitor, however, estimates made by the company were included in the mass balancing.

Table B4.1: List of cotton inputs and outputs for 1998.

Description	Department	Note	Mass (t / annum)	Total Mass (t / annum)	Total Mass %	Value of item / annum (R / annum)[1]	Value of item / annum Total (R / annum)
COTTON IN				**1810.0**	**100.0**		
raw cotton fibre		2	843.4		97.5		
veg. matter, oils, waxes			21.6		2.5		
yarn stock		2	852.0				
medtex yarn		2	54.0				
import cloth/unaccounted		9	39.0				
COTTON OUT				**1810.0**	**100.0**		
process production	bleach house	3		1129.0	62.3		26 367 795.0
total measured waste		3		116.9	6.5	2 520 668.0	16 838 890.0
measured waste	preparation		7.4				
measured waste	spinning		58.5				
measured waste	size & weave		53.5				
measured waste	bleach house		11.9				
measured waste	sanpro		15.6				
reworkable waste		4		338.0	18.7	3 070 730.0	
sampling	quality control	5		144.0	8.0	1 918 080.0	
fly	prep, spinning, sanpro	6		6.1	0.3	104 087.0	
wash away	bleach house	7		56.5	3.2	1 318 390.0	
fly&wash away	size & weave	8		19.5	1.0	596 950.0	

The value of item (1) is calculated using price / kg given in the administrator's waste report for periods 6 & 11 for each department. Raw cotton, yarn stock and Medtex yarn (2) are calculated using the 13-Jan-98 quoted year-to-date average use per week x 47 weeks for the annual consumption. The bleach house production and waste values (3) are taken from the textile administrator's waste report for periods 6 & 11. Based on employee estimates about 40 % of total production in the sanpro department is reworkable (4). Based on employee estimates approximately 12 t / month of cloth is sampled (5). Cotton fly (6) is primarily generated at the early stages of cotton processing, employees estimate 0.1 % of production in the preparation, spinning and sanpro departments. The price / kg amount is based on these three departments. Wash away (7) is estimated at 5 % of bleach house process production, the major wet process. Loss of cotton via fly or wash away for the weaving and sizing department (8) is estimated at 1 %. The difference between output and input (9), 39 t / annum, comprises import cloth or unaccounted for materials.

Chemical use

Cloth was subjected to wet processes, many of which require chemical input. A summarised list of chemicals used in the textile processes was tabulated (**Table B4.2**). Recorded stock sheets indicated that the chemical components with the highest annual consumption by mass were sodium hydroxide flakes (32 759 kg/annum), Actwet G05/030 (17 343 kg/annum), and Ricadex B4 (29 422 kg/annum). Sodium hydroxide was commonly used in bleaching, scouring and dyeing processes. Actwet was used as a wetting agent. Ricadex was a starch-based sizing agent used for industrial cloth, but the common sizing agent used for yarn was an organic compound, carboxymethylcellulose. Various direct and vat dyes were used, but only a small proportion of cloth was dyed and thus impact of the dye on effluent colour was considered to be insignificant. Chemicals that may pose a problem to the surrounding waters were softening agents which have been reported to be endocrine disrupting chemicals.

Table B4.2: Inventory of some commonly used textile chemicals.

Chemical	Description	Uses
Actwet	wetting agent	bleach, kier, desize, direct dye
Calcium hypochlorite	pH control	bleach
Carboxymethylcellulose	starch	sizing agent
Caustic soda	scour	kier, vat dye reduction
Caustic soda flakes	pH control	bleach
Caustic potash	scour	kier, vat dyeing
Crosoft	softening agent	softening
Dicalcium phosphate	dispersant	kier, vat dyeing
Ethylene diamine tetraacetic acid	chelating agent	direct dyeing
Hydrochloric acid (30 %)	acid	bleach, vat dyeing
Hydrogen peroxide (50 %)	bleach	bleach, vat dye oxidation
Matexil	setting agent	bleached gauze, muslin, lint bandage, vat dyeing
Ricadex	starch-based	sizing agent
Sandofix	fixing agent	direct dyeing
Soda ash	pH control	direct dyeing, vat dye bleaching, neutralising, and soaping
Stabicol	stabiliser	bleach
Tetrodirect brown BRL	direct dye	bandage, Elastoplast, strip dressing direct dye

Water use and waste water produced

Water flows in and out of the factory were tabulated (**Table B4.3**). Process water (1) was primarily obtained from a municipal source (207 ML / annum taken from the water account), and occasionally borehole water was used (13 ML / annum measured volume / time).

Table B4.3: Water sources, losses and uses during 1997.

Description	Notes	Volume (kL / annum)	Total volume (kL / annum)	(%)
WATER IN			**220 836**	**100**
Municipal water	1, Table B4.4	207 516		94
Bore hole water	1	13 320		6
WATER OUT			**220 836**	**100**
Discharge to sewer	2	70 000		32
Boiler consumption	Table B4.5	13 560		6
Cloth absorption	3	37		negligib le
Domestic purposes	Table B4.6	36 053		16
Cooling tower & washer	4	33 000		15
Unaccounted leakages	5, Table B4.7	8 157		4
Process losses, Pharmaceuticals, sizing	Table B4.8	1 493		1
Unaccounted water out	6	58 533		26

Table B4.4: Average monthly municipal supply in 1997.

Meter ID number	Average consumption (kL / annum)
GS 2362423	169 260
GS 2679555	480
BC 601985	Negligible
CK 594488	2 172
HS 0673	360
EC 114533	Negligible
EC 3278031	35 244
TOTAL	**207 516**

Waste water was treated on-site (**Figure B4.2**) prior to being discharged to sewer (2). Discharged effluent was calculated using a V-notch. The calculated value of 70 000 kL / annum was significantly less than the 100 000 kL / annum for which the Metro Council charges the company. The remainder of water was used and lost via various means, namely boiler use, cloth absorption, domestic use, evaporation, leakages and process losses. Of the total incoming water, domestic and evaporation losses were responsible for the majority water use. The company estimated water absorption by cloth (3) at about 2.5 x dry weight of cloth (1500 t / annum). Evaporation by the cooling towers (12 400 kL / annum) and washer make-up (20 600 kL / annum) (4) were obtained from the manufacturer's specifications. Unaccounted leakages (5) were calculated during shut-down in December 1997. This value was obtained from the difference between the water meter reading, and contractor use plus obvious leakages noted. Other process losses were also incorporated into the mass balancing. Although all these aspects were included in the mass balance, a total of 58 533 kL / annum of water use (more than 26%) was unaccounted.

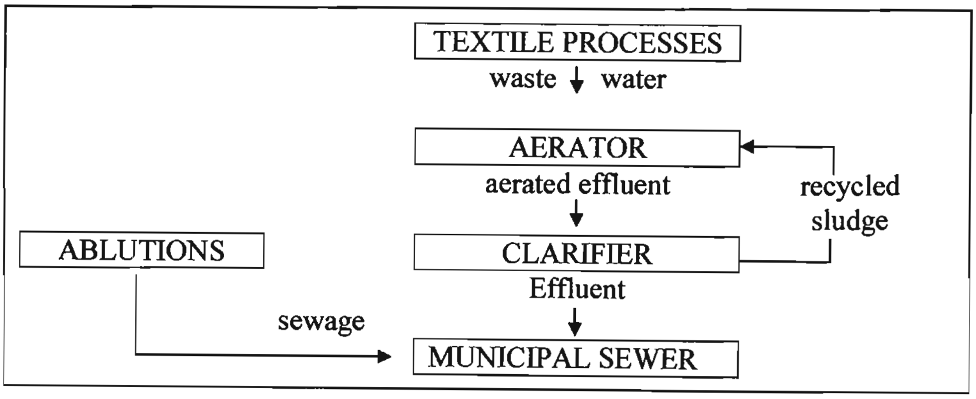

Figure B4.2: Effluent plant at Company A.

Effluent quality was monitored by the municipality and in the future would be charged according to the Durban Metro bylaws as follows:

Payment for use of sewage disposal system

Prescribed tariff rate for the disposal of sewage

Tariff per kilolitre of sewage R1.400 + R0.196 = R1.596

Tariff calculation for the additional charge for trade effluent

(1) The tariff rate per kilolitre for the additional charge for the disposal of trade effluent to the sewage disposal system shall be determined in accordance with the formula:

$$X + V\frac{C}{R} + Z\frac{B}{S}$$

(2) The tariff rate in cents per kilolitre for the additional charge for the disposal of high strength sewage to the sewage disposal system shall be determined in accordance with the formula:

$$X + V\frac{C-1}{R} + Z\frac{B-1}{S}$$

where

(a) Conveyance and preliminary treatment cost 'X' = R0.440 + R0.061 VAT: R0.501

(b) Treatment cost 'V' = R0.128 + R0.018 VAT: R0.146

(c) Treatment cost 'Z' = R0.142 + R0.020 VAT: R0.162

(d) Chemical oxygen demand value 'R' = 360

(e) Settleable solids value 'S' = 9

(f) 'C' is the chemical oxygen demand value of the trade effluent; and

(g) 'B' is the settleable solids value of the trade effluent.

(3) Charge for trade effluent applies when volume of trade effluent discharged exceeds specified minimum volume = 100 kL / month

Table B4.5: Coal Boiler 1 Losses.

Detail	Unit	Amount
Steam raised	t / h	6
Time steamed per month	h	600
Fresh water make-up	kL / annum	12 960
Water for coal wetting and ash quenching	kL / annum	600
TOTAL	**kL / annum**	**13 560**

Table B4.6: Water used by staff for domestic purposes.

Detail	Amount	Period	Allowance/Estimate (kL)	Total (kL / annum)
Day worker	624	24 days / month	0.09 / person / day	16 174
Shift worker	462	23 shifts / month	0.14 / person / shift	17 852
Meals served per month	6790		0.005 / meal	407
Watered Garden Area (m^2)	200		0.05 / m^2	120
Ablution				1 500
TOTAL DOMESTIC USE				**36 053**

Table B4.7: Water monitoring during shut down.

Usage for 7 days	Volume (kL / 7 days)
Total consumption as per water meter	279
Consumption by 30 contractors	29
Overflowing tank	35
Leaking pump	7
Leaking urinal	25
UNACCOUNTED WATER LOSS	183
TOTAL	**8157 kL / annum**

Table B4.8: Other process losses.

Process	Calculation	Loss claimed (kL / annum)
Cloth wetting	cloths sent to drier	624
Air conditioning (tampon dept)	43.2 kL / month	518
Pharmaceutical water allowances	regard & bactrazine (2.0 kL / month), mediswabs (7.7 kL / month), toiletries (18.0 kL / month)	332
Loss through spills or evaporation in sizing process	60 L / day (26 days / month)	19
TOTAL		**1 493**

B5 ASSESSMENT PHASE

Table B5.1: Occurrence of cloth faults as determined by the laboratory.

Regular faults	Less regular
missing weft*	gutter faults (no leno - warp related)
oil and dirt	double picks*
weft tails*	single picks*
lashing in*	slubs* (Thick warp or weft)
sloughing off*	broken ends (warp related)
short bent picks*	snarls (yarn has too much twist)
thick places	
thin places	
broken picks*	

*weft faults

Table B5.2: Categorisation of machine stops.

Code	Reason	Code	Reason
S/00	stop/ out of production	BO	warp change
F	fill (weft)	QC	quality change
W	warp	NB	no beam
OL	overlock	EB	electric breakdown
BK	breakdown	CL	maintenance
EL	electric	SC	shift-cleaner
CR	cloth rollers	FM	foreman
MT	no work	KB	knot
RK	re knot	NW	no weft

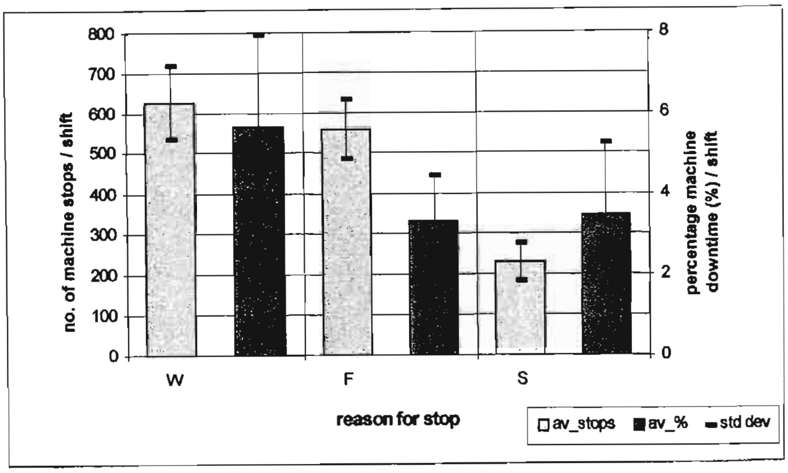

Figure B5.1: Frequent machine stops and associated downtime for May 1998 (n=64 shifts).

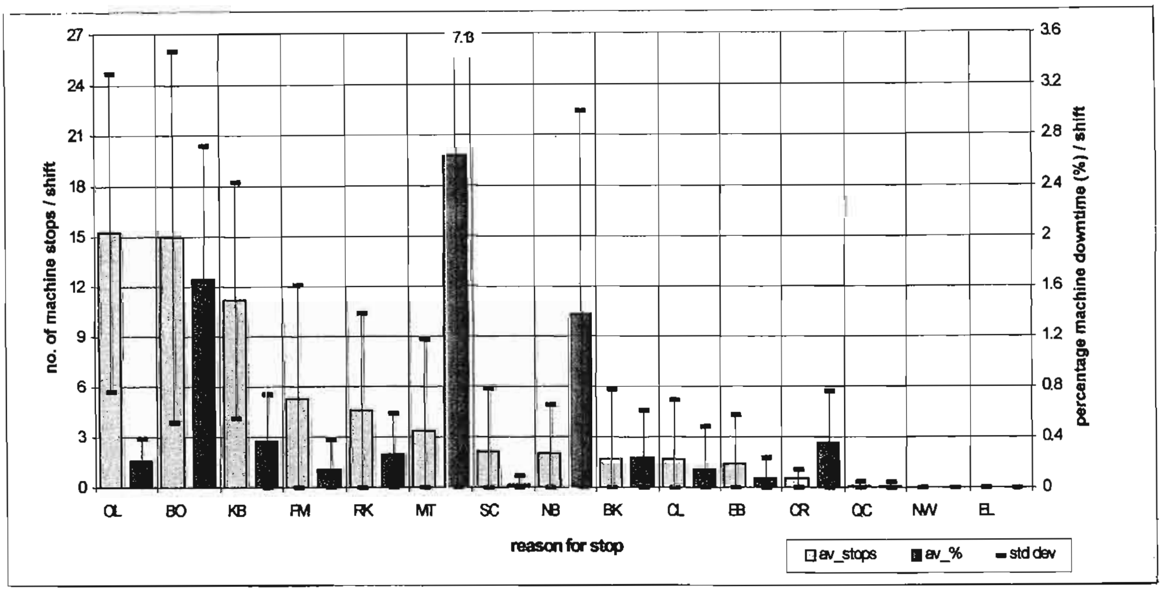

Figure B5.2: Comparison of average machine stops and proportion downtime in May 1998 (n=64 shifts).

Figure B5.1 was discussed in the main body. In **Figure B5.2** OL (overlock), BO (warp change), and KB (knott), were the most common occurring reasons for machine stop. BO was due to the frequency of warp replacement which was necessary due to the limitation in yarn length. Following **Figure B5.1**, MT (no work), BO (warp change), and NB (no beam) had the highest machine downtime per shift - 2.6% ± 4.5, 1.7 % ± 1.1 and 1.4 % ± 1.6, respectively. However, MT (no work) did not represent an error and was thus not considered as an aspect for further investigation. The large downtime for BO and NB was attributed to the time involved in changing the warp and replacing the beam. All the other machine stops had on average, less than 1 % machine downtime. QC (quality change), NW (no weft) and EL (electric) were relatively insignificant in terms of influence on waste production.

B6 ANALYTICAL METHODS AND RESULTS

Where possible, a 1-m cloth sample was taken at the end of a run (limited due to cloth expense) and three to four liquid samples (at intervals throughout the run) were collected in 100 mL brown bottles.

Cloth Samples

Fluorescence

The cloth was placed under fluorescent light in a sealed box. The SATM 521 specification stipulated that not more than an occasional point of intense blue fluorescence should be visible.

Absorbency

Three specimens were taken from the cloth sample, each weighing approximately 2 g. The SABS 263 specification stipulated that the sample was to be fully immersed in 10 s. All results prior to the last bleaching tank had an absorbency greater than 10 s (**Table B6.1**).

Table B6.1: Absorbency rates for various cloth samples.

Sample description	Absorbency rate (s)
batch	>10
rinse 1	>10
rinse 2	>10
bleach 1	>10
bleach 4	<10
hot rinse 2	<10
cold rinse 1	<10
cold rinse 2	<10

Alkalinity and Acidity

Three specimens were taken from the sample, dried at 105 °C for 20 min and left in a desiccator for a further 10 min. pH indicators were placed on the specimen and a colour change noted. Bromocresol green was used to determine acidity and phenolphthalein for alkalinity. The SABS 255 specification for the acidity test using bromocresol green test stipulated that no distinct yellow colour should develop. The SABS 254 specification for the alkalinity test using phenolphthalein stipulated that no distinct pink colour should develop. All the samples were within specification, with the exception of cloth from the first bleach tank, Bleach 1 (**Figure B6.1**).

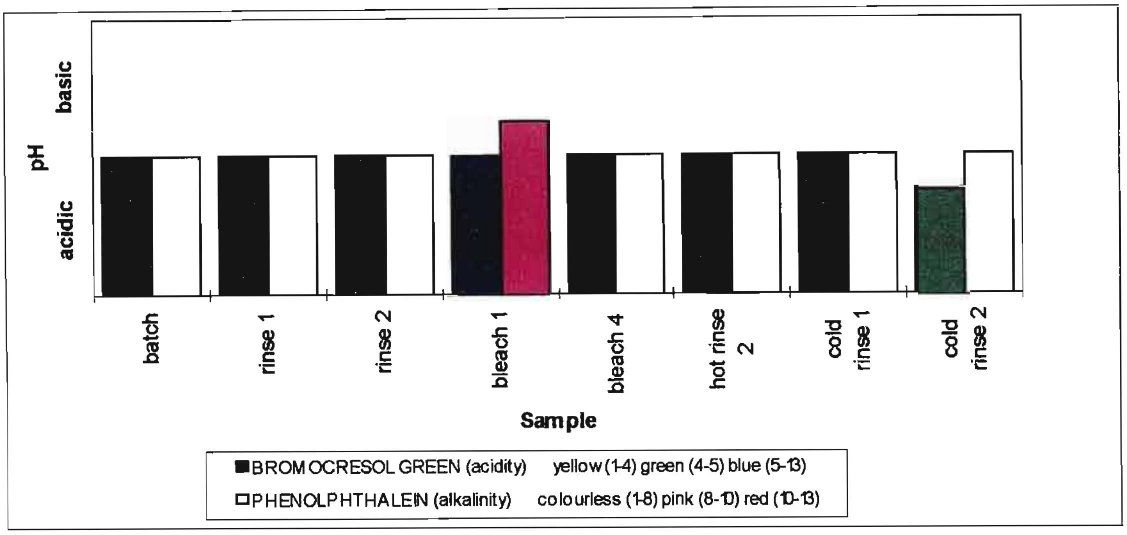

Figure B6.1: Acidity / alkalinity results for various cloth samples.

Foreign Matter Analysis

Cloth samples weighing 5 g were placed in 250 mL reflux flasks containing approximately 200 mL of ether and antibumping crystals. The samples were refluxed using a Isopad Isomantle reflux for 2 h at a temperature between 40 - 60 °C. The samples were air dried. Once dry they were rinsed with water and oven dried at 105 °C until completely dry. The cloth samples were then placed in a desiccator for about 10 min and weighed. The SABS 114 specification stipulated that a non-fibrous material content of below 1.0 g was acceptable. The calculation used was as follows:

$$\text{foreign matter} = \text{mass of cloth sample before reflux} - \text{mass of cloth sample after reflux} \quad \text{(B6-1)}$$

$$\text{non-fibrous content} = \frac{\text{foreign matter} \times 100}{\text{mass of cloth sample after reflux}} \quad \text{(B6-2)}$$

Ash Content Analysis

Cloth samples, each weighing 5 g, were placed in crucibles and burnt over a bunsen burner. Samples were then placed in a Carbolite furnace LMF4, at 900 °C for an hour. Thereafter the samples were placed in an oven set at 105 °C for 20 min and cooled in a desiccator. The sample was re-weighed. The SABS 257 specification stipulated that an ash content below 0.5 g was acceptable. The ash content was calculated as follows:

$$\text{Ash content} = \frac{\{(\text{weight of crucible and sample after furnace}) - (\text{weight of crucible before furnace})\} \times 100}{\text{weight of sample before furnace}} \quad \text{(B6-3)}$$

Liquid Samples

Chemical Oxygen Demand

A 2 mL sample was added to a prepared HACH vial, containing digestive solution specific for the analysis. After thorough mixing, the vial was placed into a HACH digester at 120 °C for 2 h. Once cooled the CODs were measured (range 0 to 1500 ppm). A water blank was used which had been exposed to the same digestive treatment as the samples.

Conductivity

A conductivity probe was used to measure the conductivity of the liquid sample. The insturment was calibrated using a standard sample of NaCl which measured 78 µS / cm at 21 °C. On average the samples were measured at a temperature of 21 °C.

pH

A Knick pH meter 766, Calimatic was used to analyse the pH of the solutions.

APPENDIX C: CASE STUDY 2

C1 NETWORK ANALYSIS

Company B is a fundamental element in an industrial network (**Figure C1.1**). Supplier and buyer interactions up and down the production line include, for instance, metal and chemical suppliers, car assemblers, local and overseas competitors and waste contractors (**Table C1.1, C1.2, C13**). Each organisation contributes to the manufacture of the product. A company must identify, promote and maintain its relationships with its stakeholders, such that improvement opportunities and efforts can be unified to achieve sustainable development.

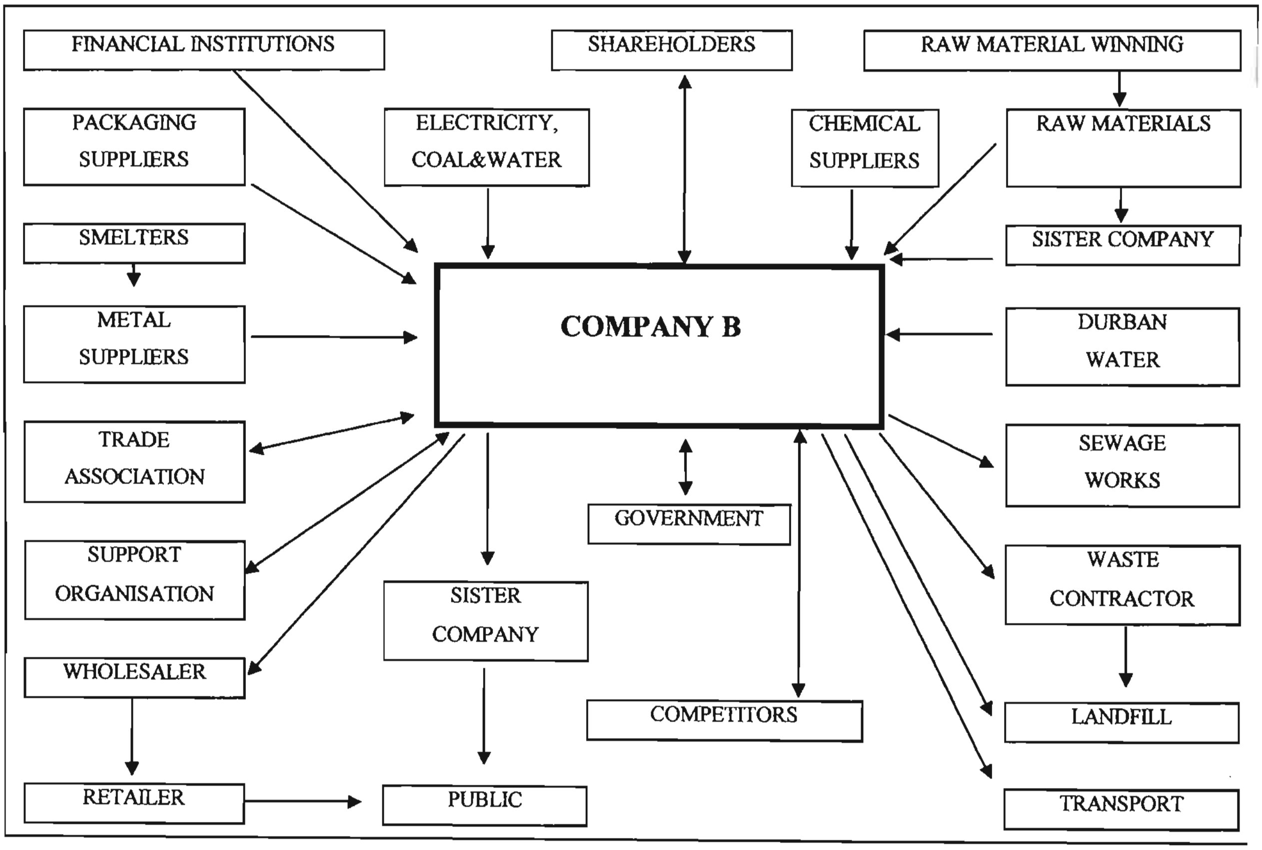

Figure C1.1: Level 1 stakeholder relationships of Company B, a metal finishing company.

Networking interactions involve product, information or money exchange; the frequency is dependent on the type of relationship and demand. A detailed assessment of relationship intensities was conducted by a Cape Town University student, D. van Beers, and a general network map has been illustrated (**Figure B1.2**).

Table C1.1: Major suppliers to Company B.

Raw material	Supplier
aluminium ingots and foil	Alusaf / Hullets Aluminium
steel strip (used at main branch)	Bradbury
tin	Fry's Metal
plating chemicals, trichloroethylene	Chemserv Trio / Polifin
oil and grease lubricants	Castrol
municipal water and effluent	Durban Water and Waste
Electricity	Eskom
tooling and machinery	Intergroup Suppliers
cardboard packaging boxes	Kohler
cardboard packaging boxes, shrink wrap	Nampak

Table C1.2: Major clients buying from Company B.

Suppliers	Intensity (%)	Product
Sister x (UK) }		AM European bearings
Sister y (USA) }	45	AM Asian / Japanese bearings
Sister z (JHB)	50	OE and AM bearings
Volkswagen (SA)	3 to 4	OE bearings
Atlas Diesel Engines }		AM bearings
Small clients }	1	OE and AM bearings

OE original equipment AM after market

Waste contractors are important in establishing industrial ecosystems where waste products are used as raw materials (**Table C1.3**). Certain wastes were recycled internally, such as lead tin fluoroboracic acid, others were reclaimed externally, such as old trichloroethylene collected by Enfield Services, used oil collected by Oil Separation Services, and metal wastes collected by Chicks. Other waste was removed by Waste Services and disposed.

Table C1.3: Treatment and reclamation companies associated with Company B.

Waste	Treatment Company	Treatment
trichloroethylene	Enfield Services	distillation
lead tin fluoroboracic acid	Internal recycling	distillation
oil	Oil Separation Services	unknown
metals	Chicks / Scrap Deales	resell
general / hazardous waste	Waste Services	landfill
waste streams	treated on-site prior to sewer discharge	pH control

C2 POTENTIAL FOR INDUSTRIAL SYMBIOSIS

Four employees were interviewed in March 1998, using a detailed questionnaire compiled by African Environmental Solutions (**Appendix A2**). It was established that Company B was partially suited to participation in an industrial symbiosis network. The company valued and supported learning. There was a high degree of in-house expertise related to production, and relationships with its group partners strengthened the company's knowledge base. Areas which could pose constraints included the uncertainty of ownership changes and staff downsizing at the time of the interviews; internal discord due to ineffective communication, non-participatory decision-making; racial boundaries; and license agreements which could limit innovation. Issues such as these need to be addressed prior to successful participation in an industrial symbiosis network. Success of symbiotic networks is dependent on each company practising cleaner operations, and minimising waste at source.

C3 WASTE MINIMISATION PREASSESSMENT

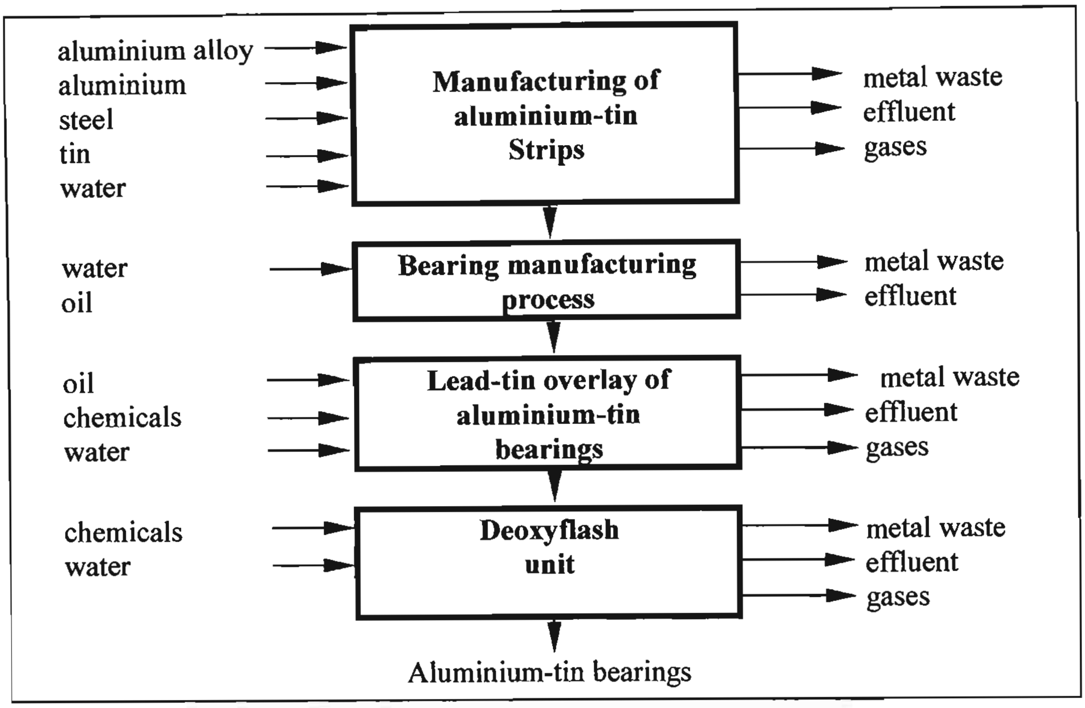

Figure C3.1: Process flow of aluminium-tin bearing production at Company B.

The manufacturing processes of the two bearing lines, namely aluminium-tin and copper-lead, described below refer to **Figure 4.1** in **Chapter 4**.

A1. Manufacturing of aluminium-tin bearings

Aluminium alloy billeting (in the foundary area)

Tin and aluminium alloy are melted in the induction furnace at 800 °C (#1) and transferred to the holding furnace for degassing and refinement (#2). The alloy is run into a graphite casting die to produce an alloy bar, cooled by water (#3). The bars are cut to required length billets (#4) and heated in a furnace at 355 °C for to soften them (#5). Billet edges are trimmed and the surfaces are milled to obtain specific thickness (#6).

Aluminium ingot preparation

Aluminium ingots are melted and then rolled into strips of specific thickness (#7). The aluminium strips are heat treated to soften them (#8), washed in trichloroethylene to remove dirt (#9) and brushed to remove residual dirt and to prepare for cladding (#10).

Aluminium billet and ingot bonding

The aluminium strip is folded over the billet and rolled to clad the aluminium-tin alloy in an aluminium layer. The aluminium cold welds to the aluminium-tin alloy (#11). The clad alloy is trimmed to size required for bonding with steel strips (#12). The clad alloy is washed in trichloroethylene (#13) and brushed (#14) to remove dirt. The annealed aluminium strips are stored to be used when needed.

Steel preparation

Steel strips are stored until needed. These vary in thickness depending on the bearing size to be manufactured. The steel is dipped in trichloroethylene to remove dirt and rust (#15) and roughened (linishing) to aid the bonding process (#16).

Bimetal bonding

The annealed aluminium strip is folded over the steel (#17). The bimetal ends are cropped to remove any uneven extensions (#18). The strips are heated at 320 °C to 380 °C for 11 h (#19) and later inspected and tested to ensure quality (#20).

A2. Manufacturing of copper-lead bearings

Aluminium alloy billeting (in the foundary area)

Steel coils are degreased (#1), water rinsed (#2) before entry into an acid wash (#3) and after (#4). The cleaned steel coils are copper plated (#5), water washed (#6) and dried (#7). Following cooling (#8) the bimetal is placed in an expander unit (#9) and undergoes a flattening procedure (#10). Powder is applied to the bimetal (#11) and passed through a furnace to enhance annealing (#12), cooled (#13) and again flattened (#14). The metal strip is passed through a coiling unit (#15), heated in the furnace (#16) and again cooled (#17). This procedure is repeated and the metal again undergoes flattening (#18) and coiling (#19), and is then cut (#20). The process is completed with a physical inspection (#21), packaged and prepared for transfer to the main branch for further manufacturing (#22).

B. Bearing manufacturing process

The bimetal is cut into small rectangular pieces and bent into a convex shape with the steel on the convex side. The name and type is stamped on the half bearing (#1). The sides of the bimetal are shaped (#2) and holes are drilled and pierced into the half bearing (#3). A nick, placed on the one end of the half bearing, ensures proper placement in the automotive engine (#4). Grooves are milled into the half bearing, depending on the design requirements (#5). Half bearing joints are broached to achieve the correct peripheral length (#6). Aluminium-tin half bearings are cleaned to remove oxides from the steel back caused at the annealing process (#7). The half bearing is inspected for any quality faults (#8).

C1. Aluminium-tin bearing treatment

Approximately 30 half bearings are placed in a jig for batch process plating (#1). The jig is placed in a trichloroethylene degreasing bath (#2). The jig is are cleaned in a Merso-alkali bath (#3), rinsed with cold water (#4) and transferred to an acid pickling bath containing hydrochloric acid (#5). The jig is again rinsed with water (#6) and transferred to an acid pickling bath containing phosphoric acid (#7). A final water rinse (#8) and then the jig is dried (#9). The half bearings are oiled to reduce rust formation (#10), and packed into small clingwrapped boxes for distribution (#11).

C2. Copper-lead bearing treatment

Approximately 30 half bearings are placed in a jig for batch process plating (#1). The jig is placed in a bath containing trichloroethylene (#2) prior to the soak cleaner tank (#3). The jig is then transferred into an electocleaner bath (#4), two consecutive cold rinse water baths (#5 and #6), and an acid pickling bath containing hydrochloric acid (#7). The jig is again rinsed in two consecutive cold water rinse tanks (#8) and then carried into a lead plating bath (#9). A lead plating dragout bath follows the plating bath (#10) followed by another two rinse baths follow (#11). The jig is then finally transferred into a tin plating bath (#12) followed by the dragout tank (#13) and a cold water bath (#14). A hot water bath at 80 °C concludes the rinsing (#15), and the jig is then passed through two drier tanks at 60 °C and 40 °C respectively (#16). The half bearings are oiled to reduce rust formation (#17) and packed into small batch boxes which is then clingwrapped and distributed (#18).

C4 MASS BALANCES

Conducting a detailed mass balancing equation is not always possible if the company does not have an established monitoring system is in place. For this reason only a limited material flow analysis could be conducted at Company B for the 1998 financial year.

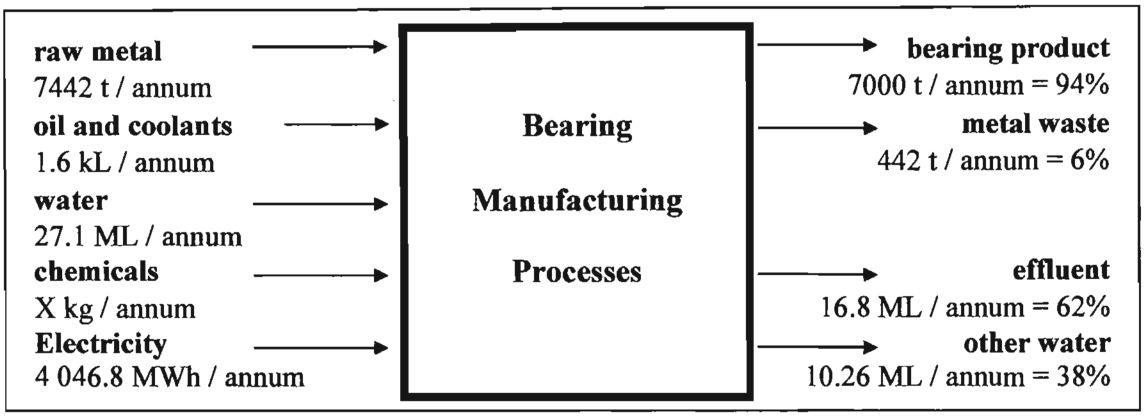

Figure C4.1: Overall inputs and outputs into the bearing process at Company B.

The majority of raw material inputs were the metal components, such as steel, aluminium and tin (7442 t / annum). A small volume of oil and coolants (about 840 L / month) were used in the machines, and water (27.1 ML / annum) and chemicals (no mean volume was presented) were used in the cleaning, plating and deoxyflash processes. Of the output, a small proportion of metal product was wasted (6%) and approximately half of the influent was released to sewer (16.8 ML / annum). Other waste included evaporative losses, pipe leakages, process losses, etc (10.26 ML / annum). Mass balances of metals was further detailed (**Table C4.1**).

Metal Balance

Table C4.1: Metal input and output at Company B on average per annum (1998).

Description	Notes	Mass ton / annum	Total mass ton / annum
MATERIAL IN			**7442.6**
Steel	1	4400.0	
Aluminium foil	1	260.7	
Aluminium ingot	1	337.7	
Aluminium alloy	1	6.6	
Tin	1	79.2	
Lead	2	22	
copper lead powder	2	880	
reclaimed furnace metal	3	223.3	
Production metal	4	1233.1	
MATERIAL OUT			**7442.6**
bearing product	5	5277.8	
Incomplete bearings	5	1721.5	
Machining waste	6	442.2	

Steel was the base metal used and comprised the largest metal input. Other metals for the manufacturing processes of aluminium-tin bearings (1) and copper-lead bearings (2) were detailed. The reused furnace metal originated in the early stages of the production process, where annealing with another metal had not yet occurred. This scrap metal could be recycled as it was a relatively pure metal. The amount was calculated from percentages quoted by company (3). Production metal comprised an additional variety of metals and bimetals supplemented along the production line (4). The mass of metal product and incomplete bearings was obtained from actual data collected (5). A detailed description of parts manufactured was given of two specific months, September and November 1998 (**Table C4.2**). The manufacturing process waste was calculated from data received (6). Estimated waste volumes used by the company were illustrated (**Figure C4.2**).This scrap metal had been annealed (comprising two or more different metals) and could thus not be reused, and was sold to Waste Services.

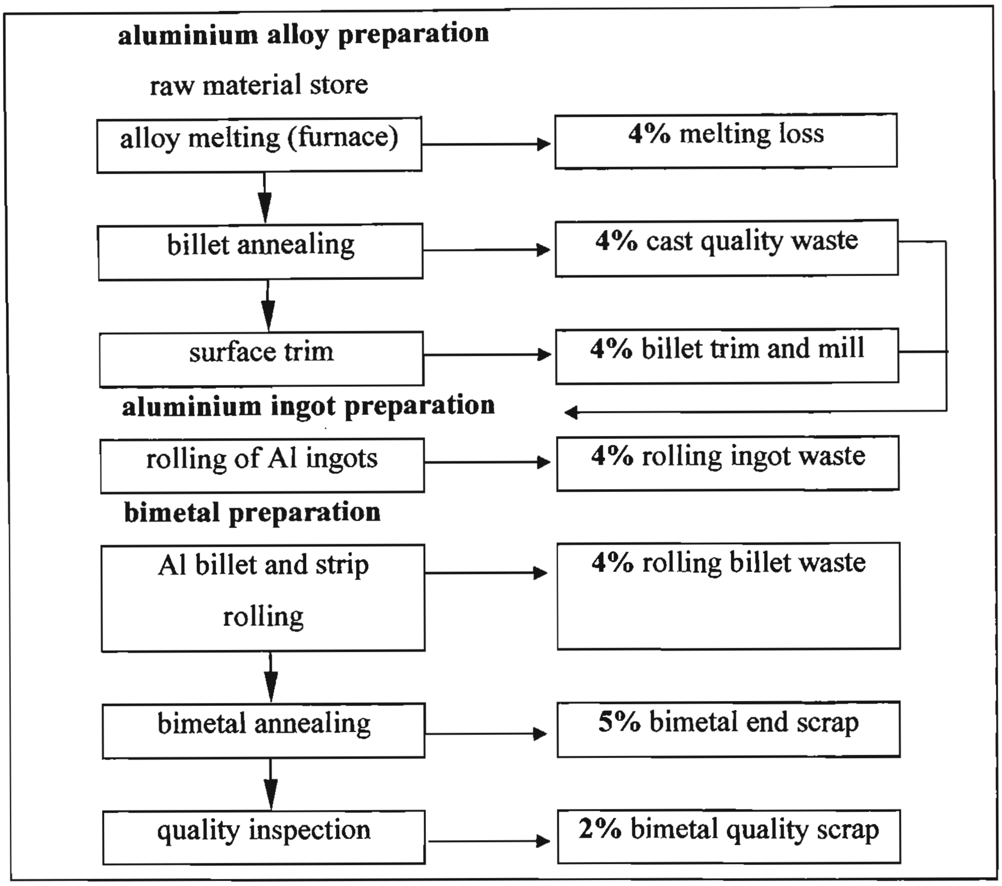

Figure C4.2: Company estimates of waste production along the production line.

Table C4.2: Scrap metal produced during the machining process for two months (September and November 1998).

Department	Total made (parts)		Total scrap (parts)		Av_scrap (%)	
	SEPT 98	NOV 98	SEPT 98	NOV 98	SEPT 98	NOV 98
Press	519117	760662	3668	2141	0.71	0.28
S/face	614053	764451	1068	1813	0.17	0.24
Drill	614053	764451	1567	2008	0.26	0.26
Nick	651318	786805	625	1938	0.10	0.25
Groove	398934	491660	727	2226	0.18	0.45
Strip			1254	1115		
C/Sink	617832	770260	1486	2038	0.24	0.26
JFB	649044	821477	1823	4963	0.28	0.60
Bore	625268	796155	1755	7823	0.28	0.98
TOTAL	**4689619**	**5955921**	**13973**	**26065**	**2.22**	**3.33**

Chemical usage

Due to the confidential nature of chemicals used, detailed information could not be provided. Approximately R67 000 / annum was spent on chemicals. Some chemicals are tabulated. The majority of chemicals were used in the lead-tin overlay plating unit and in the deoxyflash unit. Attention was directed towards the use of harmful chemicals such as trichloroethylene. The plating plant was installed by Chemserv Trio, who continue to provide a service on chemical and operational management. This company managed the operation of the plating process through the supply of chemicals, monitoring the condition of the plating solutions and providing operational advice and assistance by well qualified personnel. The process was well controlled. The deoxyflash unit was a fairly old process and had a significant environmental impact in terms of the chemicals used.

Table C4.3: Inventory of some of the chemicals used at Company B.

Process	Chemical
Aluminium ingot preparation	wetting agent
	nitric acid
	nitrous oxide
	acetylene
Bearing manufacturing	trichloroethylene
	coolants
	lubricants
Plating	lead tin fluoroboracic acid
	ammonium acetate
	ammonium hydroxide
	barium chloride
	sodium hydroxide
	potassium iodide/iodate
	ethylene diamine tetraacetic acid
	soda ash
	hydrochloric acid
	tin stannate
Deoxyflash	oil
	Mersol
	phosphoric acid
	hydrochloric acid

Water use and effluent

Water from Durban Metro was shared jointly between Company B and the other company on the premises. Water was charged at R2.70 / kL and approximately R73 156 was spent in 1996 on water costs. An average of 27 100 kL of water was used per annum. Water savings that have been implemented in the past include a closed circuit cooling tower with the water circulation. Of the water use, 14.6 % was for domestic use. The domestic effluent was discharged directly to sewer. Water was lost through evaporation from the cooling tower and washer, leakages and processes (from carry over during plating).

Effluent was charged jointly between the Company B and the other company on the premises. Effluent collected from the various processes was pH treated at the on-site effluent plant to between 7 and 9 as stipulated by Durban Metro. Treated effluent was pumped to the municipal sewerage systems. On a weekly basis the Pinetown Waste Water Division (Industrial Effluent Control Section) check the metal ion concentration of the effluent tanks. An illustration of the effluent plant was given (**Figure C4.3**).

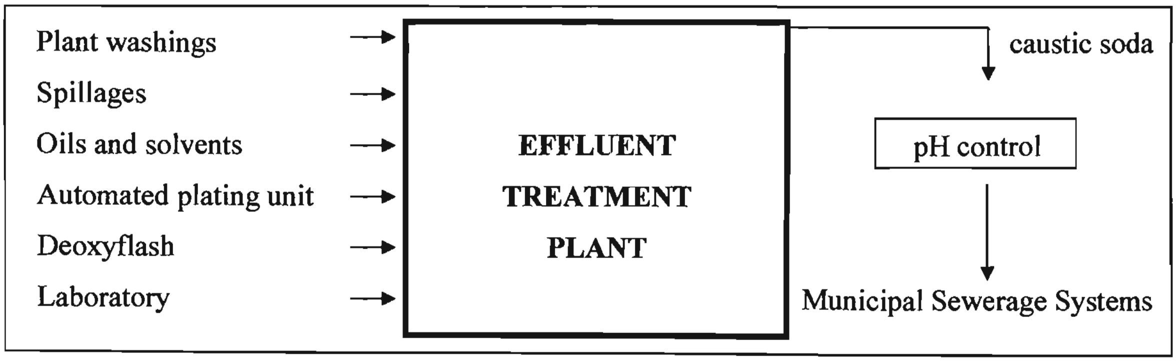

Figure C4.3: Effluent treatment plant at Company B.

Energy

Electricity supplied by Durban Electricity was generated by Eskom. At a charge of R0.16 / kWh, approximately R647 483 was spent in 1997 for electricity. Electricity savings that have been initiated include interaction with the consulting agency, Comelec, who have assisted in obtaining financial savings by means of selecting best tariffs for electricity. On-site improvements include identification of the power factor within the factory and training of good house keeping.

C5 PLATING CALCULATIONS FOR COPPER-LEAD BEARINGS

Table C5.1: The time layout of the lead-tin plating process.

	Process	Across to tank (min : s)	Lowering (min : s)	Submerged (min : s)	Raising (min : s)	Drip time (min : s)	Total (min : s)
	load	*0:16	0:08	4:15	0:08	0:00	4:47
2	soak	0:04	0:08	4:00	0:08	0:06	4:26
3	electroclean	0:04	0:08	4:15	0:08	0:06	4:41
4	rinse	0:04	0:08	3:20	0:08	0:00	3:40
5	rinse	0:04	0:08	0:10	0:08	0:00	0:30
6	acid	0:04	0:08	1:00	0:08	0:06	1:26
7	rinse	0:04	0:08	0:50	0:08	0:00	1:10
8	rinse	*0:28	0:08	1:10	0:08	0:00	1:54
15	Pb-Sn plating	0:04	0:08	4:00	0:08	0:06	4:26
14	drag-out	0:04	0:08	2:30	0:08	0:00	2:50
13	rinse	0:04	0:08	3:30	0:08	0:00	3:50
12	rinse	0:04	0:08	0:40	0:08	0:00	1:00
11	Sn plating	0:04	0:08	4:30	0:08	0:06	4:56
10	drag-out	0:04	0:08	2:00	0:08	0:00	2:20
9	rinse	*0:32	0:08	3:40	0:08	0:00	4:28
1	hot rinse	0:04	0:08	3:15	0:08	0:06	3:41
	dryer 1	0:04	0:08	4:20	0:08	0:00	4:40
	dryer 2	0:04	0:08	4:20	0:08	0:00	4:40
	TOTAL	**≈ 60:00**					59:25

* transfer times are longer due to tank location in process sequence

In order to calculate how many half-bearings were being processed, two separate calculations were carried out so that a comparison could be established. The first calculation was based on a combination of visual observation and process information (**Table C5.1**). The second calculation was based on the average income per annum. The average of the two calculations was used to calculate the average number of half-bearings that were run through the process. Using the actual and process information, on average one flight should take about 60 min. Using the financial basis, half-bearings of all qualities (copper-lead and aluminium-tin) to the value of about R40 million were produced in 1998. The ratio of Al-Sn : Cu-Pb half-bearings was approximately 70 : 30 and thus approximately R12 million was made on plated half-bearings. The average value of a half bearing was R4.00. The calculations in **Table C5.2** indicated that 10 flights per hour is a reasonable estimation of the annual average production.

Table C5.2: Calculation of the number of flights of copper-lead half-bearings plated per hour.

Quantity	Unit	Total
BASED ON TIME:		***≈ 10 flights / h***
30 half-bearings	jig	
5 jigs	flight	
10 flights	h	1 500 half-bearings / h
8 h	day	
5 days	week	
4,3 weeks	month	
11 months	year	1 892 h / annum
R4.00	half-bearings	**R11 352 000 / annum**
BASED ON INCOME:		**≈ R12 000 000 / annum**
R 12 000 000	annum	
R 1 090 909	month	
R 6 342.5	h	
R4.00	half-bearings	1 586 bearings / h
30 half-bearings	jig	
5 jigs	flight	150 half-bearings per flight
		10.6 flights / h

Based on a difference between optimum drip time (as calculated and 90s for those where no optimum time was obtained) and the current drip time (6s), drag-out volumes and costs were calculated (**Table C5.3**). These costs indicate potential savings if the drip time were extended to the optimal calculated time.

Table C5.3: Volume and cost of potential drag-out savings per day if drip time were extended to an optimum.

Solution	Drag-out volume (L / day)	Cost (R / day)
2 soak cleaner	0.14	3.98
Water (in) + (out)	2.48	0.01
3 electrocleaner	0.18	5.19
water	3.90	0.02
4 cold rinse	7.81	0.04
5 cold rinse	22.32	0.12
6 HCl pickle	1.36	2.07
water	15.68	0.09
7 cold rinse	6.84	0.04
8 cold rinse	17.74	0.10
15 lead plating		72.11
sodium stannate	0.79	67.56
sodium hydroxide	0.11	0.39
resorcinol	0.05	4.13
water	6.24	0.03
14 lead drag-out	6.33	0.03
13 cold rinse	6.20	0.03
12 cold rinse	23.30	0.13
11 tin plating		12.89
lead fluoroborate	0.24	8.04
tin fluoroborate	0.03	1.73
fluoroboric acid	0.11	3.12
Water	0.73	0.00
10 tin drag-out	5.23	0.03
9 cold rinse	7.68	0.04
1 hot rinse	4.59	0.02

Lead Drag-out

The concentration of lead in the tanks was determined using Atomic Absorption Spectroscopy (AA). This data were used to estimate the lead drag-out from the plating bath into the drag-out and rinse tanks.

Table C5.4: Lead concentration calculated theoretically and through AA analyses.

No	Tank	Actual [Pb] (g / L)	Vol. drag-out (L / 6s)	Theoretical [Pb] dragin * (g / L)	Actual: Theoretical
15	Pb/Sn plating	193.33	0.081910	NA	NA
14	Pb/Sn drag-out	92.38	0.079710	15.84	5.83
13	cold rinse	2.56	0.092590	7.36	0.35
12	cold rinse	ND	0.146147	0.24	NA

*theoretical = concentration x volume drag-out
NA - not applicable, ND - not detectable

There is evident variation between the actual and theoretical drag-out concentrations in **Table C5.4**. In the first analysis, an actual concentration of the lead drag-out tank was 92.38 g / L and the theoretical value was 15.84 g / L. This variation was predicted as the theoretical calculation took into account only one drag-out, whereas there were numerous carryovers throughout the day. Using these actual and theoretical values it was assumed that approximately 5.8 flights passed into the tank, thus accumulation of lead was evident.

The opposite is true for the rinse tanks, where the theoretical value is higher than the actual concentration. This is also to be predicted because there is a countercurrent rinse system in operation and there is a constant discharge of solution to the wastewater treatment system and thus some of the metal concentration is flushed out, thus no lead accumulation.

These calculations conclude that the lead accumulation occurs in the drag-out tank and that some lead is discharged to the wastewater treatment system from the rinse tanks which could be reclaimed through evaporation.