Waste Minimisation Guide for the Textile Industry

A Step Towards Cleaner Production
Volume 1




Susan Barclay & Chris Buckley

TT 139/00

Water Research Commission

Waste Minimisation Guide for the Textile Industry

A Step Towards Cleaner Production

Volume I

Background information
Overview of waste minimisation
Environmental Pressures

Prepared by
Susan Barclay and Chris Buckley

The Pollution Research Group

University of Natal
Durban
South Africa

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Preface

The aim of this Guide is to support the textile industry to become more efficient and environmentally conscious. It consists of two parts; **Volume I** dealing with the background to the project, an overview of waste minimisation and various chapters relating to case studies, waste minimisation suggestions and pollution control measures; and **Volume II** consisting of detailed worksheets which guide the industry through conducting a waste minimisation assessment, with an explanation of the nature and purpose of each worksheet and instructions on how they are to be used. This two-year project was sponsored by the South African Water Research Commission (WRC).

The majority of the information contained in the Guide is based on previous research conducted by the Pollution Research Group in the textile industry. The worksheets are based in principle on the US Environmental Protection Agency's *Waste Minimisation Opportunity Assessment Manual* 1988), and the Dutch publication *Handboek voor de Preventie van Afval en Emissies in de Metaalproduktenindustrie* (Kothuis and van Berkel, 1991), but have been modified specifically for the textile industry. On completion of the first draft, the *Guide* was circulated to a number of individuals for peer review and field tested by students conducting surveys within the textile industry. Our sincere thanks are extended to all these individuals whose advice and comments have been of great assistance in the development of this Guide.

Any comments or suggestions for improvements are welcomed by the Project Leaders. A form is provided at the back of **Volume II** for this purpose.

We hope that this Guide will be used widely by the textile industry to aid them in identifying areas of waste, thereby enabling the industry to become more environmentally and financially efficient.

Susan Barclay and Chris Buckley

Pollution Research Group

January 2000

E-mail : barclay@nu.ac.za
buckley@nu.ac.za

Table of Contents - Volume I

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The guidance and assistance of the following people on the Steering Committee is appreciated :

Dr HM Saayman	Water Research Commission (Chairman)
Mr G Steenveld	Water Research Commission (Chairman)
Mr A Fritz	Water Research Commission (Committee Secretary)
Dr N P Mjoli	Water Research Commission
Mr P Herbst	Department of Water Affairs and Forestry
Mr M Gordon	Department of Water Affairs and Forestry
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List of Abbreviations

ADMI	American Dye Manufacturers Institute
BOD	Biological Oxygen Demand
BS	British Standard
COD	Chemical Oxygen Demand
DEAT	Department of Environment and Tourism
DWAF	Department of Water Affairs and Forestry
EMAS	European Union Eco-Management and Audit Scheme
EMS	Environmental Management System
EPA	Environmental Protection Agency, United States of America
ETAD	Ecological and Toxicological Association of Dyes and Organic Pigments Manufacturers
EU	European Union
IBC	Intermediate Bulk Containers
ICPIC	International Cleaner Production Information Clearing House
IRR	Internal Rate of Return
ISO	International Standards Organisation
KPI	Key Performance Indicator
LC_{50}	Lethal Concentration
LD_{50}	Lethal Dose
LPG	Liquid Petroleum Gas
M&T	Monitoring and Targeting
MSDS	Material Safety Data Sheets
NEMB	National Environmental Management Bill
NF	Nanofiltration
NPV	Net Present Value
NWA	National Water Act
ppm	Parts per million
PRG	Pollution Research Group
R	Rands
SA	South Africa
SABS	South African Bureau of Standards
SEV	Specific Effluent Volume
SPL	Specific Pollution Load
SS	Suspended Solids
SWOT	Strengths, Weaknesses, Opportunities, Threats

SWU	Specific Water Use
TDS	Total Dissolved Solids
TS	Total Solids
UF	Ultrafiltration
UK	United Kingdom
UND	University of Natal, Durban
UNEP	United Nations Environment Programme
UNEP IE	United Nations Environment Programme : Industry and Environment
USA	United States of America
UV	Ultraviolet
WRC	Water Research Commission

Chapter 1

Introduction

1.1 Background to the Project

Textile industries are water intensive, and in 1993, approximately 30 million kl of water per annum was used by the industry in South Africa. The specific water intake was found to vary between 95 to 400 l/kg fabric, depending on the type of processes used and water efficiency (Steffen Robertson and Kirsten, 1993). Dyehouse effluents are complex, consisting of concentrated waste process water containing a wide and varied range of dyes and other products, rinsing and cooling water. In general, the effluent is highly coloured, high in biological oxygen demand (BOD) and chemical oxygen demand (COD), has a high conductivity and is alkaline in nature. The effluent is ranked second highest with respect to hazardous waste intensity and principally affects water quality. Due to the limited water resources on South Africa, it is important to encourage industries to implement water and effluent management strategies and reduce waste at source.

The Pollution Research Group (University of Natal, Durban) has extensive experience in waste minimisation and effluent treatment in South African industries and in particular with the textile industry. Previous research into this field is well documented in earlier Water Research Commission (WRC) publications (Pollution Research Group, 1983, 1987, 1990). In addition, numerous publications exist by organisations such as UNEP (United Nations Environmental Programme; UNEP 1991, 1994, 1996) and the United States EPA (Environmental Protection Agency; EPA 1988, 1996) as to the methodology of conducting a waste minimisation survey and describing the advantages of reducing waste at source, some of which are written specifically for the textile industry (UNEP 1994, 1996 and EPA, 1996).

However, it was felt that although these publications were useful, no guide existed that worked systematically through each phase of conducting a waste minimisation survey, from the planning through to implementation, including target key performance indicator figures for benchmarking and explanations on mass and energy balances for the specific textile processes. In addition, it was found that a large proportion of the benchmark data were generally 30 years out of date. Therefore, a two-year project (sponsored by the WRC) was initiated to develop a detailed guide to assist the industry and its employees in conducting waste minimisation surveys and implementing cleaner production technology.

1.2 The Need for Cleaner Production

The concept of sustainable development stresses the interdependence of economic growth and environmental quality. It is defined as (Welford, 1994) :

> *Development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs*

Industries are, therefore, challenged to produce higher levels of output while using lower levels of inputs and producing less waste. Cleaner Production is recognised as an important approach to reducing environmental impact and leading industries in the direction of sustainable development. It is defined as (UNEP, 1990) :

> *...the continuous application of an integrated preventative environmental strategy applied to processes, products and services to increase eco-efficiency and to reduce risks for humans and the environment..*

It is a general term that describes a preventative approach to industrial activity with an emphasis on a change in attitude in the manner in which products are manufactured. In addition to achieving a lower level of pollution, cleaner production results in economic benefits as there is a more efficient use of raw materials and less waste being produced.

There are a number of *tools* of Cleaner Production, one of which is waste *minimisation. The basic concept of waste minimisation is simple :*

> *...to reduce or eliminate waste at source rather than treat it after it has been generated.*

It includes practices that reduce the use of hazardous and non-hazardous materials, energy, water and other resources. It is an ongoing activity and an effective programme can reduce the risk of liability, reduce operating costs, improve employee morale and participation, enhance the company's public image and protect health and the environment.

An introduction to waste minimisation and the methodology of implementing a waste minimisation programme is discussed in detail in **Chapter 2.**

1.3 The South African Textile Industry

The South African textile industry was established in the first half of this century, and by 1939, was providing 3 500 jobs (Textile Federation, 1999). Major expansion took place within the industry between 1950 and 1960, and by 1960, there were 65 textile factories producing knitted fabrics, as well as cotton-based yarns and woven fabrics. This growth was not sustained over the next 2 decades, and in 1996, there were approximately 70 textile factories registered with the Textile Federation. It is the sixth largest employer in the manufacturing industry, with 77 000 direct employees and 200 000 indirect employees in dependent industries.

The textile industry is currently facing a number of challenges, particularly with respect to environmental legislation and international competition. Environmental-related issues include :

- increasing cost of water
- increasing cost of effluent treatment and/or disposal
- more stringent regulations being implemented by DWAF, especially in terms of colour, toxicity and salinity
- the introduction of ISO 14 000 and ecolabels
- new legislation

With the lowering of the textile tariffs, the industry is faced with increasing competition and in order for it to survive, it must become more export-orientated. This, therefore, exposes the South African manufacturer to the environmental pressures facing industries in Europe and the United Sates of America.

1.4 Emissions from the Textile Industry

Environmental impacts from the textile industry are mostly associated with liquid effluents, but solid and hazardous wastes, noise, energy, emissions to air, and working environment hazards such as dust, are also of importance. While all these emissions are taken into consideration in this guide, the main focus is on quantifying and minimising liquid effluent as it accounts for the largest portion of the pollutants from the textile industry. Typical pollution loads from the various process in the textile industry are listed in **Appendix 3**.

1.5 Project Aims

Under the sponsorsip of the WRC, the main aims of the project were to:

- Transfer the technology and experience gained by the Pollution Research Group to the South African textile industry;
- Enable the South African textile industry to implement their own waste minimisation and pollution prevention programmes;
- Educate and train the textile industry employees in pollution prevention strategies; and
- Enable the South African textile industry to be internationally competitive through the implementation of proactive and rational environmental management systems.

It is hoped that the publication of this guide, together with workshops to promote its application, will fulfill these aims.

1.6 Purpose of the Guide

This ***Guide*** is specifically designed to aid in identifying and quantifying emissions from the textile industry and indicating ways in which they can be reduced, resulting in savings for the company. It has a number of objectives, namely to :

- aid in establishing a waste minimisation programme;
- aid in identifying and quantifying emissions from the textile industry;
- help identify areas were waste minimisation techniques can be implemented;
- help determine the feasibility of implementing waste minimisation techniques; and
- guide the industry in conducting an economic evaluation of the various waste minimisation options.

1.7 Target Group

As the majority of the research carried out by the Pollution Research Group has been in the processing of cotton and cotton / blend fabrics, this guide is best suited to these industries. Although some aspects related to products development, solid and gaseous emissions are included, the focus is on water-intensive companies and water-related issues. However, the generic approach to carrying out a waste minimisation survey is the same for any industry, and the worksheets can be easily adapted for other textile processes.

In addition to aiding the textile industry in reducing waste and costs, the Guide can be used by local authorities to assess the level of waste minimisation within the industry. The existence of an effective waste minimisation programme is also an essential aspect of any environmental management system, and, therefore, this Guide will contribute towards compliance with ISO 14000.

1.8 How to Use the Guide

It must be stressed that this Guide is exactly that: ***a guide*** to conducting a waste minimisation survey in the textile industry. It is not meant to be an exercise in completing worksheets. These worksheets are by no means absolute and are meant only to guide a company in obtaining the relevant information and constructing mass balances over the various processes. They should be adapted to suit each company's specific needs.

The worksheets are designed to aid a project team in carrying out a preliminary investigation into the wastes and emissions from their company, identifying areas for further study, conducting a detailed study into these departments or processes, identifying suitable waste minimisation techniques and determining the feasibility of implementing these methods. The way in which the worksheets have been laid out, and the type of information that is required, is based on the experience of the

Pollution Research Group from previous waste minimisation surveys in the industry.

The Guide is divided into two parts; **Volume I**, which contains the background information, the theory of waste minimisation and waste minimisation options for the textile industry; and **Volume II** which contains the worksheets for conducting the waste minimisation survey.

Structure of Volume I :

Chapter 2 gives an overview of waste minimisation, the methodology of implementing a waste minimisation programme and the benefits to a company. **Chapter 3** covers some of the environmental challenges facing industries in South Africa, especially with respect to environmental management systems, ecolabels and pollution liability. **Chapters 4 to 9,** contain explanations of each stage of conducting a waste minimisation audit and refer to the worksheets given in **Volume II.**

Chapter 4 has been included in the guide to demonstrate the scope for potential savings and also allows comparison of the current factory performance to typical and target indicators. **Chapters 5 and 6** describe the first phase, i.e. how to establish a waste minimisation team and conduct a preliminary investigation to determine the various emissions from the industry; **Chapter 7**, explains the second phase, i.e. the methodology of conducting a detailed investigation; **Chapter 8**, describes the third phase, i.e. the feasibility analysis of selected waste minimisation options; and **Chapter 9**, the final phase, i.e. the implementation of the selected options within the industry and the monitoring and recording of results.

Appendix 1 contains suggestions as to some waste minimisation techniques that can be implemented in various departments, while **Appendix 2** covers case studies of successful waste minimisation programmes that are in place in textile industries both locally and internationally. **Appendix 3** lists the typical pollution loads from the various textile processes and **Appendix 4** describes the *end-of-pipe* treatment methods that are suitable for the liquid wastes emitted by the industry. **Appendix 5** contains the literature references and recommended readings, while **Appendix 6** contains the supporting data for some of the calculations and figures given in the guide. **Appendix 7** lists various organisations that will be able to offer advice and information to the textile industry in terms of environmental requirements and technology and **Appendix 8** contains sample overhead sheets that can be used for giving a presentation on implementing waste minimisation in the textile industry.

Structure of Volume II :

This volume is divided into 5 main sections, namely :

- Identifying the Scope for Savings,
- Planning and Organisation,
- Pre-assessment,
- Detailed Assessment, and
- Feasibility Analysis.

These are labelled "**A**" through "**I**" for easy reference. Chapters 4 to 9 in **Volume I** explain each of these stages in more detail. The aim of each worksheet and the methodology of using each one is explained alongside the respective worksheet. In some cases, completed worksheets are included as an example.

Chapter 2

A Structured Approach to Waste Minimisation

Protecting the environment should be at the core of every firm's strategic planning. Without it, a company's image in an environmentally-aware market is at stake. Until recently, primary emphasis of environmental programmes involved pollution control, which in most cases meant *end-of-pipe* treatment. However, the installation of effluent treatment systems do not solve the problem of the generation of waste, but rather move it from one place, or medium, to the next. Once waste has been created, it can be diluted, changed physically or chemically, but it cannot be destroyed. Also, these systems may become a pollution problem themselves, generating hazardous waste. The best solution is, therefore, the one where the production of effluent is avoided, i.e. waste minimisation or pollution prevention.

2.1 Pollution Regulation in the United Kingdom and United States of America

The traditional approach in the UK towards pollution regulation has been one of informal co-operation between operators and enforcing authorities. This has been fairly effective, but the introduction of the Environmental Protection Act in 1990 marked a shift towards a more structured approach to legislation. In terms of Part 1 (the regulation of polluting industrial processes) and Part 2 (duty of care in disposing of solid wastes) of this Act, industries are required to obtain a continuing process of appraisal of their waste management practices.

In the USA, the approach to pollution control has traditionally been *end-of-pipe*, but with the introduction of the Pollution Prevention Act in 1990, source reduction was embraced as national environmental policy. Companies are required to implement pollution prevention programmes and submit reports detailing the procedures for preventing the release or reusing any chemicals to the Environmental Protection Agency.

2.2 Pollution Regulation in South Africa

In South Africa, DWAF is responsible for the management of water resources, thereby ensuring the provision of adequate water supplies of acceptable quality for all recognised users. In order to counter deteriorating water quality in the country, new policies have been introduced by DWAF, one of which is the Pollution Prevention approach for hazardous effluents. This approach is aimed at the handling and disposal of hazardous wastes as toxicity, persistence and capacity for bioaccumulation present major threats to the environment. It involves source reduction and recycling to reduce the quantity and/or toxicity of waste and to minimise both present and future threats to the environment and public health.

In addition, a number of new acts, policies, bills and draft policies have been developed relating to pollution liability. These include the National Water Act 36 (1998), the Water Services Act 108 (1997), National Environmental Bill (1998), Draft White Paper on Environmental Management Policy for South Africa (1998), Draft White Paper on Integrated Pollution Control and Waste Management for South Africa (1998). All of these emphasise the importance of understanding the source of all waste generated within an organisation and aiming towards reducing emissions to a minimum. These policies are discussed in more detail in **Chapter 3.**

2.3 Methodology of Implementing a Waste Minimisation Programme

There are two fundamental approaches to waste management: waste minimisation and pollution control (end-of-pipe treatment). Of these, waste minimisation is the more effective as not only does it reduce the generation of waste, but it also results in savings to a company.

2.3.1 What is Waste Minimisation ?

Waste minimisation can be defined as :

The application of a systematic approach to reducing the generation of waste ***at source***

In other words, it is the implementation of measures to prevent the generation of waste in the first place. It applies to both product and process changes, and includes all inputs and waste outputs. Waste is not simply excess materials to the requirements for a process, but it represents the loss of valuable company assets. There is always the opportunity to achieve benefits from waste minimisation in all aspects of an organisation, no matter what the size of the operation.

Within any process, there are five main aspects that should be taken into account when considering the implementation of waste minimisation. These are shown on the left-hand side of the diagram in **Figure 2.1** and include :

- raw materials used and other input materials such as water, chemicals etc.,
- the type of technology,
- the manner is which the process is executed,
- the products that are formed, and
- the wastes and emissions that are generated.

The basics of a waste minimisation programme are therefore to:

- Effect source control by changing raw materials, i.e. change to non-toxic or purer materials, use renewable raw materials or materials with a long service lifetime.
- Change production technology and equipment, e.g. improved process automation, process optimisation, equipment re-design and process substitution. This can create less hazardous wastes and emissions.
- Improve housekeeping by making changes to procedures and management in order to eliminate waste, e.g. spill prevention, improved worker education and training.
- Redesign or reformulate products by changing the product characteristics such as shape or composition. The product life may be extended or it is made easier to repair. The manufacturing process may become less polluting. This also includes changes in packaging. Changes to product design often requires a life cycle assessment approach, the details of which are outside the scope of this guide.
- On site-recycling : i.e. useful application of waste material produced by the company, e.g. reuse as raw material, recovery etc.

These changes are represented on the right-hand side of the diagram in **Figure 2.1**. Only on-site recycling is considered to be a source reduction technique. Off-site recycling is seen as a pollution control measure.

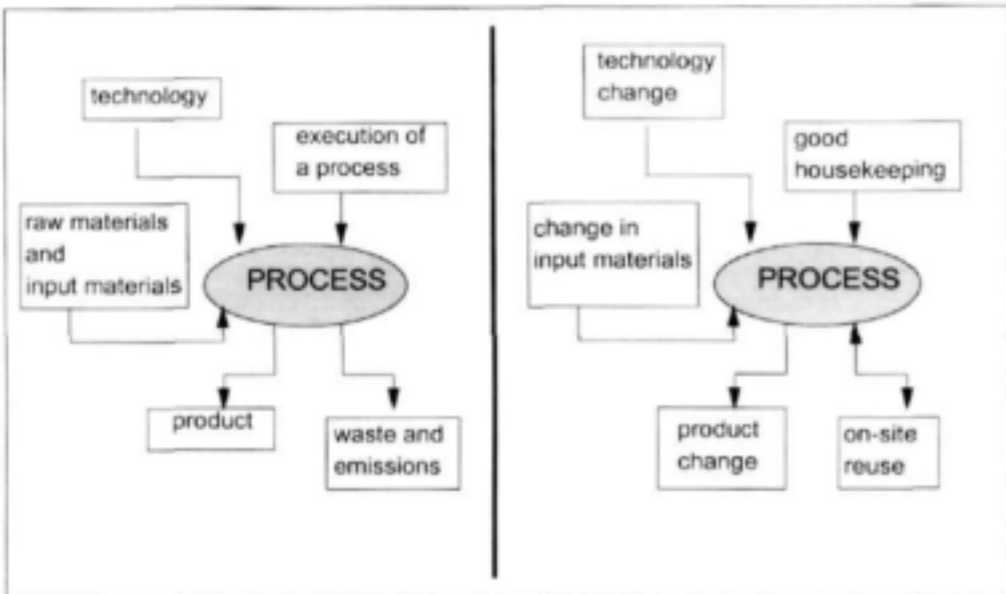

Figure 2.1 : The five possible changes that can be made to a process or business operation to reduce waste at source (UNEP)

2.3.2 Benefits of Waste Minimisation

There are a number of benefits to implementing waste minimisation. These include :

- environmental improvement as there is less impact on the environment due to a reduction in waste
- cost savings due to increased operating efficiency and reduced production costs
- risk reduction due to a better understanding, control and management of present risks and future liabilities
- a competitive advantage through an improvement in the company image
- improved communication within the company as waste minimisation requires team effort

2.3.3 Effluent Segregation

Segregation of the various effluent streams is important for the optimisation of opportunities because :

- specific treatment such as oxidation, neutralisation, reduction or decolourisation are best achieved prior to mixing of streams,
- recovery or recycling will be more effective if the waste stream is as concentrated as possible, and
- mixing of waste streams with different characteristics leads to a high volume of waste that still requires treatment.

2.3.4 Reuse and Recycling

Re-using and recycling is accomplished either by using the waste generated directly or after treatment. It helps in eliminating disposal costs, reducing raw material costs, and may provide income from the sale of recovered goods. Either on-site or off-site recovery can be carried out.

2.3.5 Treatment and Disposal of Wastes

Even after effective waste minimisation programmes have been implemented, there will still be waste that must be treated and disposed. The treatment route chosen must be one that is suitable for the particular effluents produced. Examples include, separation, neutralisation, chemical treatment and biodegradation (see **Appendix 4**).

2.4 Establishing a Waste Minimisation Programme

Action plans for implementing an effective waste minimisation programme includes :

- commitment to action
- resource allocations
- identification of all sources of waste,
- quantification of the losses,
- investigation of opportunities to reduce waste,
- setting targets,
- setting priorities.

They are broadly divided into 5 sections : Planning and Organisation; Preliminary Assessment; Detailed Assessment; Feasibility Analysis and Implementation (See **Figure 2.2**). Each of these steps is discussed in more detail in the following sections.

2.4.1 Planning and Organisation

The first stage involves planning and organising the waste minimisation programme. A more detailed discussion in given in **Chapter 5**.

The most important step is to obtain commitment from senior management to establish a waste minimisation programme. If this commitment is not forth coming, the process will not be effective. One way in which commitment to action can be shown is by preparing a **policy statement** (or mission statement), outlining the goals of the waste minimisation programme and how these are to be achieved.

The second step is to select a **project team** to run the programme. This team should include personnel from all levels of the organisation, from management to shop-floor employees. The project team is managed by a **project champion**, whose role is to co-ordinate and facilitate waste minimisation actions.

2.4.2 Preliminary Assessment

In order to conduct a preliminary assessment, data must be collected from all areas of the plant, keeping in mind that the goal is pollution prevention, not data collection. This includes :

- Investigating the **costs** associated with each effluent stream.
- **Collecting regulatory reports** to understand the nature and limits of toxic release. Engineering and operating data and plant business records must be collated as they give information such as hazardous waste quantities that have been shipped, inventory of raw materials and purchasing history etc. This may give an indication of where costs can be reduced through implementing more effective control.
- **Visiting sites** in order to prioritise areas that need more detailed assessment.
- **Assigning priorities** based on the results of the pre-assessment. They may be targeted, based on volume of waste produced or cost of waste disposal.
- **Preparing a programme plan** which assesses to what extent outside organisations will be involved, defining the objectives of the programme, identifying possible solutions and obstacles, and defining analysis and collection procedures that will be used.
- **Developing a schedule** with a list of the milestones within each stage.

Chapter 6 discusses the preliminary assessment in more detail.

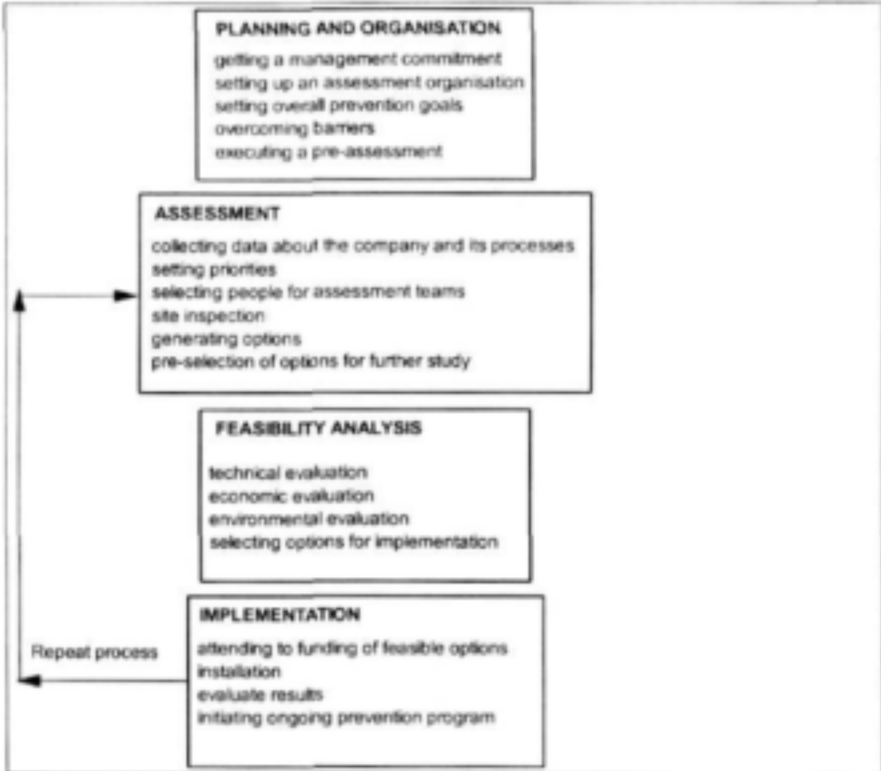

Fig 2.2 : Overview of the procedure for cleaner production

(Van Berkel and Verspeek, 1994)

2.4.3 Detailed Assessment

Once the pre-assessment has been carried out, the detailed assessment phase can be implemented where the focus is on the specific areas targeted in the first phase. This involves :

Choosing a team

This team also includes members from the original task force. Other members will include people with specific knowledge about the area under investigation or the waste streams generated.

Reviewing data and sites

This will involve a study of all data and interviewing the workers. An agenda should be prepared and inspection scheduled to coincide with operations of concern e.g. dumping of a bath, chemical addition etc. The operation should be monitored at all times and at different shifts and housekeeping should be observed. The organisational structure and controls should be assessed to determine the level of co-ordination between departments and the procedures involved in buying etc. The procedures should be followed from beginning to end and follow-up visits made. An effective means of recording data and information should be established early.

Preparing material and energy balances

This will help organise and document the process information. Simply put, the mass in must equal the mass out. A process diagram should be drawn up. It is not always easy to conduct such balances as most processes have numerous process streams each with their own environmental impact, the exact composition of some streams may not be known and phase changes may take place that may be difficult to analyse. Imbalances may also highlight where fugitive emissions are occurring.

Defining waste minimisation options

This is usually best achieved through brainstorming. Look at process changes such as optimising recipes, improved operating practices, management practices, production scheduling and inventory control etc. first and then at recycling options. The results are then screened and analysed. Options that have little or no capital cost attached to them can be implemented immediately, whilst others can be put on hold and some may require a more detailed analysis.

The steps involved in the Detailed Assessment stage are described in more detail in **Chapter 7**.

2.4.4 Feasibility Study

Once the waste minimisation options have been identified, a feasibility analysis must be conducted. In other words, the options identified should be analysed in terms of whether they are technically, economically and environmentally feasible. Refer to **Chapter 8** for further information.

2.4.5 Implementation

Implementation of the waste minimisation options is the final step and involves :

- Writing an assessment report which outlines the schedule for implementing waste minimisation projects and which forms the basis for evaluating and maintaining the programme.
- Attending to funding of feasible options.
- Implementing options and evaluating results

However, if at any stage of the preliminary assessment, feasible options are identified which are easily implemented and require no further investigation, they should be carried out immediately. These are generally options related to improved housekeeping, such as, fixing leaking taps or replacing broken valves and so on. Similarly, if options are identified that do not require a more detailed analysis, this stage may be passed over and only the feasibility analysis carried out. For example, if it has been identified that all hypochlorite bleaching should be replaced due to its harmful nature and various substitutions have been identified, a feasibility analysis is all that is necessary to determine which option is the most feasible. Those areas that require more in-depth analysis, will follow the normal route.

This approach of identifying waste minimisation options is presented in **Figure 2.3.**

Chapter 9 covers the implementation stage in more detail.

2.5 Maintaining the Waste Minimisation Programme

It is important to maintain the waste minimisation programme by:

- integrating waste minimisation into corporate planning,
- providing ongoing staff education programmes,
- maintaining internal communication,
- establishing a monitoring system and updating targets,
- rewarding personnel for their success in waste minimisation, and
- providing public outreach and education about pollution prevention efforts. (e.g. press releases, school talks etc.).

Remember that waste minimisation is not a once-off activity and should be continually monitored and updated.

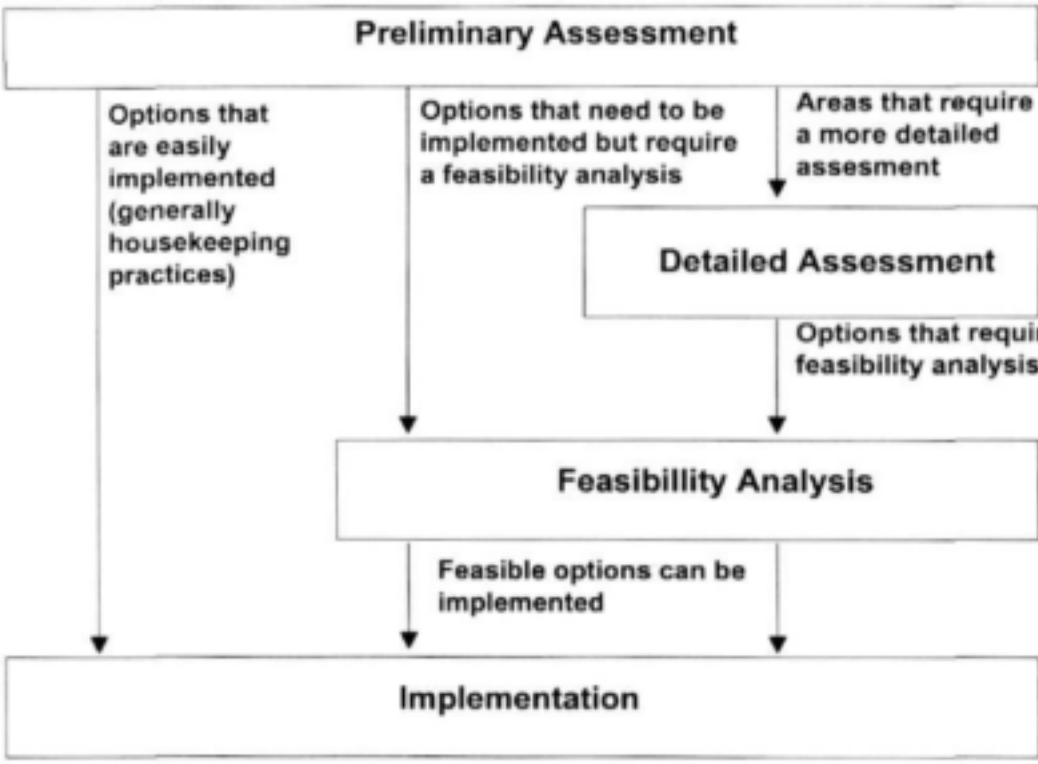

Figure 2.3 : Schematic diagram of process for determining which options are suitable for implementation (Kothuis and Petrie, 1997)

2.6 Monitoring and Targeting

An important aspect of a waste minimisation is monitoring and targeting (M&T) which ensures the long term success of the programme. It involves monitoring all inputs and outputs to a process and keeping track of any changes that have been implemented. Based on the performance of the company and best practice performance data, reasonable targets are set for, for example, water and energy use, effluent production, rejects etc. By monitoring the performance, it can easily be identified when these target levels are not being reached and the reasons for this investigated.

Monitoring and targeting consists of five main steps (Enviros March, 1999):

- monitoring consumptions of, for example, water and energy,
- determining performance levels,
- establishing regular reporting systems,
- setting up teams to discuss ways of improving performance, and
- establishing a feedback mechanism to create awareness.

Monitoring of consumption involves establishing some form of metering and then ensuring that these meters are read. Graphical methods are then used to indicate when the process is not performing as expected. Further information on M&T methods is given in **Chapter 6**.

2.7 Training

This is an important aspect of a waste minimisation awareness programme. When personnel at all levels of the organisation are included in the team and allocated waste minimisation tasks suited to their level of responsibility, experience shows that the waste minimisation programme can be both an engaging and a self-enforcing process. Engagement and idea generation at all levels tends to give an easier and more positive process to manage as opposed to a top-down waste minimisation involving only a few people at the higher levels. A programme can be included in the general orientation programme given to new employees with more detailed training provided after a few weeks on the job. This will provide them with the skills to implement pollution prevention and also emphasise the company's commitment to the environment. Specialised training can be given to employees when there is a change in job description or they are transferred. It should form part of the regular training costs.

Chapter 3

Environmental Challenges Facing the Textile Industry

As mentioned in **Chapter 1**, there are a number of environmental challenges facing the South African industry. These include the increasing cost of water, more stringent regulations regarding the discharge of waste, and the introduction of a number of new policies, bills and acts detailing pollution liability. In order to meet these challenges, industry must develop proactive waste management procedures. This can be achieved by implementing environmental and quality management systems which incorporate the concept of waste minimisation.

3.1 Environmental Management Systems

All organisational activities, products and services will interact with and have an effect on the environment, and an effective environmental management system (EMS) is needed to deal with this complexity. It must therefore be interwoven with the overall management of the company. An EMS is important because it manages, measures and improves environmental performance, and leads to efficient compliance with environmental requirements.

It should :

- identify and assess any environmental effects caused by company activities and incidents,
- identify relevant regulations,
- identify priorities and objectives and set targets,
- facilitate planning, monitoring, auditing and reviewing of the system, and
- be capable of changing as circumstances change.

EMS certification systems have been established to allow companies to seek third party approval of their systems. BS 7750, (the British Standard for EMS), EMAS, (European Union Eco-management and Audit Scheme) and the ISO 14000 series of standards (International Organisation for Standardisation) are in operation. The ISO series of standards was introduced to try and achieve harmonisation of all these systems in order to avoid potential conflicts and trade barriers.

A brief description of each of these systems is given in this section. In addition, the quality assurance standard, the ISO 9000 series will also be discussed as it contains references to waste minimisation.

3.1.1 British Standard 7750

BS 7750 was introduced in 1992 in the UK, in response to increasing concerns about environmental protection and performance.

The main aspects of the standard are :

- company environmental policy,
- environmental management system,
- environmental audit,
- environmental objectives,
- environmental management manual and documentation, and
- operational control and verification.

With the introduction of EMAS, the British standard has largely fallen away, with companies that are accredited to BS 7750 easily applying to EMAS.

3.1.2 Eco-management and Audit Scheme (EMAS)

The Eco-management and Audit Scheme was first released in December 1990 and was conceived as a mandatory requirement that was to be applied to all polluting industries. This approach was revised in 1992 when it became a voluntary scheme. It was basically developed in an attempt to develop European Union-wide environmental policies that protected the environment, but allowed for free trade and regional differences. It is a community-wide scheme that allows voluntary participation by companies for the evaluation and improvement of their environmental performance and the provision of relevant information to the public. Currently EMAS only covers a limited number of industrial sectors and can only be applied for by European Union countries. Companies that comply with the regulations set out in EMAS can use the EMAS logo in their communication, e.g. in advertising and on products.

The main aspects of EMAS are :

- environmental policy,
- environmental programme,
- environmental management system,
- environmental audit,
- environmental statement, and
- validation.

The main reasons for industries to apply for EMAS certification is market pressure. It allows a more flexible approach to regulation with a move away from command and control to voluntary and flexible instruments.

3.1.3 ISO 14000

ISO 14000 is a series of standards, developed by the International Organisation for Standardisation (ISO), which describe the basic elements of an effective EMS. The standards are being developed by Technical Committee 207 (TC207) and this committee is divided into subcommittees and working groups, each of which are setting standards for the following :

- environmental management systems (EMS),
- environmental auditing (EA),
- environmental performance evaluation (EPE),
- environmental labelling,
- life cycle assessment (LCA),
- environmental aspects in product standards (EAPS), and
- terms and definitions.

The standards themselves do not set targets for companies to achieve, but provides building blocks for their own systems, thereby laying the basis for better environmental management. A schematic diagram of the ISO 14000 series is shown in **Figure 3.1**.

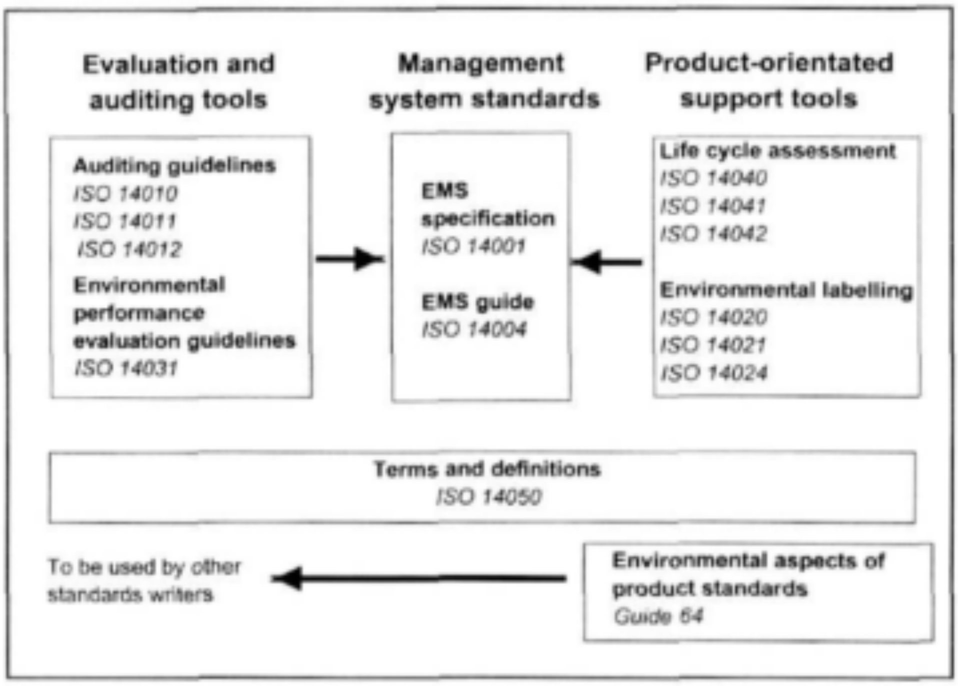

Figure 3.1 : The structure of the ISO 14000 Series of Standards (Sheldon, 1997)

Why implement ISO 14000 ?

There are a number of advantages and/or reasons for companies to implement ISO 14000. These include :

- environmental management is an integral part of business operations,
- there is increasing use of voluntary standards,
- reduces multiplicity/duplication,
- the public want to deal with environmentally-responsible companies,
- may be adopted by the government as a legal requirement,
- satisfy stakeholders' interests,
- internal benefits such as :
  - cost savings due to better management,
  - decreased non-compliance and increased operating efficiency,
  - waste reduction, pollution prevention and recycling,
  - it will help with training,
  - integration of fragmented systems,
- pollution prevention, and
- achieve environmental excellence.

Concerns of ISO 14000

Although there are numerous benefits to a company that implements ISO 14000, there are a number of concerns such as :

- increased costs - implementing an EMS can be expensive, especially for small and medium enterprises ,
- can act as possible tariff trade barriers if ISO 14000 is adopted as a pre-requisite for imports,
- it is a voluntary standard, but if it becomes a regulatory mandate, it could become a trade barrier,

- it does not lead to better environmental performance as it is a process, not a performance, standard, but better environmental management will lead to better performance, and
- concerns about registration process.

In spite of these concerns, interest in ISO 14000 is growing, with delegates from 47 countries participating in the 1995 meeting.

It is evident that the ISO 14000 series of standards have the potential to improve environmental performance of industries worldwide. A revision of the standards is planned for 1999.

Further information on ISO 14000 can be found in the following publications :

- **ISO 14 000 - A guide to the New Environmental Management Standards**; Tom Tibor and Ira Feldman (1996); and
- **ISO 14 000 and Beyond - Environmental Management Systems in the Real World**; Edited by C Sheldon (1997).

Details of these books can be found in **Appendix 5**.

3.2 ISO 9000 : Relevance to Waste Minimisation

The ISO 9000 set of standards represents an international consensus on good management practises with the aim of ensuring that organisations can deliver the products or quality of service that the customer requires on an ongoing basis. These standards, therefore, stipulate *what* requirements a company's quality system must meet, but does not dictate *how* they should be met. These requirements include management, leadership, a proactive and well-trained work force, customer feedback, measurement, documentation, internal audits, continuous improvement, and third party validation.

Companies generally implement ISO 9000 due to customer demand, but soon realise that when implemented properly, this management system saves money, reduces costs and increases product quality and employee productivity. It has been reported that a saving of at least 10 % of company revenue is possible by reducing or eliminating the cost of scrap, rework, waste and returns (The ISO 9000 Network).

The ISO 9000 series of standards, therefore, complement those of the ISO 14000 series and will aid in reducing waste and increasing company profits.

3.3 Ecolabels

Ecolabelling schemes provide for the award of a label to products which meet specific objectives, thereby allowing the public to determine which products adhere to the environmental ratings stipulated in the regulations. Generally, the same criteria would apply to products manufactured in the country or to products imported into the country.

3.3.1 European Union Ecolabel

The European Union ecolabel award scheme was adopted on 23 March 1992. The regulation is effective directly according to the laws of the EU member states which came into being on 2 May 1992.

The regulation provides for the award of the ecolabel to products which meets a specified requirements or criteria. These labelling criteria are identified by the EU Commission on the basis of life cycle assessment of a broad variety of products within the product category in question. Complying with these criteria should, of course, not compromise product quality or workers safety, nor must it significantly affect the products fitness for purpose. Environmental benignity must not be bought at the cost of the product's efficiency.

Criteria for assessing products

Ecological criteria are defined for assessing the environmental impacts of products. Criteria have been drawn up for separately identified product groups, where a product group means products which serve similar purposes and are put to equivalent uses. The same criteria apply both to products manufactured in the EU or to products imported into the EU. The criteria are set using a *cradle to grave* approach to achieve the objectives set out above and to ensure a *high level of environmental protection*.

Application for an ecolabel

An application for an ecolabel is made to the national competent body appointed by the government of each member state for that purpose. The body is independent and neutral. For example, in the UK the competent body is the UK Ecolabelling Board. The Board processes applications for the label, concludes contracts with successful applicants, suggests new product groups for inclusion in the scheme, assists in the development of EU criteria for products, handles enquiries from business and the public and promotes the scheme in the UK.

It must be noted that the European Ecolabel may, but does not necessarily, replace national labels.

3.3.2 Ecolabels Specific to the Textile Industry

The EU working party on Ecolabels for textile products is chaired by the Danish Environmental Protection Agency, with the focus (product groups) being bed linen and T-shirts. A document has been produced for EU ecolabelling of textile products.

The Swedish Institute of Standardisation also submitted a proposal on environmental labelling of textile products. However, it was rejected by ETAD as it is based on selected hazard features rather than a life cycle assessment.

There are also a number of labels currently being used in German-speaking countries (Germany, Austria and Switzerland). These are the Oko-Tex Standards, the MST (Markenzeichen Schadstoffgeprufter Textilien), MUT (Markenzeichen Umweltschonender Textilien) and OTN 100 (Austria). A harmonised version is currently in preparation. Additional models currently in regional use within the EU are the Danish score system; the Glatt model (Switzerland); the RIZA model (NL); the EPEA model (Hamburg private initiative); the Nordic swan; and ELTAC (European Largest Textile and Apparel Companies).

3.4 Pollution Liability in South Africa

Of all industrial effluents, those produced by the textile industry are considered by the DWAF to be one of the most problematic as they are highly coloured and have high COD and conductivity. The majority of textile industries in South Africa discharge to sewer and their effluents must comply with limits set by the local authorities (who in turn, have to comply with the requirements set by DWAF).

Increased fines, clean-up orders, liability for environmental rehabilitation, personal liability of directors, and the increase in public and international pollution awareness are all issues facing the South African Industries. New developments in pollution liability were introduced at a rapid rate during 1998, and these are contained in a number of new Acts, Bills, Policies and Draft Policies. These include the Water Service Act 108 (1997), the National Water Act (1998), National Environmental Management Bill (1998), Proposed Integrated Pollution Control and

Waste Management Bill (1999), Draft White Paper on Environmental Management Policy for South Africa (1998) and the Draft White Paper on Integrated Pollution Control and Waste Management for South Africa (1998). These developments stress the need for companies and their directors to assess their rights and obligations in this field (van Onsellen O,Connell, 1998). The following section will highlight some of the more important pollution liability aspects.

3.4.1 Water Services Act

The discharge of industrial effluent is controlled by either the local authorities (if discharged to sewer) or DWAF (if sent directly to a natural water resource). Permits and licenses will be issued to control standards which must be set in such a way so as to promote sustainable development, pollution prevention, waste minimisation and the Best Practicable Environmental Option. Companies will therefore, be required to either treat their effluent to a greater extent or implement some waste minimisation programme to reduce their waste. Permits are likely to be used to enforce strict pollution control measures and violation of these can lead to withdrawal of a permit and subsequent closure of operation.

3.4.2 The National Water Act (NWA) and National Environmental Management Bill (NEMB)

The NWA is aimed primarily at controlling pollution of water, whereas the NEMB covers all environmental media. Both place an obligation on owners of land on which any activity is, or was, performed which is, or has caused pollution to take place, to take all reasonable measures to prevent the pollution from occurring, continuing or re-occurring. It, therefore, imposes liability for historical activities which caused pollution as well as historical pollution itself. Both the NWA and the NEMB allow for local authorities to direct the offender to take clean-up and rehabilitation measures. If this directive is ignored, the authorities can undertake the necessary steps and recover all costs from the offender.

The NWA makes provision for the prosecution of offenders who do not comply with its regulations. The maximum penalty for a first time offender is R 50 000 and/or one-year imprisonment. This is increased to R 100 000 and one year imprisonment for second offenders. Additional penalties may be applied if deemed necessary. It has been DWAF policy not to prosecute offenders immediately. DWAF, however, due to continual deterioration in the quality of the RSA water resources, considers pollution to be a serious offence and have recently begun prosecuting offenders immediately.

Penalties that can be incurred in terms of the NEMB include :

- payment of damages, whereby any third party that was harmed / damaged due to pollution can fine the offender;
- pollution advantage; i.e. it can be shown that the company has gained financially by not disposing of waste in the correct manner, they can be forced to pay this amount; and
- investigation and prosecution costs incurred by the investigation.

3.4.3 Other Considerations

Private Prosecution

Under the NEMB, private citizens have the right to enforce pollution control by being able to prosecute any company or individual if it is felt that there is a breach of any law relating to the protection of the environment. In the event of the prosecution being unsuccessful, the accused may be required to pay the private prosecutors legal costs.

Access to Information

In terms of the NEMB, any person is allowed access to information held by the government pertaining to all emissions to the environment. In other words, the public is entitled to access the production process of a company that utilises a substance that is potentially harmful to the environment.

Director Liability

Any person who is, or was, a director of a company at the time at which the company committed an act of pollution, and it is found that the director did not take all reasonable steps to prevent the pollution from occurring, can be held liable in a personal capacity. In this case, the director can be convicted on all penalties described in the previous section, including imprisonment. There is, therefore, an obligation on the part of a director of a company to be aware of all aspects relating to the production of waste on site.

Protection of Workers

Under the NEMB, there are two clauses which aim to protect the workers. In the first instance, a worker is entitled to refuse to perform any task if they reasonably believe that it poses a threat to the environment. In this case, the employer may not take action against the worker. In the second instance, workers are encouraged to disclose any information on company activities that poses an environmental risk to the authorities. Again, no action may be taken against them by their employer.

3.4.4 Conclusions

These above sections are only a summary of the new legislation in South Africa that have an effect on industrial activity. It is evident that companies are being forced to take environmental issues into account in their business strategy.

3.5 How will this Guide Help the Textile Industry Deal with these Issues ?

This guide will enable the textile industry to establish a waste minimisation programme, thereby reducing the pollution from the industry and reducing the environmental impact. The existence of an effective waste minimisation programme is an essential aspect of any environmental management system, and therefore, this guide will contribute towards compliance with ISO 14000. In addition, by implementing a programme to reduce waste at source, the risk of pollution liability of the individual textile companies is decreased.

Chapter 4

Identifying the Potential for Savings

4.1 Introduction

This chapter aims to give an indication of the scope for savings in your company by identifying those areas that are high in cost and providing guidelines for the potential savings. The importance of key performance indicators (such as litres water used per kilogram of fabric) is explained and you are taken through the steps of calculating these for your own company. Benchmark figures, based on international data and previous studies within the South African textile industrial sector, are provided as a means of rating your performance with other textile companies. Water, energy and caustic soda consumption are the focus areas as these are generally the high consumption utilities at a textile factory. Once the potential savings have been highlighted, there will be increased support and motivation from management for implementing a waste minimisation programme.

The relevant worksheets are given in **Volume II** of this guide (Worksheets **A1** to **A7**). An explanation as to the aim and methodology of using the sheets are provided together with each worksheet. Background information is provided in this Chapter.

4.2 Conducting a Scoping Audit

A scoping audit involves collecting financial data relating to utility use within the company. Areas that are discussed are the costs of :

- raw material use such as dyes, cloth, yarn etc.;
- packaging;
- ancillary materials such as caustic soda; solvent; or any other auxiliary that is used in large quantities;
- consumables, for example internal packaging;
- energy (electricity; fuel oil; coal etc.);
- water, including treatment costs (e.g. softening);
- effluent (including treatment and disposal costs); and
- solid waste disposal, including drum disposal etc.

There are general guidelines as to the expected savings that can be achieved by implementing waste minimisation options. These ranges are given in **Table 4.1** below and are based on international data (Enviros March, 1999).

Based on the costs and savings identified, areas for improvement can be identified and ranked according to priority. This will give some indication as to the starting point of the waste minimisation audit. The general trend is for raw materials to be the area where the greatest savings can be achieved, followed by water and effluent combined and energy.

Table 4.1 : Scope for Savings (Enviros March, 1999)

Utility	Scope for Saving
Raw materials	1 to 5 %
Packaging	10 to 90 %
Ancillary materials	5 to 20 %
Consumables	10 to 30 %
Electricity	5 to 20 %
Heat for process and space heating	10 to 30 %
Water	20 to 80 %
Effluent	20 to 80 %
Solid Waste	10 to 50 %

4.3 Determination of Key Performance Indicators

Key performance indicators (KPI) are an indication of the efficiency of a process. Within the textile industry, KPI's are determined based on consumption of a utility per kilogram of fabric/yarn produced. The most commonly used KPI is litres of water per kilogram (ℓ/kg); examples of others are given in **Table 4.2**.

Table 4.2. Key Performance Indicators (or specific consumption) for the Textile Industry

Utility	KPI Units
Water	ℓ / kg
Caustic	g / kg
Salt	g / kg
Steam	MJ / kg
Electricity	MJ / kg

As can be seen, the most commonly used indicators are water, caustic soda and energy consumption. Worksheets **A2** to **A7** in **Volume II** of this guide will take you through calculating the KPI's for your factory in terms of water, caustic soda and energy use. Typical KPI's (i.e. those that can be expected based on technologies and recipes typically in use at a textile factory) and target KPI's (those based on new technologies, literature and experiences) are provided as a comparison for your factory's performance. Potential savings are also identified.

4.3.1 Specific Water Use

The KPI for water consumption in a factory is determined by dividing the overall production (in kgs) by the overall water use (in litres). The specific water use (SWU) for individual processes can also be determined. It has been found in general that the SWU can be reduced by at least 25% by implementing waste minimisation options. This aspect is addressed in more detail in the following chapters in this guide.

4.3.2 Specific Energy Use

The potential for heat recovery and energy saving is addressed briefly in this guide. Calculations are based on the energy that can be recovered from the effluent and through monitoring utilities such as steam (boiler operation), compressed air and electricity use. The importance of good housekeeping is also stressed. In addition, heat recovery is considered in the preliminary and detailed assessments.

4.3.3 Specific Caustic Soda Use

In the majority of textile mills, caustic soda is a high consumption chemical and is the cause of high pH effluent. It is not often realised that by recovering the caustic soda, savings can be made in both caustic soda purchases and in neutralisation costs.

As can be seen in **Figure 4.1**, by reducing the pH to 9, the majority of caustic soda is neutralised, and therefore, neutralisation to pH 7 is seldom required. At a pH of 12, the concentration of caustic soda in the effluent is 0.4 kg / kℓ, while at pH 13 it is 4 kg /kℓ. By reducing the pH to 9, the concentration has been effectively reduced to zero.

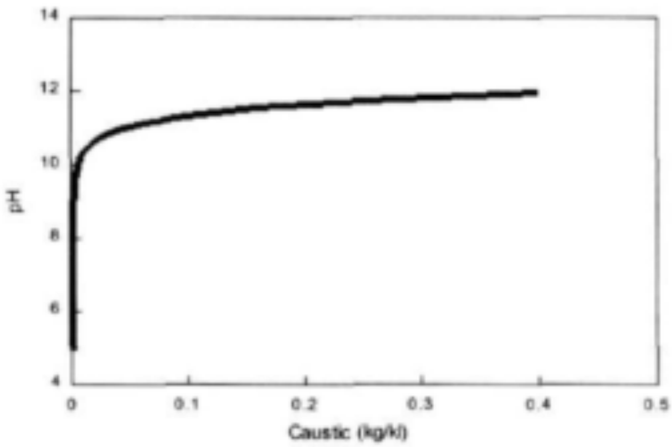

Figure 4.1 : Relationship between pH and effluent caustic soda concentration

The value of caustic soda in the effluent at the various pH values is shown in **Figure 4.2**. The cost of caustic soda is taken to be R 1 200 / ton (100%). This figure shows that at pH 9 the value of caustic soda is effectively zero and increases exponentially from approximately pH 10.

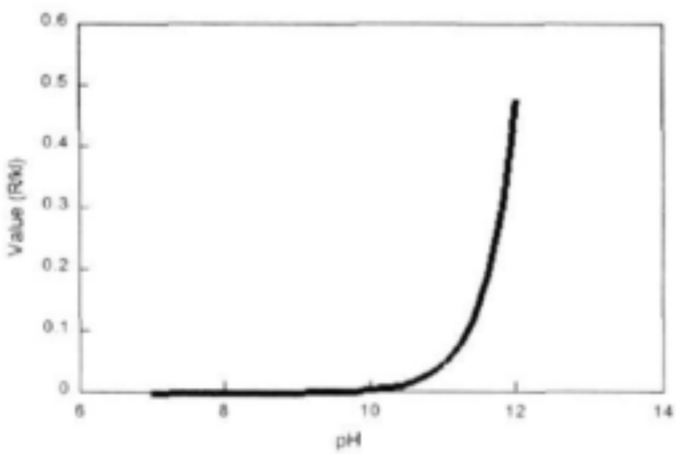

Figure 4.2 : Value of caustic soda in the effluent at various pH values

4.3.4 Overall Effluent Value

Figure 4.3 represents the total value of the effluent at various pH values and at increasing temperatures. Included in the value is caustic soda and sulphuric acid costs, and water and effluent charges (taken as approximately R 1.80 / kl for each). The purchase price of caustic soda was taken to be R 1 200 / ton (100 %), and that of sulphuric acid (98 %) as R 250 / ton.

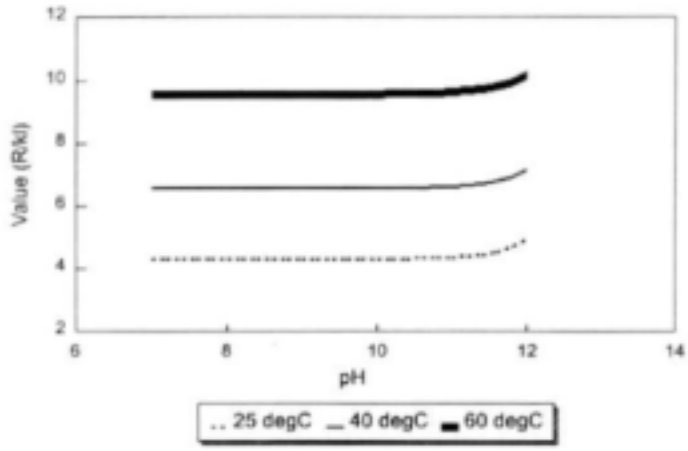

Figure 4.3 : Total value of the effluent at various pH values and effluent temperatures.

As is obvious from this diagram, the value of the effluent increases with an increase in temperature, indicating the importance of heat recovery. The fact that the effluent contains this degree of value, emphasises the need for source reduction.

4.4 Benchmarking

Benchmarking gives an indication of your company's performance in relation to other textile industries on a global scale. Benchmark figures have been included in the worksheets to enable this comparison. These figures have been taken from international and local sources. **Appendix 6** contains benchmark data for various dyeing technologies.

4.5 Conclusions

On completion of the **A** series of worksheets, you will be able to identify the potential for savings within your factory and you would have identified those areas that require further in-depth investigations.

The following chapters explain each stage in conducting a waste minimisation audit and the relevant worksheets are available in **Volume II** of the guide.

Chapter 5

First Stage : Planning and Organisation

5.1 Introduction

The first phase of establishing a waste minimisation programme involves planning and organising the programme and carrying out a preliminary assessment.

Planning and organisation involves obtaining a commitment from management, setting up a assessment team, identifying the overall goals and overcoming barriers to the concept of waste minimisation. This chapter is to be used in conjunction with the **B** series of worksheets in Volume II of the guide.

5.2 Obtaining Commitment

The first step in planning and organising the waste minimisation programme is to obtain a commitment from management regarding waste minimisation, or else no real action will take place. This commitment will ensure that there is a written company policy, provision of adequate resources, a programme for employee training and encouragement for the implementation of waste minimisation projects.

When presenting your argument to management, stress the benefits of waste minimisation such as :

- the saving that can be achieved (use results of scoping audit - Worksheet **A1**);
- it improves overall process efficiency;
- it enhances product quality;
- it helps in compliance with envrionmental legislation; and
- it provides a competitive advantage.

If the project is well-managed by the champion and the team, the time commitment from senior management should be minimal.

5.3 Electing a Project Champion

Once commitment has been obtained, a project champion needs to be appointed. The project champion has a number of duties, namely to :

- co-ordinate and faciltiate the waste minimisaiton programme;
- publicise the project within the company;
- develop action plans;
- identify team members;
- report to management; and
- establish systems to ensure success of the programme

Note that the function of the project champion is not to go out and do waste minimisaiton on his/her own. A succesful programme requires the involvement and effort of all people throughout the company.

5.4 Establishing a Project Team

The next step is to elect a waste minimisation project team. The role of the team is to :

- conduct the waste surveys;
- identify problem areas;
- brainstorm the problems;
- identify areas for improvement;

- select the most feasible measures; and
- make sure the identified minimisation measures are implemented.

The team should consist of people who have an interest in the results of the programme and include management, technical staff, production employees and a health, safety and environment officer. Employee involvement at all stages of manufacture should be encouraged to increase awareness of waste reduction. It is also advisable, although not necessary, to include an outside expert, to counter preconceived ideas held by company personnel and to ensure that deadlines and objectives that are set are achieved and that the survey does not come to a standstill. An example of the expertise required for inclusion in the project team is given in **Table 5.1.**

5.5 Setting Overall Prevention Goals

It is important to identify the goal of the waste minimisation survey. To do this, your company must identify what they hope to achieve by establishing a waste minimisation programme and prepare a policy statement. This statement must be included in the documentation to serve as an incentive to establish an effective programme.

A rough timetable should also be included at this stage to set a target date by which the company hopes to have achieved the various goals. This should not be too ambitious, but strict enough to ensure that progress is made in establishing a waste minimisation programme.

Table 5.1 Expertise for inclusion in the assessment team (Institute of Chemical Engineers, 1992)

Expertise	Function
management	demonstrate commitment; authorise resources
environmental	provide information on regulations, pollution control, waste disposal costs and hazards and risks
quality assurance and quality control	provide information on current performance and on specification constraints
design and process engineering	provide information on plant and current processes, and quantify impact of changes
production and maintenance	provide description of plant and processes, and feedback of proposed changes
legal	evaluate and interpret potential environmental liability
accounting, finance and purchasing	provide information on costs and inventory control
health and safety	provide data on costs, hazards and risks
research and development	suggest modifications and generate options
operators, supervisors and transport department	provide suggestions and help assess operational, procedural or equipment changes
external consultants	question established procedures

5.6 Identifying Barriers

The concept of reducing waste at source rather than through the traditional *end-of-pipe* treatment methods represents a new way in thinking for most companies and there are a number of barriers that need to be identified and overcome before a successful waste minimisation programme can be implemented. These barriers can be technical, economical, regulatory and cultural.

5.6.1 Economic Barriers

Economic barriers occur when management believes that there is insufficient funds to implement a waste minimisation programme. If this is the case, management should at least investigate options that require low capital input such as improved housekeeping and inventory control.

5.6.2 Technical Barriers

Some technical barriers include concerns about changes to product quality and customer acceptance, lack of information or techniques and poor employee reaction to implementation. In these cases, the company should identify the customer needs and carry out pilot testing of the new process; obtain information from all relevant bodies such as government, trade associations, consultants etc.; and ensure that there is good feedback and employee involvement.

5.6.3 Regulatory Barriers

These barriers should be relatively easy to overcome as one of the objectives of waste minimisation is to reduce the impact on the environment. If the company works in conjunction with the relevant authorities in the planning stages there should be close co-operation and limited problems.

5.6.4 Cultural Barriers

If there is lack of management commitment and awareness of the company policy and goals, and if there is poor communication and an inflexible organisational structure, friction and resistance to change within the company may become a barrier to an effective waste minimisation programme. This can be overcome though employee training and education, improved management and the involvement of employees at all levels.

5.7 Getting Started

Once management commitment has been obtained and the team established, the waste minimisation programme can be set in motion. The general steps to follow include :

- obtaining general information of the factory
- raw material inventory
- final product inventory
- SWOT (strenghts; weaknesses; opportunities; threats) analysis
- preparation of an environmental policy statement
- identification of overall goals
- conducting a scoping audit

Worksheets **B1** to **B7** will guide you through these steps. Explanations are provided together with the worksheets in Volume II.

The scoping audit will identify the scope for savings within the company. Worksheet **A1** in **Volume II** can be used for this analysis if it was not completed in **Chapter 4**.

5.8 Conclusions

On completion of the **B** series of worksheets, the basis of the waste minimisation programme will be in place and the potential for savings would have been identified. The pre-assessment can now be undertaken.

Chapter 6

Preliminary Investigation

6.1 Introduction

The preliminary investigation involves obtaining overall information about the company, the products that are manufactured, the processes that take place and the associated wastes, and estimating volumes of waste and the associated costs. Based on this overview, the areas that require more detailed investigations can be identified, be it due to high volumes of waste that are produced or the nature of the waste.

6.2 Data Collection

Typical information required for the assessment phase of the programme is listed in **Table 6.1**. The extent and degree of detail required depends on the size and requirements of your company. It should also always be kept in mind that the aim of this data collection is to reduce waste, not simply the accumulation of records. The focus of this section should be on obtaining a good inventory of waste streams, identifying the source of these wastes and quantifying the volumes, costs and hazards associated with the pollution.

Table 6.1. Information required for an assessment (After Institute of Chemical Engineers, 1992)

Environmental information	- waste manifests and disposal records - waste analyses, flows and concentrations - wastewater discharge records and analyses - compliance requirements - air emission limits - discharge consents - site licence controls - environmental assessment reports - environmental management systems (ISO 14000) - environmental audit reports - environmental health and safety data - environmental policy
Design information	- site plan of factory with all drains marked - process descriptions - process flow diagrams - design and actual material and energy balances for production and pollution control processes - operating manuals - equipment lists, specifications and data sheets - piping and instrumentation diagrams - plot and elevation plans - equipment layout and work flow diagrams
Raw materials and production information	- recipes - raw material, product and intermediate specifications - material health and safety data sheets - NOSA assessments - product and raw material inventory lists - operator data logs - operating procedures - production schedules
Economic information	- treatment and disposal costs for all waste - water and sewer charges - product, utility, energy and raw material costs - operating and maintenance costs - departmental cost accounting reports - storage and transport costs
Other information	- standard procedures - organisational charts - planning consents and conditions

In order to do this, there are a few steps that must be followed; namely :

- prepare process flow charts;
- make preliminary mass and energy balances; and
- assign costs to waste streams.

6.2.1 Process Flow Diagrams

Flow diagrams are schematic diagrams representing the flow of water, chemicals and emissions from the area under investigation. These diagrams should list, and where possible, characterise, the input and output streams and make note of any recycle streams. Materials that are only used occasionally, or those that only appear on the input side should also be listed. The drawing of a process flow diagram is an important step towards constructing mass and energy balances.

Begin by listing all the process operations within the organisation and use the information obtained during the scoping audit to record the inputs and outputs for each process. Start with a flow diagram for the site as a whole, then for each department and finally, for each process. An example of how to construct flow diagrams is given in **Figure 6.1**. In general, flow diagrams per department are all that are necessary for the preliminary assessment stage of the programme. The more detailed process diagrams will be constructed in the detailed assessment phase when areas of concern have been identified for further investigation.

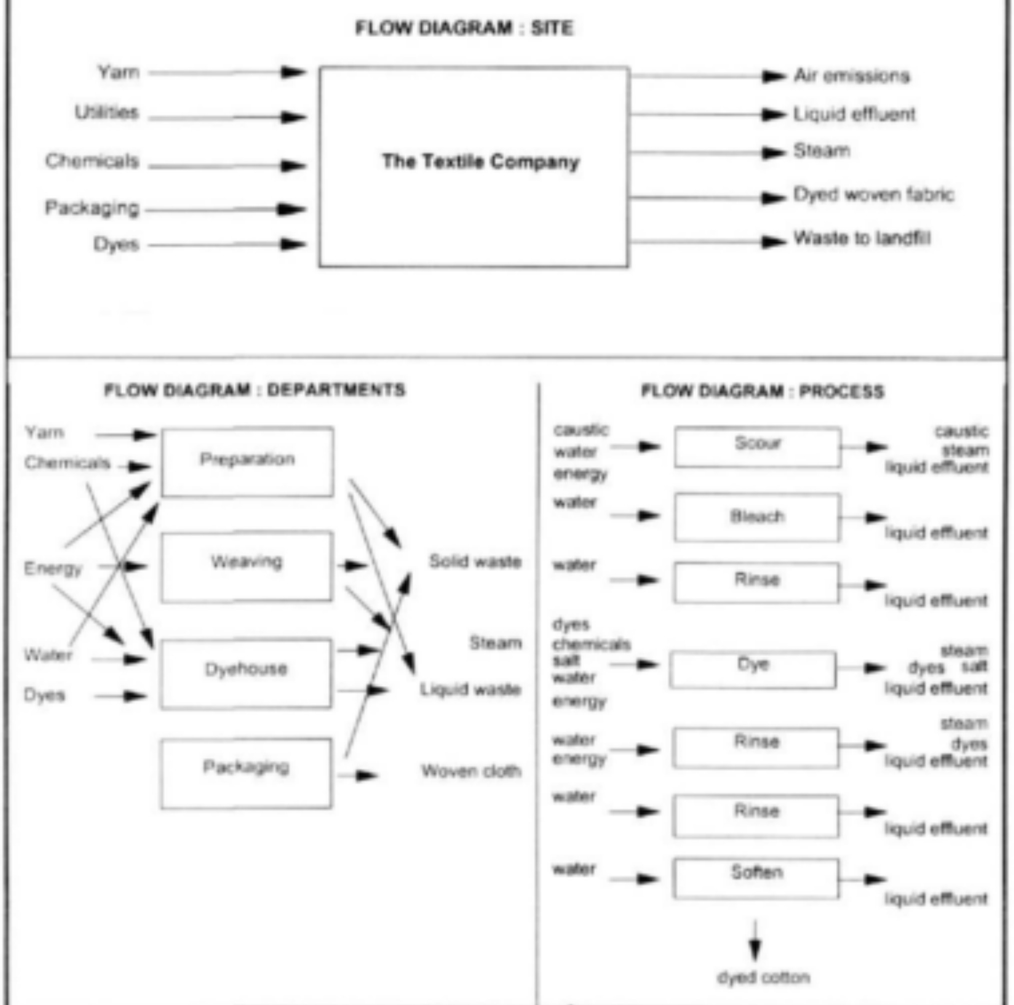

Figure 6.1 : Example of flow diagrams for a textile processing site; processing departments; and cotton dyeing process

6.2.2 Mass and Energy Balances

Mass and energy balances are important for any waste minimisation survey as they help identify and quantify previously unknown emissions. They are also useful in monitoring the progress made in the waste minimisation programme and for evaluating the costs and benefits of implementing the various options. An example of the components of a material and energy balance is given in **Figure 6.2**. These balances do not have to be perfect (do the best to reflect the situation as accurately as possible), but do not get bogged down with fine details. If quantification of an emission is not possible, try to give an estimation of the size (e.g. large, negligible etc. As long as all emissions are listed, waste minimisation is possible. Again, the preliminary assessment phase focuses on the site and departments rather than individual processes. More detailed mass and energy balances are prepared for each process in the detailed assessment.

6.2.3 Assign Costs to Waste Streams

This cost will reflect the value of the stream that is discarded. Remember to include factors such as :

- cost of raw material in waste (fibre, chemicals, dye),
- manufacturing cost of material in waste,
- cost of product in waste,
- cost of treatment of waste to comply with regulatory requirements,
- cost of waste disposal, and
- cost of waste transportation etc.

Once you have calculated what it costs to produce waste, you will realise the importance of waste minimisation to your company.

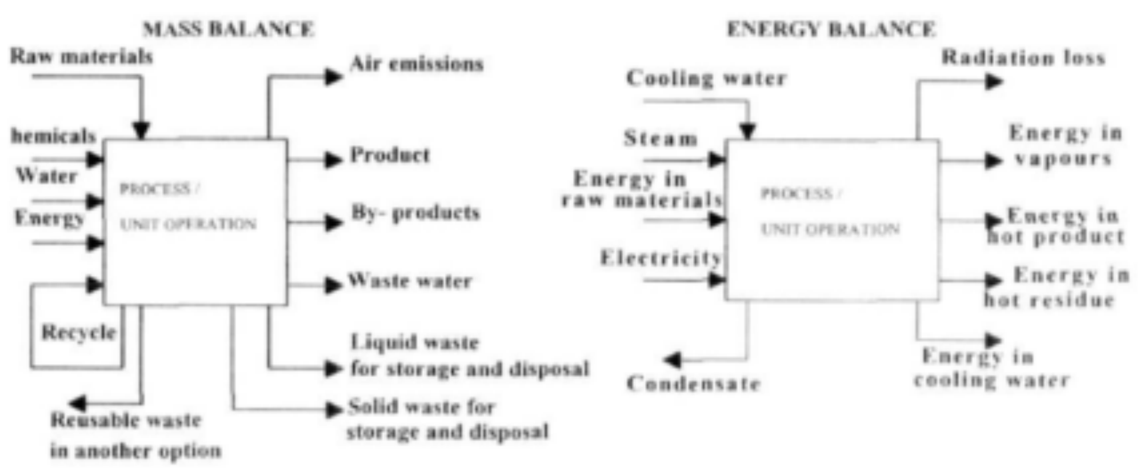

Figure 6.2 : Typical components of a mass and energy balance (National Productivity Council, 1994

6.3 Assessing the Scope for Energy Savings

Large savings in energy costs are possible through routine monitoring and maintenance of utilities such as electricity, steam, compressed air and refrigeration systems. Energy savings in terms of heat recovery from effluent has been addressed in **Chapter 4** (Worksheet **A4**), this Chapter (Worksheets **C15** and **C16**) and will be used in the construction of energy balances over specific processes in the Detailed Assessment phase (**Chapter 7**). However, assessing the scope for savings in the generation of the utilities mentioned above has not been addressed as yet in this guide. Although theoretically this is an area that should be dealt with in the preliminary assessment, it is felt that an individual set of worksheets is required to cover all aspects relating to energy savings and should be dealt with as part of the Detailed Assessment Phase (**Chapter 7**, Section 7.2.5; Worksheets **H1** to **H20**).

General working practices relating to energy use are covered in Worksheet **C8**. The questions posed in this Worksheet will aid in highlighting those areas that require further investigations.

Further options for improvements are given in **Appendix 1**.

6.4 Setting Priorities

At the end of the preliminary assessment phase, the project team should target those processes, operations or waste streams for the detailed assessment. Targeted processes can be based on the hazardous nature of the waste, the large volumes of water consumed or the use of excessive energy. In time, all operations should be assessed in more detail, but for large complex processes, some prioritisation is necessary.

6.5 Monitoring and Targeting

As mentioned in **Chapter 2**, an important aspect of waste minimisation is establishing some sort of M&T programme to ensure the long-term success of the project. This involves determining the consumption of utilities such as water, energy or chemicals and relating them to a variable such as production. Performance levels are then reflected graphically and in this way process inconsistencies are easily identified. In order to obtain this information, it is necessary to have some kind of metering available to measure consumption and ensure that readings are taken on a regular basis.

It has generally been found that insufficient metering is present in textile factories. If the main utility consumptions such as water and energy are to be monitored, it is important to have sufficient sub-metering. Suggested areas for water meters include :

- main incoming water
- borehole water if applicable
- boiler feed water
- each water - consuming department (sizing, dyehouse etc.)
- high water - consuming dyeing equipment (e.g. wash ranges, relaxers etc.)
- ablutions

Similarly meters should be installed to record energy use. Steam, electricity and LPG use should be monitored. Again, meter those areas that are high users and then individual equipment if they are used frequently (e.g. LPG fired stenters).

Remember : ***You can't manage what you can't measure***

There are a number of techniques used in M&T. These include the use of X-Y scatter graphs, the Trend Graph, Variance Graphs and Casum Plots.

6.5.1 X-Y Scatter Graph

The X-Y scatter graph compares consumption to a relevant production variable over the same period of time (Enviros March, 1999). The scatter plot shows variation in material/utility consumption and uses this information to set targets. The consumption is plotted against the production variable and the *best fit* line drawn through the points. The base load (the amount consumed at zero production) of the process is given by the point at which the y-axis is intersected; the running efficiency of the plant is given by the slope of the graph; and the spread of the points indicates how tightly controlled the process is compared to production.

A target consumption can then be set below the actual consumption and this can be used to predict future process efficiency.

6.5.2 Trend Graph; Variance Graph and Casum Plots

A trend graph shows material consumption over a period of time. This merely indicates a trend in utility use and shows no measure of performance unless a target is included to indicate variances in performance. A variance graph represents the difference between actual and target consumption, and in this way, indicates when there is a change in performance. A Casum plot is another method of determining the variance from the target consumption and is constructed by calculating the cumulative variances over a period of time.

This gives a brief overview of M&T as a more detailed description is not within the scope of the Guide.

6.6 Conclusions

On completion of the **C** series of worksheets, the project team will have prioritised those areas that need to be investigated further for quantification of all inputs and outputs of the processes/departments. The costs associated with the wastes generated on site will have been identified and an indication as to the most appropriate areas for metering identified. **Chapter 7** and relevant worksheets will guide the team through the construction of detailed mass balances over batch, continuous, and printing process, the kitchens and energy utilities.

Chapter 7

Second stage : Detailed Assessment

Once the preliminary assessment has been completed and the areas for further investigation are chosen, a detailed assessment is then carried out on these areas. The data from the preliminary assessment have helped you to pinpoint the exact sources and causes of your wastes and emissions. This information is now expanded in order to identify waste minimisation options within your company. This involves collecting quantitative data about the processes so that mass balances can be created to determine accurately the amount of waste produced.

The third series of worksheets in **Volume II** (**D** through **H**) have been designed to guide you in collecting the required information and making the necessary calculations. Remember that these worksheets are meant to be used as a guide only and you should adapt them to your specific needs. An explanation of each worksheet is provided in **Volume II**.

The detailed assessment is divided into a number of sections; namely :

- batch processes (**D1 to D16**),
- continuous and semi - continuous processes (**E1 to E18**),
- printing (**F1 to F13**),
- kitchens (**G1 to G6**), and
- energy (**H1 to H20**).

The main stages in conducting the Detailed Assessment is discussed in this chapter.

7.1 Site Inspection

The first step in carrying out a detailed assessment is to inspect the site / area / process that has been chosen for the investigation. This involves a detailed study of each input and output into and from the area, thus enabling a mass balance to be drawn over the process. The process should be tracked from where raw materials enter the area to the point where the products and wastes leave that area. All suspected sources of waste should be investigated, such as; the production process, the piping, maintenance operations, storm water management and the storage area for raw materials, products and waste.

7.2 Constructing Mass and Energy Balances

Whereas in the preliminary assessment, mass and energy balances were conducted over the factory as a whole, a detailed assessment requires quantitative data specific to the process under investigation. This involves collecting data on production, water consumption, effluent production and chemical and energy use. If, for example, flow, temperature or concentration data are not readily available, measurements must be taken to obtain the information. These balances should be as accurate as possible in order that informed decisions can be made on implementing waste minimisation. See **Chapter 6, Figure 6.1** for an example of a process flow diagram.

7.2.1 Batch Processes

The first series of worksheets (**D to D16**) in **Volume II** of the guide will cover the detailed assessment of batch processes.

This includes processes carried out on the following machines:

- jet,
- jig,
- beam,
- winch, and
- yarn.

These worksheets will aid you in calculating water, chemicals and dye to drain and preparing a mass balance over the process. If you have identified that both the jets and the jigs require detailed assessment, a set of worksheets should be completed for each machine.

A summary sheet is provided at the end of this section to aid in the construction of the mass balance and quantifying the cost of each waste stream.

7.2.2 Continuous and Semi-continuous Processes

This **E** series of worksheets have been designed to aid you in constructing a mass balance over the continuous and semi-continuous processes in your factory (if these were chosen as areas for further investigation). The processes that are covered in this section are :

- padding (cold - batch pad, continuous)
- continuous desizing, scouring and bleaching
- mercerising
- washing-off of fabrics after processing

A set of worksheets should be completed for each machine under investigation.

7.2.3 Printing Department

The **F** series of worksheets are designed to guide you in establishing a mass balance over the printing department. If your company carries our sample printing for customers where there is a large volume of fabric being printed with many colour changes, this section must not be overlooked in the waste audit. Although it may seem to be a negligible department in terms of production, it is one of the main sources of pollution, both in colour and water volume. This is due to the large number of colours that are used in conducting test runs and the number of paste containers and screens that have to be washed.

7.2.4 Kitchens

The **G** series of worksheets are intended to aid you in obtaining an idea of the discharges to drain from the various kitchens. It is not easy to construct a mass balance over the kitchen, but estimations of the volume of water to drain and the volume of chemicals dumped can be obtained. These sheets should be used in conjunction with the other detailed investigation worksheets, whether you are investigating, batch, continuous or printing processes in order to calculate the total waste for that process.

7.2.5 Energy Use

The **H** series of Worksheets are designed to identify where energy savings are possible in terms of steam and compressed air generation and use and refrigeration.

Options to reduce the costs associated with these utilities are given in **Appendix 1**, Section 7.3. It is recommended that these suggestions are used in conjunction with the worksheets to ensure that all aspects are investigated.

7.3 Generating Options

Once the assessment phase is completed, the various waste minimisation options should be identified. This is best achieved through brainstorming with the project team. Some suggestions are given in **Appendices 1 and 2.**

7.4 Evaluation of Options

Once the options have been generated, they need to be screened to determine which options require further investigation and technical and economic evaluations. Those options based on **source reduction** should be given priority as they avoid or minimise waste. Second highest should be those options that involve **recycling**, both on- or off- site. Finally, **treatment options** should only be considered if feasible source reduction or recycling options could not be identified.

There are a number of criteria to keep in mind when analysing the options, such as: what benefits are to be gained (economic, liability etc.); does the technology exist; what is the effect on the environment; how easy are they to be implemented etc. A formal record should be made of this ranking so it can be referred to during the reviewing and auditing phases and when lower priority options are being considered for implementation

7.5 Conclusions

On completion of the detailed assessment, all inputs and outputs of various processes and their associated costs will have been obtained. Options to reduce the waste produced will have been identified and prioritised. The next stage is to conduct as feasibility assessment to determine which options will be implemented. This process is discussed in **Chapter 8.**

Chapter 8

Third Stage : Feasibility Analysis

Once the detailed assessment has been completed, mass balances constructed, and waste minimisation options identified and analysed in terms of their suitability for your company, you will need to conduct a feasibility analysis of each option. There are 5 stages to this analysis, namely :

- ranking of waste minimisation options to determine if a feasibility analysis is necessary,
- technical evaluation,
- economic evaluation,
- environmental evaluation, and
- selection of options for implementation.

The first and last steps must always be completed. The results of the first step will help determine which, if any, of the other 3 steps should be carried out. The various stages of conducting a feasibility analysis are discussed in this chapter with the relevant worksheets being found in **Volume II**.

The information contained in this Chapter has been adapted from training manuals prepared by Enviros March, United Kingdom.

8.1 Ranking of Options

Firstly, the various waste minimisation options that were identified in the detailed assessment phase should be ranked in order to determine whether an analysis is necessary. In this way, the evaluation process is streamlined and unnecessary work is eliminated. Not all options require a technical evaluation, and good housekeeping methods, such as turning off taps, do not require a full economic evaluation.

You can start by separating the options into the various types (i.e. process changes, housekeeping, material substitution etc.). Simple options such as procedural changes and improved housekeeping can be implemented directly after reviewing and training. Similarly, those options involving material substitutions can be implemented quickly if there are no major impacts on the production rate or product quality and if no equipment changes are required. However, those options which involve process and / equipment changes are more expensive and require in-depth investigations to ensure that they will operate successfully in the field. For this reason, both technical and economic evaluations are necessary.

8.2 Technical Evaluation

A technical evaluation will help determine if the proposed waste minimisation option will work in a specific application.

There are a number of criteria that need to be considered in the technical evaluation :

- Can it be done ?
  Is the solution too far-fetched ?

- Is it appropriate ?
  Is the solution appropriate for the problem?

- Does it solve the problem or merely fix the symptoms ?
  Don't look only at end-of-pipe options ; consider the root cause of the problem.

- What is the timescale ?
  How long will it take ? Is there pressure to implement the project/solve the problem ?

- What are the risks involved ?
  Is there going to be interruption of production ? Is the technology well-proven ?

Another aspect that needs to be considered includes taking into account any training that might be necessary in order that there is sufficient expertise on site to maintain the equipment. These costs must be included in the project evaluation.

Company culture should also be considered. Will the proposed changes be accepted by employees on all levels ? Is there resistance to change ? Does the project correlate with the current objectives of the company ? These aspects may be the deciding factor in which projects are implemented.

Time scale is another important consideration affecting project implementation. If training is required, the time needed for this must be considered in the project proposal. Is there a time limit for implementation, such as new legislation ? If this is the case, it may be necessary to implement a short-term solution and replace it with a longer term option at a later date.

When implementing a project, all risks need to be taken into account, the likelihood of them happening assessed and the possible consequences considered. Projects may fail due to a number of reasons such as poor planning, poor implementation and lack of training. It is important to consider the impact that a failed project will have on the overall waste minimisation programme and the management responsible for the project.

If the supplier of the new technology is essential to the success of the project in terms of back-up, a financial assessment of that company may be necessary and an alternative found if required.

Procedures that should be followed in a technological evaluation include :
- reviews of technical literature,
- visits to existing installations, and
- bench- or pilot- scale demonstration.

If after the technical evaluation the option appears to be not feasible or impractical, then it should not be investigated further. If they are technologically feasible, they can then be assessed for economic feasibility.

8.3 Economic Evaluation

The economic evaluation is carried out using standard methods of determining profitability, such as payback period, return on investment and net present value. During the evaluation, various costs and savings are considered. These are broken down into capital and operating costs. The **I** series of worksheets in **Volume II** will guide your company through the basics of conducting an economic evaluation.

The basic economic goal of a waste minimisation programme is to reduce overall operating costs; i.e. reduce the cost of waste disposal and the cost of input materials (e.g. water, chemicals and energy). However, there are a number of other costs (and savings) that need to be considered. In the worksheets in

Volume II, use is made of incremental operating costs; in other words, comparing the operating costs that would be incurred with the waste minimisation options, to the current costs in your company with the existing situation.

An economic evaluation consists of four objectives :

- To identify the best investments - i.e. How can the available capital be utilised in order to obtain gain maximum returns?
- To optimise the benefits from each investment. A detailed assessment takes all relevant factors into account and enables optimisation to ensure maximum benefit.
- To ensure minimum risk
- To analyse performance - A detailed appraisal provides information that may be used at a later date to evaluate project performance.

The economic evaluation provides information on the financial performance of each option, the effect on the business, identifies risks and defines the expected costs and benefits. This enables informed decisions to be made regarding the implementation of the project.

8.3.1 Types of Expenditure

Business expenditure can be broadly divided into two catagories : Revenue expenditure and Capital expenditure. The first comprises money that is spent on services and consumables such as wages, raw materials, fuel and so on. These items make their major contribution to the business in the financial year in which the money was spent. The latter refers to goods, equipment etc. that may be purchased and paid for in one year, but remain in the company for a number of years providing a contribution over a period of time.

8.3.2 Rules for a Successful Appraisal

- Do not underestimate the benefits so that the project does not look attractive.
- Fully explore the technical aspects of the project such that the costs and benefits are optimised.
- Do not underestimate the costs of the project.
- Ensure that decisions are made at the correct level of management where all information is taken into account.

8.3.3 Identifying the Savings

When considering the implementation of a project, it is important to take all potential savings into account. These can be broadly divided into three areas :

- easily identified savings (i.e. easily quantified)
- hidden costs (i.e. may be difficult to quantify but can provide substantial savings)
- uncertain costs (i.e. savings may be less obvious and take longer to accrue)

Table 8.1 lists some areas to consider when investigating possible savings.

8.3.4 Determining Profitability

The profitability of implementing a waste minimisation option can be easily determined from using estimated net cash flows (cash income minus cash outlay). If a waste minimisation option has no significant capital costs, then its profitability can be determined by whether there is a savings or not in operating costs. If there is a reduction in operating costs, then the option should be implemented as soon as is practically possible.

Table 8.1. : List of Possible Cost Savings (Enviros March, 1999)	
Easily Identified Savings	
Lower Capital Costs :	
Site Permitting	Engineering and supervision
Reduced footprint	Equipment
Buildings	Services
Reduced Operating Costs :	
Inputs	Utilities costs
Packaging	Labour
Rental	Insurance
Procurement	
Hidden Costs	
Reduced Pollution Control Costs (Handling; treatment, monitoring)	
Capital costs	Operating costs
Waste disposal costs	Off-site treatment costs
Reduced Regulatory Compliance Costs (staff time)	
Environmental training	Level of monitoring / testing
Level of medical surveillance	Number of inspections
Number of notifications	Reporting and record keeping
Uncertain Costs	
Reduced Contingency (Future Costs)	
Compliance costs	Penalties and fines
Response to pollutant releases	Legal expenses
Remediation costs	Damage to property / persons
Damage to natural resources / economy	Utility and feedstock costs
Costs of capital	
Stakeholder (Intangible) costs	
Customers / suppliers	Investors / shareholders
Lenders	Insurers
Employees	Managers
Regulators	Local community
Local authority	

For those options that have significant capital outlays, a more detailed analysis is required. There are two groups of investment :

- **Traditional Non-discounting techniques**
  - payback period,
  - Return on capital employed
- **Modern Discounting Techniques**
  - internal rate of return (IRR), and
  - net present value (NPV).

Non-discounting techniques can be misleading as they ignore the time value of money.

Discounting techniques, on the other hand, take into account that money will not have the same value in the future and, therefore, cash flows at different points in time are not comparable. In order to enable an evaluation to be undertaken, cash flows have to be converted to equivalent values by using a *discounting factor*.

Discount factor = $1 / (1 + r)^n$
Where r is the discount rate and n the number of years.

"r" is usually the interest rate of the loan (as a fraction) that is being used to finance the project. If for example the interest rate is 10 %, "r" would be 0.1. In most cases, the discount factor can be read from a table (Enviros March, 1999).

Payback period

The payback period (the length of time it takes to recover the initial cash outlay on the project) is simply determined from the ratio of the capital investment that is required to the annual savings that can be achieved. Payback periods are normally measured in years, but a particularly attractive option may have a payback measured in months.

Payback = Capital costs / Net savings
Where Net savings is the difference between the annual gross savings and the annual operating costs.

Properly calculated with accurately determined costs and benefits, payback can measure the liquidity of the company and financial risk. It is simple to calculate and does not require any assumptions to be made in terms of project timing, lifetime or interest rates. The disadvantages are that it does not take into account any savings achieved after the payback period or the time value of money.

IRR and NPV

The internal rate of return (IRR) and the net present value (NPV) are both discounted cash flow techniques for determining profitability. These techniques are commonly used by companies to determine the ranking of projects competing for funds. The capital funding of a project often depends on the ability of that project to generate positive cash flows beyond the payback period.

8.3.1 Adjustments for Risks and Liability

Allowance should be made for the reduction in environmental and health and safety risks for your company. While these risks are identifiable, they are not always easily quantified. One method for accounting for the reduction in these risks is to make adjustments to the financial requirements for the project, such as extending the payback period, or reducing the IRR. These adjustments recognise the risk exposure of the company which cannot be included directly in the analyses. It is important that the personnel responsible for making these judgements are made aware of the possible risk reduction and benefits of the waste minimisation options.

8.4 Environmental Evaluation

The waste minimisation options must also be assessed for their impact on the environment. In most cases the environmental advantage is obvious; e.g. a reduction in toxicity and / or quantity of waste. Other impacts to consider could be changes in the treatability of the waste, changes in the applicability of environmental regulations, etc.

It must also be remembered that although economic benefits are important in determining if a waste minimisation option should be implemented, environmental factors are just as important. For example, waste reduction may be a requirement to achieve compliance with regulations and legislation. A company that continues to operate outside of these limits may face increasing fines, legal actions and ultimately closure. In this case, the total cash flow of the company will depend on implementing the project.

8.5 Selecting Options for Implementation

After the technical, economic and environmental evaluation, you can now select an option for implementation. Understandably, the most attractive options to your company will be those with the greatest financial benefit, providing that it is technically feasible, but as mentioned previously, environmental factors must be taken into account. Those options chosen for implementation must, therefore, take all these factors into account.

8.6 Report

On completing the feasibility analysis and choosing the options for implementation, a report should be prepared documenting the work that has been carried out to date. This report will not only serve as a reference document for seeking approvals for implementation, but will also be useful for obtaining financing from external organisations, reporting to other agencies and establishing base levels for the performance evaluation and review.

For each waste minimisation option the following details should be included :

- the waste minimisation potential,
- whether the technology is established with reference to successful applications,
- the overall economics,
- the required resources,
- estimated down time,
- estimated construction time, and
- methods of evaluating the performance after implementation.

Before finalisation of the report, it should be reviewed by the affected departments. By having the involvement of the departments at this stage, support for the options can be obtained. In summarising the results of the study, intangible benefits, such as reduced liabilities and improved public image, should be discussed.

8.7 Conclusions

On completion of the feasibility analysis, those options that are suitable for implementation will have been identified based on technical, environmental and economic terms. The process of implementation will be discussed in **Chapter 9.**

Chapter 9

Final stage : Implementation

The final stage of the waste minimisation programme is to implement the chosen options. There may be a number of options that can be implemented immediately; e.g. sealing leaks, fitting hand triggers to hoses, closing off taps etc., but for several others a systematic approach to implementation may be required.

The waste minimisation team should be flexible enough in their thinking to develop modifications or alternatives to an option. They should also be committed to doing background and support work, and anticipate problems that could arise during the implementation.

9.1 Preparing for Implementation

The waste minimisation team and other employees must be prepared for implementation. The first stage is to obtain funding for the implementation process. It is best to plan to present the waste reduction project at the time your company is considering the capital budget. In some cases it might be necessary for the company to look outside for financing of the project. Other aspects that need to be considered are establishing linkages in the case of multi-department solutions and preparing the technical aspects. Throughout this process, it is essential to maintain good communication between the concerned persons to ensure their continued support and co-operation. It is a good idea to prepare checklists of the tasks involved and the people that need to be approached.

9.2 Implementing Options

Once the necessary financing has been obtained, the waste minimisation option can be implemented. Implementation is similar to any other industrial modification, with the basic requirements being layout and drawing preparation, equipment fabrication or purchase, transportation to site, installation and commissioning. Wherever possible, the affected employees should be trained at the same time to ensure that the waste minimisation measure does not fail due to a lack of knowledge on the part of the persons in charge of operation.

9.3 Monitoring and Evaluating Results

Once the waste minimisation option has been implemented, the performance should be evaluated to determine how effective it really is. The simplest method is to compare the quantities of waste generated before and after the implementation. Another method is to compare the results obtained with those that were estimated or worked out during the technical evaluation and determine the cause(s) for deviation(s), if any. The waste minimisation team must ensure that all concerned persons are kept informed of the progress and results.

The implementation process is only considered to be completed after successful commissioning and sustained stable performance over a reasonable length of time.

9.4 Maintaining the Waste Minimisation Programme

The biggest challenge in any industry is sustaining the waste minimisation programme. Very often the euphoria and zeal of the people involved dies off and the situation returns to its original status. To ensure that this does not occur in your company, it is important to conduct periodic reviews of the programme and involve as many people as possible. Rewarding the deserving employees will also ensure the long-term success of the programme.

The ultimate goal of any waste minimisation programme is to reduce the generation of waste to the lowest possible degree. Therefore, a waste minimisation programme should be ongoing rather than a once - off project. Once the highest priority options have been assessed, evaluated and implemented, you should return to those options that were considered to be of medium or low priority.

From time to time, the programme should be reviewed taking into account any changes in raw materials or product requirements, increase waste management costs, new regulations and technology, and any events that might have occurred that caused undesirable environmental problems. In other words, the concept of waste minimisation must become entrenched in the company policy and become *the norm* for all operations. All successful waste minimisation programmes have been founded on this philosophy.

Waste Minimisation Guide for the Textile Industry

A Step Towards Cleaner Production

Volume I
Appendices

by
Susan Barclay and Chris Buckley

The Pollution Research Group

University of Natal
Durban
South Africa

For The South African Water Research Commission

Appendix 1

Waste Minimisation Options for the Textile Industry

This Appendix contains detailed descriptions of the various waste minimisation options that are available for the textile industry. They are divided into 2 main sections:

- General waste minimisation suggestions for reducing water, chemical and energy consumption; reducing solid waste; reducing air and noise pollution; and minimising the emission of toxic substances.
- Specific waste minimisation suggestions for each textile process.

A more detailed description of these options can be found in the literature and it is suggested that you refer to the following books / reports :

- ***Best Management Practises for Pollution Prevention in the Textile Industry,*** United States Environmental Protection Agency (1996);
- ***Water and Chemical Use in the Textile Dyeing and Finishing Industry,*** Environmental Technology Best Practice Programme (1997);
- ***The Textile Industry and the Environment***, United Nations Environment Programme (UNEP) (1994);
- ***Cleaner Technology Transfer to the Polish Textile Industry - Idea Catalogue and Selected Options***, Danish Environmental Protection Agency (1997).

A1.1 Reducing Water Consumption

Water consumption in a textile factory can be reduced by implementing various changes ranging from simple procedures such as fixing leaks, to more complex options such as optimising water use and reducing the number of process steps. Some suggestions are outlined in this section.

A1.1.1 Repair Leaks, Faulty Valves, etc.

A simple method of determining if leaks exist is to take incoming water meter readings before and after a shut-down period when no water is being used. A difference in the readings could indicate a leak.

A1.1.2 Turn off Running Taps and Hoses

Encourage workers to turn off taps and hoses when water is not required. The fixing of hand triggers to hoses also reduces water consumption.

A1.1.3 Turn off Water when Machines are not Running.

Encourage workers to turn off machines and water during breaks and at the end of the day. Avoid circulating cooling water when machines are not in use.

A1.1.4 Reduce the Number of Process Steps.

This involves a study of all the processes and determining where changes can be made. For example, fewer rinsing steps may be required if a dye with high exhaustion is used.

A1.1.5 Optimise Process Water Use.

Examples include using batch or stepwise rinsing rather than overflow rinsing, introducing counter-current washing in continuous ranges, and installing automatic shut-off valves.

A1.1.6 Recycle Cooling Water

Cooling water is relatively uncontaminated and can be reused as make-up or rinse water. This will also save energy as this water will not require as much heating.

A1.1.7 Re-use Process Water

This requires a study of the various processes and determining where water of lower quality can be used. For example, final rinse water from one process can be used for the first rinse of another process.

A1.1.8 Using Water Efficient Processes and Equipment

Although replacing outdated equipment with modern machines which operate at lower liquor ratios and are more water efficient requires capital investment, the savings that can be made ensure a relatively short pay-back period.

A1.1.9 Sweeping Floors

Instead of washing the floors of the dyehouse and kitchens, rather sweep up any spillages and wash down only when essential. Not only will this reduce water use, but also the concentration of contaminants to drain as the waste is disposed of as solids.

A1.1.10 Reusing Water from Auxiliary Processes

The water used in the rinsing of ion-exchange columns and sand filters can be reused elsewhere in the factory.

A1.2 Reducing Chemical Consumption

The majority of chemicals applied to the fabric are washed off and sent to drain. Therefore, reducing chemical consumption can lead to a reduction in effluent strength and therefore lower treatment costs, as well as overall savings in chemical costs. Various options for reducing chemical use are listed below :

A1.2.1 Recipe Optimisation

Recipes are generally fail-safe designed which results in the over-use of chemicals. Optimising the quantity of chemicals required will lead to more efficient chemical use and lower costs. Continual updating of recipes should be carried out when new dyestuffs enter the market as, in general, less of these chemicals are required.

A1.2.2 Dosing Control

Overdosing and spillages can be reduced by mixing chemicals centrally and pumping them to the machines. Check that manual measuring and mixing is carried out efficiently and automatic dispensers are properly calibrated.

A1.2.3 Pre-screen Chemicals and Raw Materials

Avoid dyestuffs containing heavy metals, solvent-based products and carriers containing chlorinated aromatics. Safety data sheets should be obtained from the chemical manufactures to obtain information such as toxicity, BOD and COD. Check that raw materials do not contain toxic substances. Check that companies will accept expired raw materials for disposal.

A1.2.4 Chemical Substitution

Review chemicals used in the factory and replace those hazardous to the environment with those that have less of an impact. Use dyes that have high exhaustion rates and require less salt.

Specifically :

- replace metal-containing dyes
- use bi-reactive dyes in place of mono-reactive
- avoid the use of APEO detergents and replace with more biodegradable alternatives
- replace stilbene optical brightners with alternatives, or eliminate alltogether
- dye wool with dyes that do not require after-chroming

A1.2.5 Correct Storage and Handling

More effective control of the storage and handling of chemicals will results in less spillages reaching the drains.

A1.2.6 Chemical Recovery and Reuse

Chemical use may be reduced through recovery and reuse. For example, sodium hydroxide from mercerising can be recovered through evaporation. Dye baths may be reused and size can be recovered for reuse.

A1.2.7 Process Changes

Investigate the feasibility of changing to cold-pad batch dyeing. This results in less chemicals being used (and in particular, salt) and reduces water consumption significantly.

A1.2.8 Improve Scheduling

Review the scheduling of continuous processes such as sizing, desizing, padding etc. to ensure that the same chemical bath is used as many times as possible, thus reducing the number of dumps to drain per day.

A1.3 Energy conservation

As with water conservation, reductions in energy use can result in substantial savings and lower emissions from boilers or generating plants. Some energy efficient options are listed below.

A1.3.1 Compressed Air

Optimise compressed air generation

To keep generation costs to a minimum:

- pressure control should be based on the pressure at the most sensitive / critical pieces of machinery;
- compressor sequencing should be based on a narrow pressure band in order to achieve the minimum generation pressure at all times. Care should be taken, however to avoid excessive cycling.

Reducing generation pressure by 10% will yield savings of 5% of annual compressor operating cost.

Fix compressed air leaks

No-load tests should be carried out regularly, approximately every 2 to 3 months. All air leaks should be tagged and repaired at the earliest opportunity. Ultrasonic detection devices are available to assist in leak detection.

Optimise compressor sizing

Compressors should be sized as closely as possible to the duty. It is not economical to run any machine for long periods at low loads; the off-load power consumption can be between 15% to 70% of on-load power once motor inefficiencies have been taken into account. In general, reciprocating compressors offer the highest part-load operating efficiently, if it is well maintained

Install compressor control systems

For multiple compressor installations, a modern compressor control system can save between 5% and 20% of total generation costs for a modest capital outlay. Many modern controllers comprise cascade control, run-on timers and pressure control. The latter is important in installations where the demand for air fluctuates significantly. It enables a lower generation pressure at times when air demand (and therefore system pressure drops) is reduced.

General housekeeping

The following general items should be considered when addressing compressed air efficiency:

- Ensure that the air fed to compressors is as cool as practicable. A 4°C drop in inlet temperature will give savings of 1% of generation efficiency. Air-cooled compressors should be fitted with ductwork to atmosphere, such that the exiting warm air does not overheat the plantroom.

- Ensure that air dryers are installed downstream of the air receiver. The receiver acts as a pre-drier. Only dry (or treat) compressed air for processes that require it. If air lines are subject to condensate problems, fit appropriate drainage points.

- For all end-users of compressed air, ask the following questions:
  - Does it need to be operated by compressed air at all?
  - Is the supply pressure greater then necessary?
  - Is there an adequate facility to isolate the supply line when not in use?

A1.3.2 Refrigeration

Reduce Cooling Loads

The most common application of refrigeration in Southern African textiles industries is for the provision of air conditioning of production areas. There are two issues here.

- Ensure that heat gains (from machinery, unnecessary air ingress, lighting, etc.) are kept to a minimum. Bear in mind that heat gains from electrical machinery operating when not needed is paid for twice: once to operate the machine and again to remove the heat gain.
- Ensure that the control temperature is set to an acceptably high level. Do not over-cool.

Decrease Condensing Temperature

Causes of unnecessarily high condensing temperatures include:

- Non-condensable gas build-up in the condenser
- Liquid refrigerant backing-up into the condenser
- Head pressure control set too high
- Fouling of the condenser heat exchanger
- Fan and pump malfunction

As a guideline, reducing condensing temperature by 1°C will yield savings of between 2% and 4% of annual refrigeration cost

Increase Evaporating Temperature

Causes of unnecessarily low evaporating temperatures include:

- Low refrigerant charge. Excessively low refrigerant charge can lead to gas by-passing of the expansion valve, increasing costs by 30 % or more.
- Fouling of the evaporator heat exchanger.
- Control temperature set too low.
- Poor expansion valve performance.

As a guideline, increasing evaporator temperature by 1°C will yield savings of between 2% and 4% of annual refrigeration cost

Compressor Control

The type of control strategy adopted can have a significant effect on operating costs. An effective control strategy could be adopted using the following guidelines:

- Avoid excessive part-load operation.
- Ensure that compressors are sequenced to avoid operating more than one compressor at part-load at any one time.
- Use reciprocating compressors for part-load operation, in preference to screw or centrifugal types.
- Avoid the use of compressor capacity control mechanisms that throttle the inlet gas flow, raise the discharge pressure or use gas by-pass.
- Ensure that all auxiliaries are switched off when the compressor is off.

Incorrect control of compressors can increase costs by 20%, or more. Poor control of auxiliaries can increase costs by 20%, or more.

A1.3.3 Steam Generation

Boiler blowdown

It is necessary to control the build-up of total dissolved solids (TDS) within any steam-raising boiler, through periodic blowing-down. It is essential that boiler TDS is monitored regularly in order that excessive blowing down is avoided. Increasing blowdown by 5% will increase fuel consumption by between 1% and 1.5%.

Economisers

Boiler efficiency may be increased by preheating feedwater through the use of an economised installed within the boiler flue. In general, **an increase in feedwater temperature will result in 1% less fuel being burned at the boiler**.

Combustion air temperature

Boiler efficiency can be increased by recovering waste heat from the flue gas and preheating combustion air. **An increase in combustion air temperature will result in about 2% efficiency increase.**

Firing rate and load variation

Highest boiler efficiencies generally occur over the range of firing rates from 70% to 90% of rated capacity. Boiler efficiency can be optimised, therefore, by ensuring, as far as possible, that equipment is used within this range.

Fluctuating loads have adverse effects on boiler efficiency, especially if frequent periods of low load are a characteristic. There are several ways to improve this situation:

- rationalisation of the load demand, if possible. Steam accumulators enable a dampering effect of load variation.
- rationalisation of boiler firing schedule.
- improvements to the firing control system.
- installation of a flue-gas shut-off damper to eliminate the circulation of cold air in the event of boiler shut-down.
- installation of a number of smaller boilers as opposed to a single large one.

A1.3.4 Steam Distribution and Use

Insulation

All hot surfaces of a steam distribution system must be insulated. Justification can be made on the grounds of a reduction of heat loss, improvement in steam quality (through reduced condensate formation) and health and safety issues.

Heat loss charts are available for various combinations of pipework diameters and surface temperatures over a range of insulation thicknesses. As a rough guide, **insulation can be economically justified to reduce bare pipe losses by 90%.**

Flash steam recovery

Flash steam is generated when hot condensate is allowed to reduce in pressure, allowing a certain amount of condensate to evaporate (flash). The total heat content of the new system at equilibrium is the same at the total heat content of the original condensate. The quantity of flash steam generated may be calculated using a flash steam chart, or from steam tables. Wherever the generation of flash steam occurs, it is important to consider alternative possible uses for it (this includes the use of flash steam from boiler blowdown).

Good housekeeping

The following guidelines should be used to ensure good housekeeping of steam distribution systems:

- All steam traps should be surveyed annually to ensure their correct operation.
- Ensure that all steam leaks are attended to at the earliest opportunity.
- Reduce temperature levels to the minimum required by the process.
- Optimise end-user requirements by ensuring that the plant is fully loaded when possible and shut down (isolated) when not operational.
- Ensure that end-user heat exchanger surfaces are maximised by provision of adequate air venting (during start-up only) and steam trapping.
- Valve off steam supply lines that are out of use for considerable periods.
- Consider heating small, distant or occasional users by other means.

A1.3.5 Install Heat Exchangers

The installation of heat exchangers on the high temperature effluent streams to recover energy and heat incoming water results in substantial savings.

A1.3.6 Optimise Plant Environmental Conditions

Optimise the temperature, humidity etc., of the factory so that only the required amount of energy is used.

A1.3.7 Shutting off of Lighting, Air-conditioning, etc.

Shutting off the lights in areas not in use and during shut down periods will reduce electricity costs, as will turning off the air-conditioning over weekends and shut-downs. Shutting off machines when not in use also results in savings.

A1.4 Reducing Air Pollution

Some steps to reduce the emissions to air include:

- Decreasing emissions of organic solvents by changing to water-based products.
- Using scrubbers to collect particulate matter.
- Optimising boiler operations to reduce the emissions of nitrous and sulphur oxides.
- Pre-screening chemicals using the Material Safety Data Sheets to ensure that chemicals are not toxic.
- Identifying sources of air pollution and quantifying emissions.
- Designing and manufacturing products that do not produce toxic or hazardous air pollutants.
- Avoiding fugitive air emissions from chemical spills through improved work practices.

A1.5 Reducing Solid Waste

In terms of volume, solid waste is the second largest waste stream in the textile industry next to liquid effluent. There are a number of waste minimisation options available to reduce solid waste, and these include :

- Reducing the amount of packaging material by improved purchasing practices such as ordering raw materials in bulk or returnable intermediate bulk containers (IBCs). This reduces spillages, handling costs, exposure of workers to chemicals and the amount of storage space required.
- Purchasing chemicals in returnable drums. Enquire if vendors will accept unwashed drums as this will reduce the waste water generated in the factory.
- If possible, ordering chemicals in IBCs rather than bags as these are easily broken, causing spillages.
- Purchasing yarn on reusable plastic cones rather than cardboard cones.
- Reducing seam waste through effective training programmes.

- Selling waste fibres, sweeps, rags, yarn and cloth scraps.
- Selling used pallets to a recycler.
- Donating damaged pallets to institutions (e.g. schools) for the wood.

A1.6 Reducing Toxicity

Compounds that contribute to the aquatic toxicity of textile effluent include salt, metals, surfactants, toxic organic chemicals, biocides and toxic anions. Some methods of reducing the use of these compounds are to :

- Reduce metal content through careful pre-screening of chemicals and dyes for metal content and using alternatives where possible.
- Eliminate galvanised plumbing as reactions with brass fittings can take place in the presence of acids, alkalis or salt and lead to the release of zinc.
- Reduce the amount of salt in the effluent by optimising recipes, using low-salt dyes, reusing dyebaths and optimising dyeing temperatures.
- Use biodegradable surfactants such as linear alcohol ethoxylates.
- Replace chlorinated solvents with unchlorinated alternatives.
- Replace the use of biocides with ultraviolet light as a disinfectant for cooling towers.
- Carefully pre-screen chemicals for their toxic nature using MSDS.

A1.7 Reducing Noise Pollution

The following steps can be implemented to reduce noise pollution :

- install screens and sound baffles on fans,
- regular maintenance of machinery,
- fit anti-vibration mounts on machines, and
- fit walls with sound-absorbing material.

A1.8 Waste Minimisation in Specific Textile Processes

The following sections will describe various waste minimisation techniques that can be implemented in specific textile processes.

A1.8.1 Sizing

Size selection

Replace starch-based sizes with synthetic sizes. The advantages of this is a reduced pollution load as synthetic sizes have lower BOD levels, and they can be recycled for reuse.

Raw materials

Test incoming raw materials for toxic compounds. Purchase size in bulk in drums rather than bags etc. as this produces less solid waste and reduces the chances of spills due to breakages.

Recipe optimisation

Ensure that only the minimum required size is added onto the yarn. This reduces chemical consumption as well as the pollution load to drain during desizing.

A1.8.2 Preparation Department

Preparation includes desizing, scouring, bleaching and mercerising. Desizing accounts for > 50% of the pollution load of preparation while scouring contributes between 10 and 25%. Good preparation is essential for subsequent processing as any impurities remaining on the fabric will interfere with the dyeing and finishing processes. Some waste minimisation options for the preparation department are listed below.

Desizing

The effluent from desizing will contain the sizes that were added onto the yarn before weaving/knitting. Using and recycling synthetic sizes in place of starch sizes will reduce the pollution load from desizing.

Scouring

- Incoming raw material should be screened for toxic chemicals as these will be removed during the scouring process.
- Detergents should be easily biodegradable. Avoid the following detergents: linear alkylbenzenesulphonate; nonylphenoletoxylate; dialkyldimthyl ammonium chloride; distearyl dimthyl amonium chloride; di dimithyl ammonium chloride; sulphosuccinates; alkylphenolethoxylates; complexing agents with poor biodegradability (e.g. EDTA; phosphonic acid; NTA; phosphonates).
- Reuse scour washwater for desizing. Recycle continuous scour washwater to batch scouring.

Bleaching

- Replace the use of chlorites and hypochlorites with hydrogen peroxide.
- Ensure that bleaching is carried out efficiently.
- Recycle bleach washwater for scouring.
- Use vacuum slots to remove excess solution which can then be reused

Singeing

Little or no pollution arises from singeing. Ensure that air scrubbers are installed to trap particles that are burnt off the fabric. Cooling water can be reused elsewhere in the factory. Remove lint from the pad solution to reduce the frequency of dumping.

Mercerising

Recycling of sodium hydroxide through evaporation for reuse in mercerising or scouring will decrease the pollution load and chemical consumption.

General

- Use modern equipment.
- Replace batch processes with continuous processes.
- Install counter-current washing.
- Combine processes such as desizing, bleaching and scouring.
- Replace harmful chemicals with those of lower environmental impact.
- Reuse washwater for cleaning equipment and screens.

A1.8.3 Batch Processing

There are a number of waste minimisation options for batch processing. These include :

- Cascading multiple rinsing operations.
- Reusing softening baths with reconstitution.
- Reusing preparation baths (scouring and bleaching) with reconstitution after filtration to remove impurities.
- Segregating coloured effluent streams from *clean* streams (preparation and rinsing) to ensure that only concentrated effluent is treated. This *clean* effluent may be used elsewhere in the factory.
- Installing automatic shut-down of water in overflow cooling when the required temperature has been reached.
- Replacing outdated machines with high liquor ratios with more modern equipment.
- Carrying out softening on a pad mangle.
- Replacing batch-wise rinsing with continuous rinsing with counter current flow.
- General water, chemical and energy conservation measures as listed at the beginning of this Appendix (Sections A1.1 to A1.3).

A1.8.4 Dyeing

Batch dyeing

Careful selection of dyes is important. Dyes should have high fixation/exhaustion, low toxicity, absence of metals, and be appropriate for the end use. Correct and efficient application procedures must be used and right-first-time production should be achieved.

The main areas for waste minimisation include :

- Using low liquor ratios.
- Using automated dye and chemical dosing systems.
- Reusing dyebaths, rinse water and softening baths.
- Ensuring a good cloth preparation.
- Optimising pH and salt for each recipe.
- Avoiding the use of auxiliaries that reduce or retard exhaustion.
- Using bireactive dyes.
- Using the newer low-salt reactive dyes.
- Optimising dyeing temperatures.
- Avoiding the addition of more chemicals to offset the effects of other chemicals - use other non-chemical methods such as procedural or mechanical alterations or change the dye selection.
- Replacing the use of acetic acid in neutralising after dyeing with formic acid or dilute hydrochloric acid (acetic acid adds to the COD of effluent).

Continuous dyeing

The main waste minimisation strategies in continuous dyeing are to :

- Maximise dye fixation.
- Minimise wash - off.
- Avoid discards and machine cleaning wastes during start-up, shut-down and changes of colour and style.
- Minimise the number of times a dyebath has to be dropped and cleaned due to a colour change by careful scheduling.
- Use automated colour kitchens to minimise the working losses and discards.
- Improve washing efficiency through the installation of flow restrictors to control water volumes. Use counter current washing procedures.
- Optimise dosing of chemicals through monitoring of relevant parameters such as pH, absorbance, turbidity etc.

General waste minimisation options for dyeing

- Operate at lowest possible bath ratio. This leads to a reduction in operating costs, water consumption, chemical use, energy use and less effluent discharge.
- Minimise stripping and / or redyeing procedures.
- Avoid shading additions.
- Avoid the use of detergents to wash fabric after reactive dyeing; high temperatures are just as effective.
- Minimise auxiliary use. Some auxiliaries interfere with dye fixation and should be replaced with alternatives or removed as this will reduce the colour load of the effluent. Some auxiliaries are added to compensate for inefficiencies in the process, equipment, or substrate design. Therefore, optimising these factors will reduce auxiliary use.
- Right-first-time dyeings. Corrective measures are chemically intensive and have much less chance of achieving the required quality. The greatest costs in reprocessing are associated with the cost of dyes and chemicals - typically, the costs can increase by as much as 30%. Right-first-time dyeing leads to an

increase in productivity and more efficient use of resources (e.g. labour, capital).

- In dyeing polyester, avoid the use of carriers by upgrading dye machinery or replace with less harmful alternatives.
- Good fabric preparation. This increases the chance of right-first-time dyeing as fixation is improved.
- Improved dye fixation. Dye fixation onto cotton can be improved by mercerising the yarn or fabric prior to dyeing.
- Pad-batch dyeing. This is a cold dyeing method used mostly on cellulosics that results in a reduction in pollution, energy use, and costs. The advantages include :
    - no salt or chemical specialities are required,
    - more efficient use of dye,
    - improved quality of dyeing,
    - can be used on wovens or knits, and
    - low capital investment results in savings in dyes, chemicals, labour and water.
- Reuse dyebaths, especially those using dyes with high exhaustion such as acid or basic dyes. There are 4 main steps to follow :
    - save the exhausted dyebath - this can be done by pumping it to a holding tank (or identical machine doing the same processes) and returning it to the machine for use in the next dyeing procedure.
    - analyse the dyebath for residual chemicals - most auxiliaries do not exhaust in the dyeing process. There is approximately a 10% loss due to adsorption onto the fabric. Others however, are used or lost during the process and must be replaced. Unexhausted dyestuffs need to be analysed to determine the concentration remaining in the dyebath to ensure correct shading in further dyeings. Dyebath analysis can be performed using a spectrophotometer and specific guidelines for such a procedure.
    - reconstitute the dyebath - water is added to replace that which is lost to evaporation or to the product. Auxiliaries are added in proportion to the water volume (these can be estimated) and finally the dyestuff is added for the required shade.
    - reuse the dyebath - check the temperatures to ensure that the reused dyebath is the right temperature to minimise spotting and unlevel dyeings.

If properly controlled, dyebaths can be used for up to 15 or more cycles. Use dyes that undergo minimal changes during dyeing (acid, basic, direct and disperse) and reuse dyebaths to repeat the same shades.

Dyebath reuse is limited by impurity build-up from, for example, the fabric, salt build-up, steam contamination and surfactants. In addition, speciality chemicals may be lost during the dyeing process and these should be screened for their reuse potential. Close scheduling is also required which may limit the flexibility required for bath dyeing.

- Water reuse. This can be achieved by dyeing multiple lots in the same dyebath. This is generally possible for those products where high quality dyeing is not essential (e.g. work gloves, hosiery).
- Install improved machinery that have better controls.
- Screen azo dyes to ensure that they do not degrade to produce amines that are listed as being toxic (**Appendix 3, Table A3.14**).
- Metal containing dyes should be replaced where possible.

A1.8.5 Printing

Pollutants associated with printing include suspended solids, solvents, foam, colour and metals, and in general, large volumes of water are consumed during the washing-off stages. The main areas of waste minimisation in printing include raw material conservation, product substitution, process and equipment modifications, material handling, scheduling and waste recovery. Other options include :

- Waste minimisation in the design stages can eliminate the need for dyes containing metals.
- Careful selection of surfactants.
- Reducing air emissions by replacing solvents with water-based alternatives.
- Routine and careful maintenance of printing equipment.
- Training employees in the practices of good housekeeping.
- Reusing water from washing the print blanket.
- Turning off wash water when machine is not running.
- Installing automated colour kitchens.
- Reusing left over print paste.
- Removing excess paste from drums, screens and pipes by *dry* techniques (wiping with a squeegee etc.) before washing with water. This reduces the colour load discharged to drain.
- Careful scheduling to prevent expiration of print pastes before use.
- Investigating alternatives to urea as this increases the nitrogen in the effluent.

A1.8.6 Finishing

There are a number of finishing processes that are carried out on the fabric after dyeing and/or printing. These can be achieved by chemical or mechanical methods. Some waste minimisation options are listed below :

- Design fabrics such that the need for chemical finishes are minimised.
- Use mechanical alternatives to chemical finishes.
- Use low add-on methods.
- Minimise volatile chemical use.
- Avoid mix discards through careful preparation.
- Install automated chemical dispensing systems.
- Train employees in good housekeeping practises.
- Use formaldehyde-free cross-linking agents.
- Reduce solid waste by reducing the need for selvedge trimming through better width control, training workers and collecting selvedge trim for resale.
- Investigate the use of spray application of finishes as these have a low add-on and require no residual dumping at the end of a run.

Appendix 2

Case Studies

This chapter will discuss various case studies where textile companies have implemented successful waste minimisation programmes. The techniques used and the savings obtained will be highlighted. These case studies are taken from three main references : The **United Nations Environment Programme (1995),** the **Environmental Technology Best Practice Programme (1997),** and the **Environmental Protection Agency (1996).**

CASE STUDY 1: CONSERVING WATER, ENERGY AND CHEMICALS

Background

The Hitega textile mill in Chile is an integrated mill producing dyed yarn and fabric with an average ratio of 65 : 35 % polyester to rayon. Large volumes of water are used and various dyes, bleaches and chemicals are added.

Waste minimisation principle

Internal recycling; Process modification.

Description of implementation

- Recycling of cone-dye cooling water for reuse.
- Recycling water from the air-conditioning system.
- Improving softener regeneration and service.
- Improving maintenance of steam traps to prevent leaks.
- Reducing suspended solids in effluent by installing screens in the dyehouse drains.

Three of these options were analysed in detail.

Economics

Option	Payback period
Recycling cooling water	20 months
Recycling aircon. system water	14 months
Softener system	24 months

Remarks

The implementation of these options results in savings in water, energy and chemicals.

Source

United Nations Environment Programme (1995) *UNEP / IEO ICPIC International Cleaner Production Information Clearing House.*

CASE STUDY 2
SAVINGS THROUGH NEW TECHNOLOGY

Background

The Skjern Tricotage-Farveri textile mill in Denmark produces approximately 5 000 tons of fabric/annum. They are a major supplier to Novotex, a Danish company that sells ecologically sound cotton.

Waste minimisation principle

Material substitution.

Description of implementation

Raw cotton fabric requires bleaching, usually with hydrogen peroxide. The bleaching chemical has to be removed, generally through a number of rinsing stages or by the addition of a reducing agent to neutralise the bleach. In both cases, large volumes of water are used for rinsing.

Replacing the traditional reducing agent with an enzyme formulation considerably decreased water and energy use. The by-products of the reaction with hydrogen peroxide are oxygen and water. The enzyme is also biodegradable.

Economics

Approximately 15 to 30 US $/ton fabric can be saved, depending on the local cost of water and energy.

	Savings / annum
Energy	2 780 GJ
CO_2 emissions	160 t
Water	13 500 kl
Natural gas	70 800 kl

Remarks

The substitution of the enzyme formulation for traditional bleach clean-up methods results in savings in water, energy and process time.

Source

United Nations Environment Programme (1995) *UNEP / IEO ICPIC International Cleaner Production Information Clearing House.*

CASE STUDY 3
SAVINGS THROUGH PROCESS CHANGE

Background

The Australian Dyeing Company is a commission dyehouse, processing knitted and woven fabrics. Dyeing of 100% cotton and cotton blends takes place on a large scale.

Waste minimisation principle

Application of new technology.

Description of implementation

- Changing from the traditional exhaust dyeing methods to cold pad-batch processing. This removes salt from the effluent, reduces water consumption by 88% and decreases energy use.
- The introduction of Cibracon C dyes which have greater levels of fixation, thereby reducing the colour entering the effluent stream.

Economics

A payback period of 8 months was achieved on the capital outlay.

Remarks

Cold pad-batch processing has a number of advantages such as improved product quality, larger runs of fabric of the same colour can be made, and it takes up less space on the production floor.

Source

United Nations Environment Programme (1995) *UNEP / IEO ICPIC International Cleaner Production Information Clearing House.*

CASE STUDY 4
REDUCING WASTE AND ENERGY USE

Background

Quimica y textiles Proquindus SACI in Chile dyes a variety of materials for fabric manufacturers. It processes both wool and cotton fabrics.

Waste minimisation principles

Process modification; Material substitution; Improved house-keeping.

Description of implementation

37 waste minimisation options were identified which were divided onto groups according to the priority. Six of the 19 high priority options were costed in detail. These included :

- repairing steam traps to reduce fuel consumption by 36%.
- modifying rinsing techniques to reduce water consumption by 50%.
- reducing sulphate in the effluent through chemical substitution.
- improving process controls, screening drains, regular cleaning of sumps, repairing steam leaks, improving dyeing equipment etc.
- recycling of solid waste before disposal.

Economics

Action	Payback period
replacing leaking steam taps	1 week
modifying rinsing process	< 1 week
replacing sulphate with sodium chloride	immediate
repairing leaks in laundry	< 1 week
repairing leaks on washer	immediate
filtering sulphuric acid	2.5 years

Remarks

The implementation of these waste minimisation procedures saved on raw materials, water and energy, reduced toxic waste and improved product quality and operating efficiency.

Source

United Nations Environment Programme (1995) *UNEP / IEO ICPIC International Cleaner Production Information Clearing House.*

CASE STUDY 5
SAVINGS THROUGH REDUCING ENERGY USE

Background

Dyeing of fabric requires large volumes of hot water. The recovery of heat from this used water using conventional heat exchangers is difficult due to clogging by fabric particles. An Irish wool and fabric dyeing textile mill investigated the use of a new design of heat exchanger.

Waste minimisation principle

New technology.

Description of implementation

A heat exchanger was designed in which there was turbulent flow through the machine to prevent fibres settling on the surface of the heat exchanger. This also improved heat transfer.

The temperature of the hot water was reduced from 95 to 38°C and cold water is heated from 10 to 67°C.

Economics

13.2 MJ of heat was saved annually. The payback period was less than 2 years

Source

United Nations Environment Programme (1995) *UNEP / IEO ICPIC International Cleaner Production Information Clearing House.*

CASE STUDY 6
SAVINGS THROUGH DYEBATH REUSE

Waste minimisation principle

good housekeeping, improved operating practices, reuse of raw material.

Description of implementation

- Replenishing dyes were added to used dye liquor at the end of a cycle.
- Depletion of the dye carrier was higher than that of the dye, requiring higher recharge of dye carrier.

Economics

A payback period of months was achieved.

Remarks

Water use was more than halved and energy consumption also decreased.

Source

United Nations Environment Programme (1995) *UNEP / IEO ICPIC International Cleaner Production Information Clearing House.*

CASE STUDY 7
REUSE OF WATER AND CHEMICALS USING NEW TECHNOLOGY

Background

Water and chemicals in the effluent from Italian textile dyeing mills was treated and recovered for reuse by reverse osmosis.

Waste minimisation principle

New technology.

Description of implementation

- Three main steps are involved :
  - biological treatment,
  - physico-chemical treatment, and
  - reverse osmosis.
- These are followed by conventional decolourising, concentration and make-up before being reused as process water.
- The pollutants are virtually eliminated and the recovered water improves textile quality when recycled.
- 95 % of the water is recovered, energy is saved and chemicals are reused.

Economics

Capital and operating costs are quite high, but the payback period is 1 to 2 years of the plant operation.

Remarks

The plant paid for itself in a short period. This process reduced pollution and makes wiser use of raw materials, thereby saving water, chemicals and energy.

Source

United Nations Environment Programme (1995) *UNEP / IEO ICPIC International Cleaner Production Information Clearing House.*

CASE STUDY 8
REDUCING COD IN THE TEXTILE INDUSTRY

Background

The Misr Spinning and Weaving Company is situated in Egypt.

Size agents are essential during the weaving process, but can interfere with dyeing and, therefore, need to be completely removed after weaving. Commonly used sizes are those based on starch. The wash water for this process contains these size chemicals which contribute significantly to the COD of the effluent.

Waste minimisation principle

Material substitution.

Description of implementation

- Reducing the COD occurs through substitution of the starch size with one that can be reclaimed by ultrafiltration.
- Starch was replaced by water-soluble starches, mixtures of water-soluble starches and PVA, PVA and CMC.
- A UF plant was installed.

Economics

- 80% of size was reclaimed.
- 90% of hot water used in rinsing could be reused.
- There were decreased costs in weaving due to improved sizes.
- It eliminates the need for processes to solubilise the original starch sizes (oxidative, enzymatic etc.).
- Less energy is required.
- Payback period is estimated to be 8 to 18 months for a medium-sized European textile mill.

Remarks

This process allowed recovery of the most significant pollutant, reduced water, chemical and energy consumptions, reduced production costs and improved the quality of the fabric.

Source

United Nations Environment Programme (1995) *UNEP / IEO ICPIC International Cleaner Production Information Clearing House.*

CASE STUDY 9
RECOVERING WATER AND CHEMICALS

Background

The Chieng Sang Industry Co. Ltd is a medium scale dyeing plant in Thailand. It produces mainly a cotton-polyester blend.

Waste minimisation principle

New technology.

Description of implementation

- Installation of a EVAC vacuum suction system to recover and reuse finishing chemicals. This also resulted in a more even distribution of chemicals. A 25% savings in chemicals was achieved.
- Installation of a computerised spectrophotometer to match colours more accurately. Process efficiency was improved and re-dyeing has been cut by 70% resulting in a reduction in chemical consumption by 20%.
- Condensate is recovered and reused in the boiler after make-up.
- Cooling water is reused for rinsing fabric after dyeing.

Economics

- Savings from condensate and cooling water :
  - 140 kℓ steam/d
  - 30 kℓ cooling water/d
  - 3% of fuel
- Significant savings are also made owing to a reduction in waste water volumes and therefore effluent treatment.
- The payback period is estimated to be 3.5 years.

Remarks

The implementation of these waste minimisation option resulted in an increase in productivity, savings in water, chemicals and fuel and a reduction in the pollution load of the effluent.

Source

United Nations Environment Programme (1995) *UNEP / IEO ICPIC International Cleaner Production Information Clearing House.*

CASE STUDY 10
SAVING WATER BY IMPROVED HOUSEKEEPING

Employees at a small hat dyeing company left hoses running after cooling the hats as part of the manufacturing process. By simply fixing hand triggers to the hoses, effluent costs were reduced by approximately GBP 2 000 / year.

Source

Environmental Technology Best Practice Programme (1997) *Water and Chemical Use in the Textile Dyeing and Finishing Industry*, United Kingdom.

CASE STUDY 11
SAVING WATER THROUGH PROCESS MODIFICATION

Instead of softening in a final rinse, a Leicester-based textile mill softens fabric in a pad-batch process. This reduces the number of process steps and the process time, resulting in savings in water, chemicals and energy and an increase in production.

Source

Environmental Technology Best Practice Programme (1997) *Water and Chemical Use in the Textile Dyeing and Finishing Industry*, United Kingdom.

CASE STUDY 12
SAVING WATER THROUGH RECYCLING AND REUSE

Recycling of their cooling and condensate water saves a medical textile company in Lancashire 11 000 kℓ of borehole water. Estimated savings in effluent disposal are about GBP 3 000/year. In addition, recycling of the last rinse water from beam and winch dyeing saves a further 7 000 kℓ of water and about GBP 2 700 in effluent disposal costs.

A Wigan-based dyer and finisher halved its water consumption by recycling the bleach effluent for the scouring process. Approximately GPB 10 300/year are saved in effluent disposal costs.

Source

Environmental Technology Best Practice Programme (1997) *Water and Chemical Use in the Textile Dyeing and Finishing Industry*, United Kingdom.

CASE STUDY 13
SAVINGS THROUGH CHEMICAL SUBSTITUTION

A Scottish finishing company saves GBP 20 000/year in effluent disposal costs by reducing the COD of their effluent from 2 460 mg/ℓ to 700 mg/ℓ. This was achieved through replacing the use of soap in scouring with anionic/non-ionic detergents and conducting trials to ensure that minimum detergent was used.

Source

Environmental Technology Best Practice Programme (1997) *Water and Chemical Use in the Textile Dyeing and Finishing Industry*, United Kingdom.

CASE STUDY 14
WATER SAVINGS THROUGH DYEBATH REUSE

Background

The Adams-Millis textile company has two mills located in North Carolina and conducts batch dyeing of nylon pantyhose.

Waste minimisation principle

Segregation, direct reuse, scheduling, audit and analysis.

Description of implementation

Direct dyebath reuse for the dyeing of nylon pantyhose was implemented in rotary drum dyeing machines.

Economics

Water use was decreased by 35% and energy use reduced by 57%.

Source

Environmental Protection Agency (1996) *Best Management Practices for Pollution Prevention in the Textile Industry*, U.S. Environmental Protection Agency, Document No. EPA/625/R-96/004, Ohio, USA.

CASE STUDY 15
REDUCING TOXICITY THROUGH MATERIAL SUBSTITUTION

Background

JP Stevens & Company INC., situated in North Carolina is a yarn formation company. Biocides are added to the air washers and cooling towers.

Waste minimisation principle

Substitution; Process alternatives; Monitoring and control.

Description of implementation

Ultraviolet light was substituted for the chemical biocides. During a 6 month trial period data were collected on safety, chemical inventory and handling, workplace air quality, air washer performance and wastewater problems.

Economics

Based on chemical savings, a payback period of 11 to 18 months was acheived.

Remarks

The substitution of a physical process for a chemical one lead to improvements in worker safety and health, reduced toxicity the toxicity of the effluent and eliminated pH and foaming problems in the wastewater.

Source

Environmental Protection Agency (1996) *Best Management Practices for Pollution Prevention in the Textile Industry*, U.S. Environmental Protection Agency, Document No. EPA/625/R-96/004, Ohio, USA.

Appendix 3

Typical Pollution Loads from the Textile Industry

This appendix summarises the typical water consumption and pollution loads from the various processes in the textile industry. This includes liquid effluent, solid waste and energy use.

A3.1 Liquid Effluent

The specific water intake for the textile industry varies from 95 to 400 ℓ/kg fabric depending on the type of processes used and water efficiency (Steffen Robertson and Kirsten, 1993). Dyehouse effluents are complex, containing a wide and varied range of dyes and other products such as dispersants, levelling agents, acids, alkalis, salts and sometimes heavy metals (Laing, 1991). Emissions to water consist of concentrated waste process water, rinsing and cooling water. Rinsing water may represent 60% to 70% of the total water consumption (Swedish Environmental Protection Agency, 1989). The waste water contains natural impurities extracted from the fibres and a mixture of the process chemicals such as organic compounds, dissolved inorganic salts, dyes and heavy metals. In general, the effluent is highly-coloured, high in biological oxygen demand (BOD) and chemical oxygen demand (COD), has a high conductivity and is alkaline in nature. **Table A3-1** lists the typical pollution characteristics of the effluent from the textile industry (Environmental Monitoring Group, 1993, Kothuis and Schelleman, 1995, Cooper, 1978).

Table A3-1 : Effluent characteristics from the textile industry

Process	Composition	Nature
sizing	starch, waxes, carboxymethyl cellulose, polyvinyl alcohol	High in BOD and COD
desizing	starch, glucose, carboxymethyl cellulose, polyvinyl alcohol, fats and waxes	high BOD, COD, suspended solids, dissolved solids
scouring	caustic soda, waxes, grease, soda ash, sodium silicate, fibres, surfactants, sodium phosphate	dark coloured, high pH, high COD, dissolved solids
bleaching	hypochlorite, chlorine, caustic soda, hydrogen peroxide, acids, surfactants, sodium silicate, sodium phosphate	alkaline, suspended solids
mercerising	caustic soda	high pH, low COD, high dissolved solids
dyeing	various dyes, mordants, reducing agents, acetic acid, soap	strongly coloured, high COD, dissolved solids, low suspended solids, heavy metals
printing	pastes, starch, gums, oil, mordants, acids, soaps	highly-coloured, high COD, oily appearance, suspended solids
finishing	inorganic salts, toxic compounds	slightly alkaline, low BOD

Table A3-2 : Specific pollution loads for various textile mills							
Fibre processed and factory operation	pH	SWU (ℓ/kg)	SEV (ℓ/kg)	SPL (g/kg)			
				COD	TDS	TSS	SO_4
Polycotton/cotton woven fabric finishing	9.3	284	227	345		317	225
Cotton woven fabric finishing	9.9	140	115	64	409		
cotton/synthetics woven fabric finishing	6.9	277	222	352	495	365	170
cotton knit fabric finishing	9.7	256	309	159	762	660	
cotton/synthetics woven fabric finishing	11	<151	113	304	548	277	40
synthetics/cotton woven fabric finishing	6.5		226	43	349	216	67
All fibres knit fabric finishing; commission dyeing	8.5	364	106	9	101	62	19
All fibres commission dyeing		120	138				
synthetics/cotton knit fabric finishing			113				
cotton accessory/haberdashery		173	413				

Table A3-2 gives the specific water use (SWU), specific effluent volume (SEV) and specific pollution loads (SPL) for various textile mills in South Africa (Steffen Robertson and Kirsten, 1993). As can be seen, the pollution load differs depending on the type of fabric processed. The effluent characteristics for the various stages in the processing of 100% cotton, 50/50 cotton-polyester blend, wool and synthetic fibres are given in the following sections.

A3.2 Pollution Load from the Processing of 100% Cotton

The two main processes carried out at a mill processing cotton are weaving, preparation and finishing. Sizing takes place with starches, modified cellulose and synthetics. The woven cloth can contain 8% to 15% size. In general, the effluent has a high pH, is coloured, has a BOD of approximately 300 mg/ℓ and uses approximately 350 ℓ/kg fabric. **Table A3-3** lists typical pollution loads and effluent volumes produced from a cotton mill (UNEP, 1996, Pollution Research Group, 1983, Kothuis and Schelleman, 1995, Cooper, 1978).

Table A3-3 : Typical pollution loads for the processing of 100% cotton

Process	pH	SEV (ℓ/kg)	BOD	COD	TSS	TDS	O & G
			kg per 1000 kg of product				
Desizing							
enzyme starch	6 - 8	2.5 - 9	45.5	91	89	5	5
acid starch	6 - 8		45.5	91	89.5	7.5	5
polyvinyl alcohol (PVA)	6 - 8		2.5	5	5	48	2.5
carboxymethyl cellulose (CMC)	6 - 8		4	8	5	45	9.5
Scouring							
unmercerised greige fabric	12.5	2.5 - 43	21.5	64.5	5	50	40
mercerised greige fabric	12.5		16.5	49.5	5	50	30
Mercerising							
greige fabric	12	231 - 306	13	39	5	148	10
scoured fabric	12		4	12	5	148	nil
bleached fabric	12		2	6	5	148	nil
Bleaching							
hydrogen peroxide	9 - 12	2.5 - 124	0.5	2	4	22	nil
sodium hypochlorite	9 - 12		1	4	4	5	nil
Dyeing							
fibre reactive HE dyes (woven)	12		6	24	-	180	
basic	6 - 7.5	149 - 300					
direct	6.5 - 7.6	14 - 53					
vats	5 - 10	8.3 - 166					
sulphur	8 - 10	24 - 212					

A3.3 Pollution Load from the Processing of 50/50 Cotton-polyester blend

Table A3-4 lists typical pollution loads from a South African textile factory processing a 50/50 blend of cotton-polyester (UNEP, 1996, Pollution Research Group, 1983).

Table A3-4: Effluent characteristics for a mill processing 50/50 cotton-polyester blend

Source	Effluent (ℓ/kg)	pH	OA	COD	BOD	TS	SS	TDS
			kg per 1000 kg product					
Desizing								
starch	12.5	6 - 8			38.5	97	77	20
PVA	12.5	6 - 8			2.5	55.4	5	50.4
CMC	12.5	6 - 8			3.93	59.5	5	54.5
mixture	4.2		9.7	74		78		
Scouring								
unmercerised	25	12			10.8	14.8	5	9.8
mercerised	25	12			8.34	14.7	5	9.7
Bleaching								
peroxide	16.7				1.3	24	4	20
oxidative-desize-bleach	5.1		23	23		184		
Mercerising								
poly/cotton	16.7				3.2	82	5	77
Dyeing								
disperse - vat	42	12		68	22.8	122		122
vat	100					150		
disperse	80					20		
direct - disperse		6 - 8		32	10.7			114
sulphur - disperse		11		68	22.8			69.7
reactive - disperse		12		41	13.8			192
Printing								
pigment (woven)		6 - 8		5	1.26		0.13	2.5
pigment (knit)		6 - 8		5	1.26		0.13	2.5
vat (woven)		10		86	21.5		25	34
vat (knit)		10		86	21.5		25	35
machine wash	100							
screen wash	7							
hose vessels	30							
pig. wash	12.5				1	3	0	3
Finishing								
resin finishing		6 - 8						22
resin finishing flat curing		6 - 8		25	6.32			17.3

A3.4 Pollution Load from Wool Processing

Effluent is produced in the scouring, dyeing, rinsing, fulling, carbonising and washing processes. Scouring removes natural impurities and the effluent is therefore oily, alkaline, high in solids and high in BOD. Wool fibre accounts for only 40% of mass, the remainder is impurities. Typical wastes for a mill that scours and finishes wool are given in **Table A3-5** (Cooper, 1978) and **Table A3-6** lists the pollution loads from the various processing steps (Kothuis and Schelleman, 1995, Cooper, 1978).

Table A3-5 : Typical wastes from wool processing

Parameter	Value
BOD	900 to 3 000 mg/ℓ
TS	3 000 mg/ℓ
pH	9 to 10.5
SS	100 mg/ℓ
alkalinity	600 mg/ℓ
grease	100 mg/ℓ
Cr	4 mg/ℓ

Table A3-6 : Pollution loads from wool wet processing

Process	pH	BOD (ppm)	TS (ppm)	Volume (ℓ / kg)
Scouring	9 to 10.4	30 000 to 40 000	1 129 to 64 448	45.6 to 99.6
Dyeing	4.8 to 8.0	380 to 3 000	2 000 to 10 000	15.8 to 22.2
Washing	7.3 to 10.3	4 000 to 11 455	4 830 to 19 267	332 to 830
Neutralising	1.9 to 9.0	28	1 241 to 4 830	104 to 130
Bleaching	6.0	390	908	2.5 to 22.2

A3.5 Pollution Load from the Processing of Synthetic Fabrics

There are no natural impurities in synthetic fibres. Desizing is not required and very little scouring and bleaching takes place. The major fibres and liquid wastes produced from each process are given in **Table A3-7** (Cooper, 1978).

Table A3-8 (Steffen Robertson and Kirsten, 1993) lists the pollution loads from various synthetic textiles, while **Table A3-9** lists the pollution load per process (Kothuis and Schelleman, 1995, Cooper, 1978).

Table A3-7 : Effluent characteristics from processing of synthetic fibres

Fibre	Process	Liquid waste
Rayon	scour and dye	oil, dye, synthetic detergent, antistatic lubricants
	scour and bleach	synthetic detergents, hydrogen peroxide
	salt bath	synthetic detergent, chloride or sulphate
Acetate	scour and dye	antistatic lubricant, dye, sulphonated oils, synthetic detergent, esters, softeners
	scour and bleach	synthetic detergents, hydrogen peroxide or chlorine
Nylon	scour	antistatic lubricants, soap, soda, fatty esters
	developed disperse dye	dye, sodium nitrate, hydrochloric acid, developer, sulphonated oils
	bleach	peracetic acid
Acrylic	dye	dye, formic acid, wetting agents, aromatic amines, retarding agent, sulphates
	thermosol dyeing	acid
	bleach	chlorite
	scour	synthetic detergent, pine oil

Table A3-8 : Typical pollution loads for synthetic textiles

Fabric	Vol. (ℓ/ kg)	BOD	COD	SS	TDS
		kg per 1000 kg product			
Rayon	42	30	52	55	100
Acetate	75	45	78	40	100
Nylon	125	45	78	30	100
Acrylic	210	125	216	87	100
Polyester	100	185	320	95	150

Table A3-9 : Pollution loads from each process step for various synthetic textiles					
Process	**Fibre**	**pH**	**BOD (ppm)**	**TS (ppm)**	**Volume (kℓ / 1 000 kg)**
Scour	nylon	10.4	1 360	1 882	50 to 66
	rayon	8 to 9	2 800	3 300	17 to 34
	acetate	9 to 10	2 000	2 000	25 to 84
	acrylic	9.7	2 190	1 874	50 to 66
	polyester	8 to 10	500 to 800	600 to 1 400	25 to 42
Scour and dye	rayon	8.5	2 832	3 334	17 to 33
	acetate	9.3	2 000	1 778	33 to 50
Dye	nylon	8.4	368	641	17 to 33
	rayon	8 to 9	2 800	3 500	16.7 to 34
	acetate	9 to 10	2 000	2 000	34 to 50
	acrylic	1.5 to 3.7	175 to 2 000	833 to 1 968	17 to 33
	polyester	6 to 9	480 to 27 000	300 to 3 000	17 to 33
Salt bath	rayon	6.8	58	4 890	4 to 12
Final scour	acrylic	7.1	668	1 191	66 to 83
	polyester		650		17 to 33
Finishing	rayon				4 to 12
	acetate				25 to 42
	nylon				33 to 50
	acrylic				42 to 58
	polyester				8.3 to 25

A3.6 Solid Waste

The textile industry produces a variety of solid waste and, by volume, it is the second largest waste stream after liquid effluent. The source of solids waste includes waste fibre; tarry residues on stenters from finishing chemicals; hydrocarbons, dyes and chemicals from solvent recovery systems; sludge from effluent treatment plants; dye containers, which contain approximately 28g to 56g excess dyestuffs; chemical containers (potentially hazardous); pallets; fly ash and general paper trash.

The quantity and type of solid waste produced depends on the nature of the operation, the efficiency of the processes and the level of awareness about solid waste management. A survey in 1994 found that, by tonnage, the largest waste was due to paper followed by wastewater sludge, cardboard and fly/bottom ash (EPA, 1996). Optimising the operation of the wastewater works can lead to a reduction in sludge and introducing energy conservation measures will decrease the amount of fly ash produced as less incineration is needed. Solid waste from packaging materials can be reduced through more efficient stock control (buying in bulk) and purchasing chemicals in returnable containers.

Table A3-10 lists the various sources of solid wastes in the different manufacturing processes and the quantity produced (Kothuis and Schelleman, 1995, Cooper, 1978).

Table A3-10 : Source and type of solid waste produced in the textile industry

Waste	Source	kg / ton fabric
Wool scouring		
dirt and wool	sorting and blending	12
dirt and vegetable matter	scouring	26
fly and sweeps	drying	2
wool waste	top preparation	55
wasted sludge	effluent treatment	570 (dry)
retained sludge	effluent treatment	780 (dry)
Wool fabric dyeing and finishing		
flock	carbonising and drying	16
seams	scouring	0.7
dye containers	dyeing	1.3
chemical containers	dyeing, finishing	1.6
fabric	finishing	1.3
flock	mechanical finishing	17
fibre	pre-treatment screening	25 (dry)
wasted sludge	effluent treatment	none
retained sludge	effluent treatment	1.6 (dry)
Woven fabric dyeing and finishing		
cloth	singe and desize	0.2
cloth	mercerise	0.1
cloth	bleach and wash	0.2
cloth	mechanical finish	6
flock	mechanical finish	4
dye containers	dye / print	0.5
chemical containers	dye, printing, finishing	0.8
fibre	pre-treatment screening	0.8 (dry)
wasted sludge	effluent treatment	20 (dry)
retained sludge	effluent treatment	67 (dry)
Knit fabric dyeing and finishing		
cloth	dyeing, printing	2
cloth	chemical finish	4
cloth	mechanical finish	3
dye containers	dye, printing	0.9
chemical containers	dye, printing, finishing	0.9
cloth	wash	2 (dry)
fibre	pre-treatment screening	0.8 (dry)
wasted sludge	effluent treatment	none
retained sludge	effluent treatment	64 (dry)
Greige goods		
fibre and yarn	yarn preparation	32
fibre, yarn, cloth	knitting	10
fibre, yarn, cloth	weaving	11
Carpet dyeing and finishing		
yarn and sweeps	tufting	1
selvage	selvage trim	26
flock	fluff and shear	4
dye containers	dyeing, printing	0.13
chemical containers	dyeing, printing	0.18
fibre	pre-treatment screening	1.2 (dry)
latex sludge	effluent treatment	2.3 (dry)
wasted sludge	effluent treatment	none
retained sludge	effluent treatment	5.2 (dry)
Yarn and stock dyeing		
yarn	bleaching, dyeing	0.7
yarn	beaming, winding etc.	5.4
dye containers	dyeing	0.87
chemical containers	dyeing, finishing	2.2
fibre	pre-treatment screening	9.0 (dry)
wasted sludge	effluent treatment	none
retained sludge	effluent treatment	2.9 (dry)

A3.7 Emissions to Air

Air pollution results from various textile processes and from energy production and has been identified as the second greatest pollution problem for the textile industry. Those from process emissions include volatile organic substances and particulate matter from the printing, dyeing, and curing of fabric, and the handling of chemicals. The emission of volatile organic substances may lead to the production of photochemical oxidants and cause unpleasant odours. The textile industry requires a great deal of heating and the type of fuel determines the nature of the pollutants. Boilers are one of the major point sources for air emissions, producing nitrogen and sulphur oxides. Fugitive sources of air pollution include volatile emissions from processed fabric stored in warehouses and chemical spills. Emissions to air can be minimised by designing products that do not require the use of volatile chemicals, optimising boiler operations and reducing the use of solvents.

A3.8 Noise Pollution

Noise in the textile industry arises from fan systems, transport to and from the industry and mechanical equipment.

A3.9 Hazardous Waste

Hazardous wastes are defined as wastes, or combination of wastes, that pose a threat to human health or living organisms because they are lethal, non-degradable, persistent in nature and can cause detrimental cumulative effects. These wastes can be solids, liquids, gas or sludges.

Most textile operations produce little or no hazardous waste, but some (10to 20%) may be generators of hazardous waste. The main sources from the textile industry are heavy metals and solvents. Other components include acids, alkalis, bleaches, adhesives, polymers, cross-linking agents, detergents, dye carriers, chemical finishes, biocides, weed killers, paint strippers and solvents. The remainder (75% (m/m)) are considered to be non-hazardous. Carriers containing chlorinated aromatics are considered to be extremely hazardous and their use today is limited (Swedish Environmental Protection Agency, 1989). Organic phosphorous compounds (e.g. flame-proofing and complexing agents) may contain organic bromine compounds, such as decabromine diphenyl oxide and antimony trioxide, which are bioavailable and bioaccumulative.

The most effective means of reducing hazardous waste from the textile industry is one of avoidance by pre-screening all chemicals. This is most easily achieved by studying the material safety data sheet (MSDS). If Hazardous chemicals are required, proper handling and storage is important and workers should be trained in these areas.

A3.10 Dyes and the Environment

The loss of dyes to effluent can be estimated to be 10% for deep shades, 2% for medium shades and minimal for light shades (Laing, 1991). Dyes are present in the effluent at concentrations of 10 mg/ℓ to 50 mg/ℓ with 1 mg/ℓ l being visible to the naked eye. They are complex organic compounds which are refractory in aerobic treatment systems. Some contain metals such as Cr, Cu and Zn. Only 50% (m/m) is dye, the remainder is non-hazardous filler and surfactant.

There are 2 main factors involved in determining the risk assessment of chemicals, namely, hazard and exposure (Baughman, 1988). Hazard describes the potential biological effects (e.g. toxicity and carcinogenicity) that have a dose-response curve. Exposure is a measure of the expected environmental concentration of a chemical over time and distance. The data obtained from hazard and exposure studies will indicate what effects are possible, whereas risk assessment involves determining what is probable.

In the aquatic environment, dyes can undergo bioconcentration, ionisation, abiotic oxidation, abiotic and microbial reduction, precipitation and ligand exchange. The ionic dyes such as acid, direct, basic and metal complex dyes will not volatilise whereas, in principle, solvent, disperse, vat and sulphur dyes have the potential to be volatile. Sorption should also play a major role as dyeing is a sorption process. Hydrolytic reactions are not important because if the dyes survive the rigours of biological treatment processes, it is unlikely to degrade rapidly in the environment. Photochemical reactions may be important as dyes are good adsorbers of solar energy. However, little information is available on this. It is expected that anionic dyes would react with ions such as calcium and magnesium to form insoluble salts and thereby reduce the concentration available for other biological reactions. Similarly for basic dyes, due to their interaction with humic material and hydrous oxides. Redox reactions should also be considered, as in early vat dyeing processes, the dyes were reduced microbially before chemical replacements were introduced. Reduction in the environment would most likely occur under anaerobic conditions, however, the difficulties of working with anaerobic systems has limited research in this area. In general, there is very little literature available on the environmental behaviour of dyes. This is probably due to the lack of suitable analytical techniques.

A3.11 Toxicity

Dyes, especially, cause public concern as even small concentrations (l mg/ℓ) are visible in the environment. Safety data sheets should be available for each dyestuff where information regarding the toxicity, biodegradability, aquatic toxicity and the effect of exposure can be found. Toxicity is determined by carrying out tests on animals (usually rats) to ascertain the single oral dose of dye that will kill 50% of the population in 14 days. The results are expresses in mg/kg of body weight and is known as lethal dose (50) or LD_{50}. On the basis of these tests, toxicity gradings can be made (see **Table A3-11**) (Desai, 1992).

Table A3-11 : Toxicity gradings of dyes			
$LD_{50\ (mg/kg)}$	**Classification**	**No. of dyes**	**% dyes**
< 25	Very poisonous		
25 to 200	Poisonous	44	1
200 to 2 000	Harmful	314	7
> 2 000	Not classified	4,103	92
Total		4,461	100

Aquatic toxicity is expressed as LC_{50} (measured in mg/l) which gives the concentration of a chemical that causes 50% of an experimental population of fish during 48 hours. **Table A3-12** gives the results of a study carried out by ETAD on 3 000 commonly used dyes (Desai, 1992).

Table A3-12 : Fish toxicity levels of common dyes	
$LC_{50\ (mg/l)}$	**% of dyes**
< 1	2
1 to 10	1
10 to 100	27
100 to 500	31
> 500	28

Some dyes have been identified to be mutagenic in the Ames *Salmonella* mutagenicity test and some disperse dyes have been shown to cause allergic contact eczema.

It is difficult to asses toxicity in terms of structure as a simple change in the position of substituents etc. can alter the toxicity. ADMI carried out a survey in 1971 on the toxicity of 46 dyes tested on fish. The results of this study showed that basic dyes were the most toxic due to their cationic nature, whereas direct and vat dyes were found to be non-hazardous.

From this and other ADMI-sponsored studies, it was concluded that basic cationic dyes and some acid and disperse dyes warrant being labelled "potentially hazardous". Overall, all dye containing waste should be considered potentially hazardous as neither the effect on human health nor what occurs on decolourisation is known.

Brown and Anliker (1988) summarised the effects of textile effluent on the environment and the toxicity with respect to fish and other aquatic organisms, sewage bacteria and plants. They concluded that due to the vast number of different dyestuffs and processes in which they can be applied, an accurate environmental risk assessment can only be made on individual dyestuffs and in individual dye-houses. A similar summary of research work initiated by the ADMI into the toxicity of dyes to aerobic and anaerobic bacteria and to fish is given by Vyas (1975).

A3.12 Heavy Metals

The source of heavy metals in dyes is from premetallized dyes (3% to 4% metal); basic dyes requiring preparation as a double salt of zinc; dichromates to oxidise and fix dyes; and chromium compounds from after chroming operations in wool dyeing.

Table A3-13 : Heavy metal content of dyes

Metal	Typical conc. (ppm)	Dye type with highest metal content
Arsenic	< 1 to 1.4	reactives
Cadmium	< 1	all types
Chromium	3 to 83	vat
Cobolt	< 1 to 3.2	acid
Copper	33 to 110	vat
Lead	6 to 52	reactives
Mercury	0.5 to 1	vat
Zinc	3 to 32	basic

The discharge for heavy metals are stringent as they can be toxic to animals and aquatic life. Metal complex dyes contain chelated chromium, cobalt, copper and nickel. Some cationic dyes contain zinc and trace concentrations of mercury, cadmium and arsenic can be present as impurities from intermediates. **Table A3-13** lists the metal content of some dyes (EPA, 1996; Cooper, 1978).

Some oxidising and reducing agents contain metals (e.g. dichromate and permanganate), but in most cases, these chemicals are no longer in use. Metals are also present in finishes such as antifungal and odour-preventive finishes, water repellents and flame retardents (EPA, 1996).

A3.13 Biodegradability

Dyes are stable against breakdown by many micro-organisms and most dyes do not biodegrade under the aerobic biological treatments in a municipal sewage plant. Many dyes, including the azo dyes, degrade under anaerobic conditions and the aromatic amines thus formed have been found to degrade further aerobically. Therefore, the aerobic conditions of rivers and lakes should degrade the amines formed from the biodegradation of azo dyes if they accumulate in the river sediments.

Due to this recalcitrant nature of dyestuffs under aerobic processes, concern arose as to the toxicity of these compounds towards the micro-organisms. A screening method for determining the inhibitory effect of the dyestuffs on aerobic bacteria was developed by ETAD (Brown et al., 1981). Tests were performed on 202 dyestuffs and the results reported as the 50% Inhibition Concentration (IC_{50}) values. Dyes from the direct, disperse, reactive, vat, mordent, pigment, acid and solvent ranges gave IC_{50} values greater then 100 mg/ℓ thus indicating that they had no toxic effect towards the mjcro-organisms at the concentration expected in textile effluents. However, dyes belonging to the basic range gave IC_{50} values of less than 100 mg/ℓ, which is in agreement with the results obtained by Ogawa et al. (1989) that basic dyes are inhibitory to micro-organisms. From these tests, and the general experience of ETAD, it was concluded that although dyes may cause concern at sewage works due to their colour, there should be no concern as to their toxicity. The exception to this ruling are the benzidine-based dyes, the manufacture of which is prohibited by ETAD members. This has resulted in some ETAD members resigning from the board (ETAD Annual Report, 1993).

Finishing chemicals and dyes have BOD's of between 1% and 26% of the COD, which is far below the ratio required for easily biodegradable wastes. Typically, a COD/BOD ratio of textile effluents is 2.5:1 to 5:1. If the ration is greater than 5:1, biodegradability is a problem (Laing, 1991).

A3.14 Bioelimination

Some dyes are adsorbed 40% to 80% by the biomass. Of 87 dyes studied, 62% had significant colour removal due to sorption. This is referred to as bioelimination. With acid dyes, their high solubility causes low adsorption and this is based on the number of sulphonic acid groups. Reactive dyes also show little adsorption, but this however, is not dependent on the sulphonated groups or ease of hydrolysis. Direct and basic dyes show high adsorption and disperse dyes show high to medium adsorption.

A3.15 Dye Degradation Products

Moll (1991) summarised the carcinogenic potential of dye degradation products. Information on the carcinogenic effect of dyes on animals was only available for a limited number of dyes, most of which were azo (approximately 70% of all colourants on the market are azo dyes). The toxicity of these dyes was assessed in terms of azo separation, i.e. what aromatic amines are produced. This occurs through reduction of the azo bond or the influence of enzymatic systems. The main concern is for those azo colourants which can release carcinogenic amines during metabolism. In 1994 the German government banned the use of azo dyes that can be split into any of 22 listed amines (see **Table A3-14**; Turner, 1995). This ruling applies to any consumer goods that remain in contact with the body for extended periods of time. While the majority of ETAD members do not manufacture or sell azo dyes affected by this regulation, there are some exceptions. ETAD issued a statement in 1995 that all manufacturing companies must inform their customers whether they comply with these regulations. A review by Clarke and Steinle (1995) reports that although it is estimated that about 150 azo dyes currently commercially available would form, on reductive cleavage, an aromatic amine that is acknowledged to be an animal carcinogen, only about 15 of these aromatic amines are considered to be relevant to the colourant industry. In most cases, the reduction products of the azo dyes are aromatic aminosulphonic acids, which have little or no carcinogenic potential (Jung *et al.*, cited by Clarke and Steinle, 1995).

Table A3-14 : Carcinogenic aromatic amines (after Turner, 1995)

4-aminodiphenyl	3,3'-dimethylbenzidine
benzidine	2-methoxy-5-methylaniline
2-amino-5-chlorotoluene	3,3'-dimethyl-4-4'-diaminodiphenylmethane
2-aminonapthalene	4,4'-methylene-bis(2-chloroaniline)
2-aminoazotoluene	4,4'-oxydianiline
2-amino-4-nitrotoluene	4,4'-thiodianiline
4-chloroaniline	2-aminotoluene
2,4-diaminoanisole	2,4-diaminotoluene
4,4'-diaminodiphenylmethane	2,4,5-trimethylaniline
3,3'-dichlorobenzidine	2-methoxyaniline
3,3'-dimethoxybenzidine	4-aminoazobenzene

A3.16 Auxiliaries

The pollution potential of other contaminants is high (Laing, 1991). The most obvious source are the additives to the dyebath, but there can also be impurities present from the manufacturing processes. From a study in the USA, it was concluded that of the total BOD load of textile effluents, dye wastes only contribute 10% to 30%. Acetic acid alone can contribute 50% to 90% of the dyehouse BOD. Another study showed that dyes contribute only 2% to 5% of the COD, whereas chemicals contributed 25% to 35% (including levelling, anti-foaming and wetting agents etc.). Two of the main sources of contaminants are the electrolytes added to the dyebath to aid in exhaustion and surfactants. Others include toxic organic chemicals (e.g. acetone, chloroform, methylene chloride and cyclohexane), biocides and toxic anions (EPA, 1996).

A3.17 Energy Considerations in the Textile Industry

The textile industry is a large user of energy and in South Africa, it is the second largest user of electricity from Eskom. The main areas of energy use are in drying, followed by heating and air-conditioning. The main sources of energy and their use in the industry are listed in **Table A3-15**.

The energy utilisation for the various stages in the processing of fabric for T-shirts and bed linen are given in **Table A3-16** (Jensen et al., 1995).

Table A3-15 : Energy sources and use in the textile industry	
Energy type	**Use**
Synthetic natural gas	boiler fuel to generate steam direct fired furnaces
Electricity	machinery motors air-conditioning lights offices stenters
Fuel oil	boiler fuel standby for natural gas boilers truck fleets stenters
Coal	boiler fuel
Propane	standby for natural gas

Table A3-16 : Energy utilisation in the processing of fabric for T-shirts and bed linen	
Process	**MJ / kg product**
Production of raw materials	
Cotton production	48.60 (per kg baled lint)
Polyester fibres	111.50 (per kg fibre)
Mechanical processes	
opening, carding, combing, spinning	50.00 - 150.00
warping, knitting	16.70 - 66.70
warping, sizing, weaving	28.60 - 85.70
Total knitting	**67 - 217**
Total weaving	**79 - 236**
Wet treatment (T-shirts)	
scouring / washing	2.10 - 14.70
bleaching / washing	3.50 - 29.60
dyeing	2.80 - 8.00
drying	5.80 - 19.20
Total	**14 - 71**
Wet treatment (bed linen)	
desizing/scouring/ washing	2.54 - 12.41
bleaching/ washing	4.79 - 13.40
mercerising	4.94 - 9.17
dyeing	1.55 - 5.15
drying	8.80 - 22.33
resin finishing	5.06 - 10.00
Total	**28 - 72**

The implementation of measures to minimise the use of energy will result in substantial savings for the industry. For example, the installation of a heat exchanger on a continuous process will result in a 70% recovery of energy.

A3.18 Conclusions

The textile industry emits a wide variety of pollutants from all stages in the processing of fibres and fabrics. These include liquid effluent, solid waste, hazardous waste, emissions to air and noise pollution. The consumption of energy must also be taken into account as the fuel used to provide this energy contributes to the pollution load. It is important to investigate all aspects of reducing wastes and emissions from the textile industry, as not only will it result in improved environmental performance, but also substantial savings for the individual companies.

A3.19 References

All refereneces are listed in **Appendix 5**.

Appendix 4

End-of-pipe Treatment Methods

Once waste minimisation has been carried out in the factory, effluent will still be produced that will require some form of treatment prior to disposal to sewer, river or sea. This appendix will summarise the available technology for treating textile effluent for colour removal and list some of the treatment plants in operation at various textile mills around the world.

A4.1 Effluent Segregation

Prior to the installation of any end-of-pipe treatment method, it is essential to carry out segregation of the effluent streams to separate the contaminated streams from the relatively *clean* streams for treatment. This results in a more effective treatment system as a smaller volume of waste water is treated (resulting in lower capital and operating costs) and it allows for the use of specific treatment methods rather than trying to find one method to treat a mixture of waste with different characteristics. The segregated *clean* streams can then be reused with little, or no, treatment elsewhere in the factory.

A4.2 Treatment Technologies

There are 2 possible locations for treating the effluents, namely, at the textile factory or at the sewage works. The advantage of treatment at the factory is that it could allow for partial or full re-use of water. The following technologies have all been used :

- coagulation and / or flocculation
- membranes (microfiltration, nanofiltration, reverse osmosis),
- adsorbents (granular activated carbon, silica, clays, fly ash, synthetic ion-exchange media, natural bioadsorbants, synthetic bioadsorbants),
- oxidation (Fenton's reagent, photocatalyis, advanced oxidation processes, ozone), and
- biological treatment (aerobic and anaerobic).

Since the effluent from the textile industry is complex and variable, it is unlikely that a single treatment technology will be suitable for total effluent treatment and water recycling. A comprehensive review of these technologies is given by Southern (1995).

A4.2.1 Coagulation and/or Flocculation

Chemicals are added that form a precipitate which, either during its formation or as it settles, collects other contaminants. This precipitate is then removed either through settling or by floating it to the surface and removing the sludge. This is a well-known method of purifying water. Both inorganic (alum, lime, magnesium and iron salts) and organic (polymers) coagulants have been used to treat dye effluent to remove colour, both individually and in combination with one another. With the changes in dyes and stricter discharge limits on colour, inorganic coagulants no longer give satisfactory results. They have the added disadvantage of producing large quantities of sludge. Organic polymers show improved colour removal and produce less sludge, but then may have detrimental effects on the operation of the sewage works. Cationic polymers have also been shown to be toxic to fresh water fish.

Alum is effective in removing colour from textile effluent containing disperse, vat and sulphur dyes, but is ineffective against reactive, azoic, acid and basic dyes. However, it does have the advantage of reducing phosphorous levels, thereby improving the operation of sewage works.

A4.2.2 Membranes

The membrane methods that are available for effluent treatment are microfiltration, ultrafiltration, nanofiltration and reverse osmosis. In general, nanofiltration or reverse osmosis are the most effective processes for removing colour and recovering water. The drawbacks of these processes are the high capital costs, the fact that the concentrated effluent still has to be treated, and membrane fouling.

The most frequently tested method is **reverse osmosis**. The effluent is forced under moderate pressure (1.5 to 4 MPa) across a semi-permeable membrane to produce a purified permeate and a concentrate. This process can remove up to 99% of salts and the complete removal of most organic compounds. The concentrate will require further treatment prior to disposal as the level of impurities are up to six times that of the original effluent stream.

In **nanofiltration**, the membrane acts as a molecular filter, retaining polyvalent ions and compounds with a molecular mass greater than 200. The concentrate contains almost all of the organic impurities and a large proportion of the polyvalent inorganic salts and requires further treatment prior to disposal. The permeate contains the monovalent ions (e.g. Sodium and chloride ions). This method of effluent treatment has been found to be effective in the treatment of dyebaths from reactive dyeing where sodium chloride is used as the electrolyte, as the permeate produced contains the salt and is virtually colourless, and therefore, suitable for reuse in the reactive dyeing process, saving both water and the cost of the salt.

Ultrafiltration and **microfiltration** as stand-alone treatment methods are only suitable for reducing COD and suspended solids from solution. They are effective in combination with other treatment methods such as coagulation/flocculation. They are also useful for the partial removal of colour and organics prior to discharge to sewer. Microfiltration removes colloidal material such as disperse and vat dyes.

A4.2.3 Adsorbents

In order for an adsorbent to work effectively, the concentration of the impurities in the effluent stream must remain fairly constant to prevent the release of the adsorbed material back into the effluent if the concentration falls.

Activated carbon is the most commonly used adsorbent and it is effective in removing organic components from the effluent (but not inorganic compounds). Once saturated, it must be regenerated or disposed of. Regeneration is costly, and in most cases it is trucked off site and disposed of in landfill. Care must be taken with the disposal method as the organics may leach out over time and cause pollution problems at a later date.

Other adsorbents include inorganic compounds such as silica, cinder ash and various clays. Trade name adsorbents such as Macro-sorb and COLFLOC have been shown to be effective at removing colour from reactive dyebath effluent, although disposal of the sludge may be problematic.

Bioadsorbants are naturally occurring polymers that are biodegradable and have structures that allow the adsorption of species within them, or which act as ion-exchangers. Synthetic cellulose bioadsorbants have also been developed and preliminary investigations into their use for removing colour due to reactive dyes show promising results (Southern, 1995).

A4.2.4 Oxidation

Oxidants decolourise dyes by breaking down the dye molecule. Commonly used processes are ozone and Fenton's Reagent.

Ozone has been investigated in a number of studies. It has been found that dye wastewaters react differently depending on the composition. Effluent containing sulphur and disperse dyes are difficult to decolourise, whereas colour due to reactive, basic, acid and direct dyes is removed fairly easily. The main drawback with installing an ozonation plant is the high capital and operating costs. However, improvements in generator and contacting equipment design, together with increasingly strict environmental legislation will probably lead to a more widespread application.

Fenton's Reagent consists of ferrous salt (usually sulphate) and hydrogen peroxide. The reaction is carried out at a pH of 3 and involves the oxidation of ferrous ion to ferric ion with the simultaneous production of the hydroxyl radical. This radical is a powerful oxidising agent and will attack organic compounds and cleave the bonds. In the case of dye molecules, this would lead to decolourisation. A disadvantage (in terms of costs for the discharger) is the production of ferric hydroxide sludge, but it is thought that this sludge is advantageous to the biological treatment system.

Other oxidation methods include the use of ultraviolet light in conjunction with a photocatalyst (titanium dioxide), or other chemical agents such as hypochlorite (the use of which is not encouraged as chlorinated organic species may be formed which are themselves toxic to the environment).

The main drawback of these above methods is that it is not known what degradation products are formed from the oxidation process and it may be the case that these end products, although colourless, may be more toxic than the original dye molecules.

A4.2.5 Biological Treatment

Aerobic treatment

The majority of sewage works are based on the principle of aerobic treatment, where the incoming effluent is exposed to bacteria which convert the components into carbon dioxide and sludge, which is then sent to an anaerobic digester for further treatment. It has been found by a number of researchers that aerobic treatment methods are not sufficiently able to treat the colour from the textile industry, and any colour removal that does take place is due to adsorption onto the sludge, rather than degredation of the dye molecule.

Anaerobic digestion

Anaerobic digestion is the biodegradation of complex organic substances in the absence of oxygen to yield carbon dioxide, methane and water. It is an effective process for treating high COD wastes (e.g. size, desize washing and scouring) and the methane that is produced can be utilised as energy for heating etc. The reducing conditions in an anaerobic digester have been found to cause decolourisation of azo dyes through cleavage of the azo bond and subsequent destruction of the dye chromophore. Complete mineralisation of these degradation products does not take place and aromatic amines may be present in the effluent from the digester (Carliell et al., 1995).

A4.3 Summary

Table A4-1 discusses the available treatment technologies, together with the advantages and disadvantages of each method (Southern 1995). **Table A4-2**, lists various effluent treatment plants that are in operation both locally and internationally. A summary of the treatment methods suitable for each effluent stream produced by the textile industry is given in **Table A4-3.**

Table A4-1 : Summary of available textile effluent treatment technologies

Technology	Examples	Advantages	Disadvantages
Coagulation/ flocculation	alum lime iron polyelectrolytes	* simple equipment * relatively rapid colour removal * significant reduction in COD	* large volumes of sludge may be generated * continual addition of chemicals * high running costs * carry-over of polyelectrolytes may affect sewage works * product generally unsuitable for reuse * will nor remove reactive dyes * precise pH control necessary
Membranes	reverse osmosis nanofiltration ultrafiltration	* removes impurities of particular molecular masses * good colour removal * fast * can handle large volumes * removes ions	* high capital costs * some effluent cannot be treated * concentrate contains almost all impurities * concentrate must be treated by another technology prior to disposal * impurities in purified stream may be too high for re-use * regular cleaning is required * pretreatment required * precise pH control necessary
	Dialysis or continuous deionisation	* purified stream could be re-used * cation stream could be re-used to regenerate water softener, or as caustic or carbonate in the dyeing process	* portion of the effluent is not treated * concentrate contains almost all impurities * at least one of the concentrates must be treated by another technology * organic material could foul membranes * non-ionic species are not removed * capital and operating costs not known
Adsorbents	activated carbon, silica, charcoal, peat, synthetic polymers etc.	* good colour removal * simple technology * low operating costs for some adsorbents * removal of solvents	* high capital costs * slow * regeneration or disposal costs * no single adsorbent is suitable for all dye types * required dosage may be high
Oxidation	Ozone	* good colour removal * can handle large volumes	* high capital costs * high operating costs * not effective at removing colour from all dye types * unknown oxidation products
	Fenton's reagent	* rapid decolourisation * simple operation * sludge enhances sewage works operation	* unknown oxidation products * high running costs
	UV/peroxide UV/catalyst	* good colour removal * powerful oxidant * effective at destroying organic compounds	* high capital costs * unknown oxidation products
	chlorination	* inexpensive * good colour removal	* chlorinated byproducts
Reduction	tin chloride hydrosulphite	* good colour removal * effective for decolourising azo dyes	* aromatic amines may be formed * incomplete degradation

Technology	Examples	Advantages	Disadvantages
Biological	Aerobic	* suitable for removing colour due to insoluble dyes * usually results in mineralisation of dyes	* does not remove colour due to soluble dyes such as reactives * large volumes of sludge are generated * large energy requirements
	Anaerobic	* non-specific colour removal * decolourises most dyes through reduction mechanism * methane produced can be used as energy on-site	* unknown degradation products * high capital cost
Evaporation		* concentrates effluent stream * product water suitable for reuse	* does not "treat" colour * high capital costs * high operating costs
Irrigation		* inexpensive	* detrimental effect on soil * suitable only for uncoloured and non-toxic streams * unacceptable to authorities

Table A4-2 : Some operational textile effluent treatment plants

Location & Date	Situation	Technology	Process steps	Flow (k ℓ/d)	Results	Ref.
Germany, 1982	dye machine	coagulation (COLFLOC)	* Inject polyelectrolyte into dyebath discharge	600	* 60 % colour removal * effective for anionic dyes	1
Germany, 1982	factory discharge	coagulation (COLFLOC)	* inject polyelectrolyte into final effluent * discharge floc to sewage works	2 000	* 70 % colour removal * effective for anionic dyes	1
Germany, 1982	sewage works	coagulation (cationic poly)	* inject polyelectroyte into activated sludge	6 000	* 60 % colour removal	1
Germany, 1983 Lorrach Wiese Valley	sewage works	biological	* activated sludge * anaerobic digestion of sludge	100 000		2
Germany, 1990 Grenzach	factory discharge	membrane (tubular NF)	* direct membrane treatment * salt water recycled * wet air oxidation of concentrate	700		1
Japan, 1974 Kanebo	factory discharge	ozone GAC	* holding tank * 2 ozone reactors * GAC * pH sdjustment	3 300	* BOD and COD reduced by 60 to 80 % * good colour removal * no sludge produced	3
Japan, 1977 Kyoto	sewage works	biological	* activated sludge process	40 000	* poor colour removal	1
RSA Mooi River Textiles	factory discharge	biological	* aerated lagoon * biofilter * maturation ponds * river	1 000	* COD reduced from 320 to 50 ppm	4
RSA, 1963 DaGama King Williams Town	factory discharge	land	* land * dairy farming	5 000	* currently being phased out (1999)	4
RSA, 1963 DaGama East London	factory discharge	biological	* flocculation * bio-filter * maturation ponds * river	4 500	*effluent complied with general standard	4
RSA, 1971 Mondi paper	sewage works (textile, domestic)	biological, coagulation, carbon	* activated sludge * alum * filtration * foam flotation * granulated activated carbon beds	10 000	* water recycled for paper making	5
RSA, 1988 Hammarsdale Waste Water Treatment Works	sewage works (textile, domestic)	biological	* alum added to activated sludge		* colour unaccepatble * non compliance with regualtions	6
RSA, 1989 Dyefin textiles	factory discharge	oxidation (ferrous sulphate)	* addition of ferrous sulphate * addition of caustic * sewer	300	* colour reduced	5
RSA, 1994 Mym Textiles Umzinto	factory discharge segregated scour rinse and dye streams	membrane	* hyperfiltration * recycle of permeate	200 to 300	* permeate recycled * membrane fouling * expensive	5
RSA, 1995 Ninian & Lester	factory discharge	oxidation (Fenton's reagent)	* effluent segregation * pH reduced to 3 with sulphuric acid * ferrous sulphate addition * hydrogen peroxide addition * lime addition * discharge to sewer	800	* no colour entering sewage works * sludge enhances sewage work operation	5

Location & Date	Situation	Technology	Process steps	Flow (k ℓ/d)	Results	Ref.
RSA, 1993 Dyefin Textiles	factory discharge	oxidation (Fenton's reagent)	* effluent segregation * pH reduced to 3 with sulphuric acid * ferrous sulphate addition * hydrogen peroxide addition * lime addition * discharge to sewer	800	* no colour entering sewage works * sludge enhances sewage work operation	5
RSA, 1995 Standard Textile	factory discharge	oxidation (Fenton's reagent)	* effluent segregation * pH reduced to 3 with sulphuric acid * ferrous sulphate addition * hydrogen peroxide addition * lime addition * discharge to sewer	800	* no colour entering sewage works * sludge enhances sewage work operation	5
Sweden, 1976	factory discharge	alum	* addition of alum * flotation * sludge to press	2 880	* reduced COD from 400 to 100 mg/ℓ	7
Switzerland, 1990	factory discharge	membrane (tubular NF)	* membrane treatment * salt / water recycle	250		1
Taiwan, 1990 Far Eastern Textiles	factory discharge	COLFLOC	* equalisation * COLFLOC * alum * flotation * sludge dewater		* good colour removal	1
Turkey, 1990 Erdogan	factory discharge	biological	* nutrient addition * activated sludge	110	* COD reduced from 1 200 to 600 ppm * produced 0.12 kg/ℓ sludge	8
Turkey, 1990 Kom	factory discharge	ferrous sulphate, lime	* ferrous sulphate and lime addition * settling * sludge to press	700	* COD reduced from 600 to 360 ppm * produced 2.9 kg/k ℓ sludge	8
UK, 1978 printing	factory discharge	alum	* alum, lime coagulation * flotation * recycle	2 700	* good colour removal	9
UK, 1988 carpet weaver	factory discharge	membrane (tubular UF)	* direct membrane treatment * permeate recycled * concentrate to tanker	190	* reported to be successful	10
UK, 1990 Leek Sewage Works	sewage works	activated sludge ozone	* activated sludge * balancing lagoons * sand filters * ozone	17 424	* decrease in colour	3
UK, 1995 Courtaulds Textiles	factory discharge	adsorption (Macrosorb) coagulation	* balancing * acid * Macrosorb * alkali * coagulant * separation		* 50% of clarified effluent is reused for dyeing * effluent meets colour standards	11
USA, 1975 Alabama	factory discharge	oxidation	* electro-coagulation with aluminium * flotation	320	* effluent recycled	1
USA, 1976 Salem carpet	factory discharge	oxidation (chlorine)		7 200	* treated effluent recycled	12
USA, 1977 Vernon	sewage works	biological, carbon (PACT)	* carbon addition to aeration tank * wet air regeneration	13 000	* colour removed	13
USA, 1977		encapsulation of solids	* reaction of metal ions with silicates to form insoluble metal silicates * addition of polymer to form solid gel * waste disposal	1 600 mobile	* heavy metals removed	14

Location & Date	Situation	Technology	Process steps	Flow (k ℓ/d)	Results	Ref.
USA, 1980 (75% PE, 25% cot)	factory discharge	coagulation, biological	• lime and poly coagulation • aerated lagoon	2 700	• ADMI reduced from 100 to 75	15
USA, 1980 (80% PE, 20% cot)	factory discharge	biological	extended aeration	3 300	• ADMI reduced from 1300 to 500	15
USA, 1980 Vernon	sewage works	Powdered activated carbon	• activated sludge • powdered activated carbon with aeration tank • wet air regeneration	24 500	• ADMI reduced from 300 to 30	16
USA, 1980 (100% PE)	factory discharge	biological, coagulation	• activated sludge • alum and poly coagulation • sludge to centrifuge	2 700	• ADMI reduced from 1 340 to 110	15
USA, 1981 Penn Dye and Finish Co.	factory discharge	biological	• activated sludge • alum • settling • centrifuge	7 500	• colour reduced by 63% • BOD reduced by 76%	17
USA, 1982 Pennsylvania (bleach wash)	factory discharge	biological	• activated sludge • sludge to anaerobic lagoon	340	• COD reduced from 2 080 to 380 ppm	18
USA, 1969 Hollitex carpets	factory discharge	adsorption	granulated activated carbon	1 900	• 80% of effluent recycled	19
USA, 1989 East Burlingam	sewage works	biological, powdered activated carbon	• activated sludge • powdered activated carbon with aeration tank • wet air regeneration	45 000	• complete colour removal	20

Table A4-3 : Suitable effluent treatment methods for specific textile processing effluents

Process	Effluent problems	Coagulation / flocculation	Adsorption	Membranes[1]	Oxidation	Aerobic	Anaerobic	Other
Sizing								
starch size	COD, BOD, SS					X	X	
synthetic size	BOD, COD, SS			X			X	
Desizing								
cotton / blends	COD, BOD, SS, TDS			X		X	X	
Scouring								
cotton / blends	BOD, TDS, colour					X	X	Evap.
synthetic	BOD, TS					X	X	
wool	pH, BOD, TS					X	X	
Bleaching								
cotton / blends	SS, peroxide			X				
synthetic	SS, peroxide			X				
wool	SS			X				
Mercerising								
cotton / blends	alkaline, TDS			X				Evap.
Dyeing								
reactive	colour, BOD, TDS, metals			X[2]	X		X[3]	
vat		X	X	X	X	X	X[3]	
disperse		X		X	X	X	X	
direct		X	X	X	X		X	
acid				X	X	X	X	
basic			X	X	X	X	X	
sulphur		X		X	X	X	X	
Printing								
all fabrics	colour, BOD, SS	X				X	X	
Finishing								
cotton / blends	TDS, BOD	X						
synthetics	TDS, BOD	X						

Note :

[1] With possible recycle

[2] If NaCl is used as the electrolyte, nanofiltration will remove the colour while allowing recycle of the salt and water for reuse in dyeing

[3] Dyes based on the azo chromophore will be decolourised anaerobically

A4.4 Conclusions

The methods indicated for each process in **Table A6-3** are those that have been found to be the most suitable for that particular effluent stream. It highlights the importance of segregation of the various streams in order to treat them individually.

In general, effluents that are high in COD are most effectively treated by biological methods, either aerobic or anaerobic. There are a number of methods for removing colour from effluents, depending on the class of dye used, but the most effective over the range of dyes is oxidation methods (such as Fenton's Reagent) or membrane treatment using reverse osmosis. Effluents that are high in BOD and SS are best removed through coagulation and flocculation methods followed either by settling or dissolved air flotation. Those effluent streams containing alkaline (mercerising and bleaching) can be treated by membranes (ultrafiltration) or evaporation and reused in the same process. The same is true for synthetic sizes where they can be recycled after filtration.

As mentioned previously, there is no one single treatment technology that can effectively treat the final effluent from the textile industry and a combination of the available methods is necessary in order to achieve the required discharge standards.

A4.5 References

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Appendix 6

Supporting Data

This Appendix contains the data to support calculations and estimates that were made in the Worksheets. Benchmarking data on batch and continuous processing is also included.

DETERMINATION OF TYPICAL AND TARGET WATER USE FIGURES (Worksheet A2)

The typical water use figures were determined from literature and previous surveys conducted by the Pollution Research Group in the textile industry.

For the various batch operations (e.g. jig, jet, beam and yarn processing), typical liquor ratios were used (from literature) and it was assumed that the number of baths in a dyeing operation could vary from 8 (single dye type) to 16 (e.g. reactive/disperse dyeing). For preparation processes (bleaching, scouring etc.) it was estimated that between 3 and 4 baths would be used.

Target figures were calculated based on the typical water use figures, experience with waste minimisation in the textile industry and literature (i.e. information on new equipment and processes etc.). For example, in batch dyeing operations, the number of baths used can be reduced by reusing preparation baths with reconstitution, cascading rinses and reusing softening baths with reconstitution. For continuous operations such as desizing, scouring, and bleaching, water use can be reduced by using counter-current rinsing and by combining the operations. For printing, the water use can be decreased by counter current water flow in the washing-off stages, and turning the water off when the machine is not in use. Blanket washing water can be recycled for reuse. Screen washing can be made more efficient by removing excess paste prior to washing and using modern equipment

CALCULATION OF CAUSTIC SODA AND SULPHURIC ACID SAVINGS (Worksheet A5)

The following chemical reaction takes place between caustic soda and sulphuric acid :

$$2NaOH + H_2SO_4 = Na_2SO_4 + 2H_2O$$

Stochiometrically, this means that 1 mol of sulphuric acid (100%) will neutralise 2 mol caustic soda (100%). Using molecular masses, 98 g acid (100%) will neutralise 80 g caustic. Therefore, to neutralise a given mass of caustic (calculated in (c)), the mass of sulphuric acid (100%) is given by:

$$(\text{mass caustic} \times 98) / 80 = \text{mass caustic} \times 1.225$$

Therefore, the mass of 98% sulphuric acid required to neutralise the caustic is given by ;

$$(\text{mass caustic} \times 1.225) / 0.98 = \text{mass caustic} \times 1.25$$

BENCHMARKING DATA

The following extracts were taken from a research paper by Schramm and Jantschgi entitled : *Comparative asessment of textile dyeing technologies from a preventative environmental protection point of view* (Journal of Society of Dyers and Colorists, **115**, 1999).

The paper involves comparing textile dyeing technologies in terms of water, chemical and energy consumption and dyeing efficiency. The latest generation of dyeing technology was compared to that previously used and both batch and continuous dyeing methods of woven and knitted fabrics were investigated. Process steps were defined as textile dyeing with no pre-treatment or drying. A range of fabric types were compared and these are listed in **Table A6-1**.

Table A6-2 compares the latest technologies with previously used technologies for Batch Processing. **Table A6-3** does the same for padding technologies. The comparison is carried out in terms of utility consumption (water, steam and electricity), chemical use (salt, caustic acetic acid), fibre losses and dyeing efficiency. Previous technology refers to that available during 1990 to 1995; latest technologies is taken to be that available from 1997.

Table A6-1 : List of fabric types compared for both batch and padding dyeing processes (Schramm and Jantschgi, 1999)

Code	Fibre Type	Product Description	Type of Dyestuff	Woven / Knitted
Batch Processing				
E1	Cotton	Towelling	Reactive	Woven
E2	Cotton	Towelling	Vat	Woven
E3	Polyester / cotton	Dress fabric	Disperse and reactive	Woven
E4	Wool	Outer wear	Acid	Woven
E5	Polyester / wool	Outer wear	Disperse and acid	Woven
E6	Viscose	Lining fabric	Direct	Woven
E7	Cotton	Underwear	Reactive	Knitted
E8	Polyester / cotton	Leisure clothing	Disperse and reactive	Knitted
E9	Viscose	Ladies dress material	Reactive	Knitted
E10	Polyamide	Panty	Acid	Knitted
Continuous Processing				
P1	Cotton	Shirts	Reactive	Woven
P2	Cotton	Vocational clothing	Reactive	Woven
P3	Cotton	Towelling	Reactive	Woven
P4	Cotton	Corduroy trousers	Reactive	Woven
P5	Cotton	Corduroy trousers	Sulphur	Woven
P6	Polyester / cotton	Dress fabric	Disperse and reactive	Woven
P7	Polyester / cotton	Vocational clothing	Disperse and reactive	Woven
P8	Polyamide / cotton	Plush	Acid and reactive	Woven

Table A6-2 : Comparison of previously used methods to latest technology for batch dyeing (Schramm and Jantschgi, 1999)

No	Technol.	Fibre loss (%)	Dyeing efficiency (%)	Salt (g/kg)	Caustic[1] (m ℓ/kg)	Hydros (g/kg)	Acetic acid[2] (mℓ/kg)	Water (ℓ/kg)	Steam [3] (MJ/kg)	Electricity [3] (MJ/kg)
E1	Latest	<10	>80	200	14.00			25.00	4.53	0.63
E1	Previous	<10	>80	640	24.00			75.00	11.21	0.45
E2	Latest	<10	>90		135.00	30.00		22.30	4.21	0.63
E2	Previous	<10	>90		216.00	48.00		60.00	8.72	0.90
E3	Latest	<5	>95[4]	200	12.50			20.00	5.08	0.90
E3	Previous	<5	>90[4]	480	22.40			85.00	11.21	1.35
E4	Latest	<5	>95				5.60	18.90	2.84	0.45
E4	Previous	<5	>95				6.40	40.00	8.72	0.90
E5	Latest	<5	>95[5]				3.60	18.00	3.46	0.63
E5	Previous	<5	>95[5]				4.80	60.00	8.72	1.35
E6	Latest	<2	>95	54				15.70	2.64	0.54
E6	Previous	<2	>95	80				45.00	8.96	1.17
E7	Latest	<6	>80	200	14.50			25.00	4.53	0.63
E7	Previous	<6	>75	560	23.20			75.00	11.21	0.45
E8	Latest	<5	>95[4]	200	12.50			20.00	5.08	0.90
E8	Previous	<5	>95[4]	560	20.00			85.00	11.21	1.35
E9	Latest	<2	>80	150	12.50			25.00	4.53	0.63
E9	Previous	<2	>80	480	20.00		3.00	75.00	11.21	0.45
E10	Latest	<0.5	>95				4.80	11.00	3.31	0.72
E10	Previous	<0.5	>95					40.00	8.72	0.90

Notes :
Specific consumptions are given per kg dry clothing textile
[1] Caustic soda - 32.5% solution
[2] Acetic acid - 60% solution
[3] Values of primary energy demand given
[4] Value quoted for disperse dyes, reactive dyes = 80%
[5] Value quoted for disperse dyes, acid dyes = 95%

As can be seen from **Table A6-2**, the latest dyeing technologies for batch processing achieve better values than the previous technologies in all cases. Modern technology results in the use of less chemicals, water and energy, with little or no effect on the dyeing efficiencies and fibre losses. Overall, chemical use was reduced by 20% to 70%, water consumption by 70%, steam use by 60% and overall energy consumption by 60%.

Table A6-3 : Comparison of previously used methods to latest technology for padding processes (Schramm and Jantschgi, 1999)

No	Technol.	Fibre loss (%)	Dyeing efficiency (%)	Salt (g/ℓ/kg)	Caustic (solid) (g/ kg)	Bicarb (g/ kg)	Sod. sulph. (m ℓ/kg)	Soda (solid) (g/kg)	Water (ℓ/kg)	Gas[1] (MJ/kg)	Steam[1] (MJ/kg)	Electricity (MJ/kg)[1]
P1	Latest	<2	90-95			7			10.7	1.12	2.42	0.77
P1	Previous	<2	85-90	175	3				15.4	3.42	4.88	0.56
P2	Latest	<2	90		4				12.7	1.34	2.38	0.50
P2	Previous	<2	85	175	6				15.4	2.68	5.01	0.51
P3	Latest	<2	90		5				12.9	1.34	2.89	0.53
P3	Previous	<2	70	100	3				15.1	2.76		0.16
P4	Latest	<2	90		4				16.8	1.81	2.78	0.53
P4	Previous	<2	75	200	16		50	20	19.6	3.37	4.76	0.46
P5	Latest	<2	90		4		50		17.6	2.22		0.13
P5	Previous	2-5	80						18.8	3.37		0.13
P6	Latest	2-5	90[2]			5.5			12.6	0.90	3.15	0.83
P6	Previous	<2	90[3]	137	1			11	15.1	2.76	5.31	0.53
P7	Latest	<2	90[3]			5.5			12.6	0.90	3.18	0.60
P7	Previous	<2	90[4]	137	1			11	15.1	2.76	4.98	0.64

Notes :
Specific consumptions are given per kg dry clothing textile
[1] Values of primary energy demand given
[2] Value quoted for disperse dyes, reactive dyes = 85%
[3] Value quoted for disperse dyes, reactive dyes = 80%
[4] Value quoted for disperse dyes, reactive dyes = 75%

Previously used technologies for padding processing typically involved pad-dry or pad-steam processes with a trough volume of 50ℓ, whereas the latest technologies employ a modifies pad-dry sequence with a trough volume of 20ℓ to 35ℓ. As can be seen from **Table A6-3**, in most cases, the latest technology achieved better results than that used previously, with the overall dyeing efficiency increasing by 5%. Water consumption was decreased by 20%, steam use by 60%, gas use by 45% and total energy consumption by 45%.

Appendix 7

Useful Organisations

South African

Pollution Research Group	School of Chemical Engineering University of Natal Durban 4041 Tel : (031) 260 3375 Fax : (031) 260 1118
Water Research Commission	P.O. Box 824 Pretoria 0001 Tel : (012) 330 0340 Fax : (012) 331 2565
Department of Water Affairs and Forestry	Private Bag X313 Pretoria 0001 Tel : (012) 299 2823 Fax : (012) 326 1780
Umgeni Water	P.O. Box 9 Pietermaritzburg 3200 Tel : (033) 341 1303 Fax : (033) 341 1349
Textile Industry Training Board	P.O Box 23551 Isipingo 4110 Tel : (031) 902 8229 / 8288 / 8293 Fax : (031) 902 8297
Textile Federation	P.O. Box 16278 Doornfontein 2028 Tel : (011) 404 2423 Fax : (011) 404 2101

South African Dyers and Finishers Association (SADFA)	
Natal :	**P.O. Bpx 2246; Pinetown; 3600** **Tel : (031) 261 7565**
Transvaal :	**P.O. Box 92; Isando; 1600** **Tel : (012) 428 6587**
Eastern Cape :	**P.O. Box 2761; Port Elizabeth; 6056** **Tel : (041) 43 1888**
Western Cape ;	**P.O. Box 306; Paarl; 7620** **Tel : (021) 868 2230**
CSIR Textile Technology	**P.O. Box 1124** **Port Elizabeth** **6000** **Tel : (041) 532131** **Fax : (041) 532325**
South African Bureau of Standards (SABS)	**Private bag X191** **Pretoria** **0001**
Department of Environment Affairs and Tourism (DEAT)	**Private Bag X447** **Pretoria** **0001** **Tel : (012) 310 3646** **Fax : (012) 332 6287**
Durban Water and Waste	**P.O. Box 1038** **Durban** **4000** **Tel : (031) 302 4783** **Fax : (031) 302 4747**
South African Clothing and Textile Workers Union (SACTWU)	**P.O. Box 18361** **Dalbridge** **4014** **Tel : (031) 301 1351** **Fax : (031) 306 0788**

International

United Nations Environment Programme (UNEP) Cleaner Production	**UNEP Regional Office for Africa** **P.O. Box 47074** **Nairobi** **Kenya** **Tel : (254 2) 52 1840 / 52 1841** **Fax : (254 2) 62 3928**
United States Environmental Protection Agency (EPA)	**MC 7409** **Washington** **DC 20460**
Ecological and Toxicological Association of Dyes and Organic Pigment Manufacturers (ETAD)	**P.O. Box** **CH-4005, Basel** **Switzerland** **Tel : (061) 690 9966** **Fax : (061) 691 4278**
Society of Dyers and Colourists	**P.O. Box 244** **Bradford** **West Yorkshire** **BD1 2JB** **UK** **Tel : (01274) 725138** **Fax : (01274) 392 888**

Internet Sites

South African Department of Water Affairs and Forestry	**http://www-dwaf.pwv.gov.za/idwaf/index.html**
Business and the Environment	**Http://www.ru.ac.za/departments/Law/SAenviro/business/business.html**
UNEP Industry and Environment Home Page	**http://www.unepie.org/home.html**
USA Environmental Protection Agency	**http://www.epa.gov**
World Bank	**http://www.worldbank.org/**
UCLA Centre for Clean Technology	**http://cct.seas.ucla.edu/cct.pp.html**
UK Environmental Technology Best Practice Programme	**http://www.etu.com/ETBPP/**

OECD	**http://www.oecd.org**
UNIDO	**http://www.unido.org**
Central Services Statistics	**http:// www.css.gov.za**
Rhodes University Environmental Home Page	**http://www.ru.ac.za/**

Appendix 8

Sample presentation

This Appendix contains a set of sheets that can be used as a presentation to introduce the concept of waste minimisation in the textile industry and explain the methodology of using this Guide. They can simply be photostatted and used as is, or modified to meet specific requirements.

Waste Minimisation Guide for the Textile Industry

A Step Towards Cleaner Production

What is waste minimisation ?

The application of a systematic approach to reducing the generation of waste ***at source***

Trainer Note:

In other words, waste minimisation prevents the waste from occurring in the first place, rather than treating it once it has been produced by end-of-pipe treatment methods.

Waste minimisation applies to:

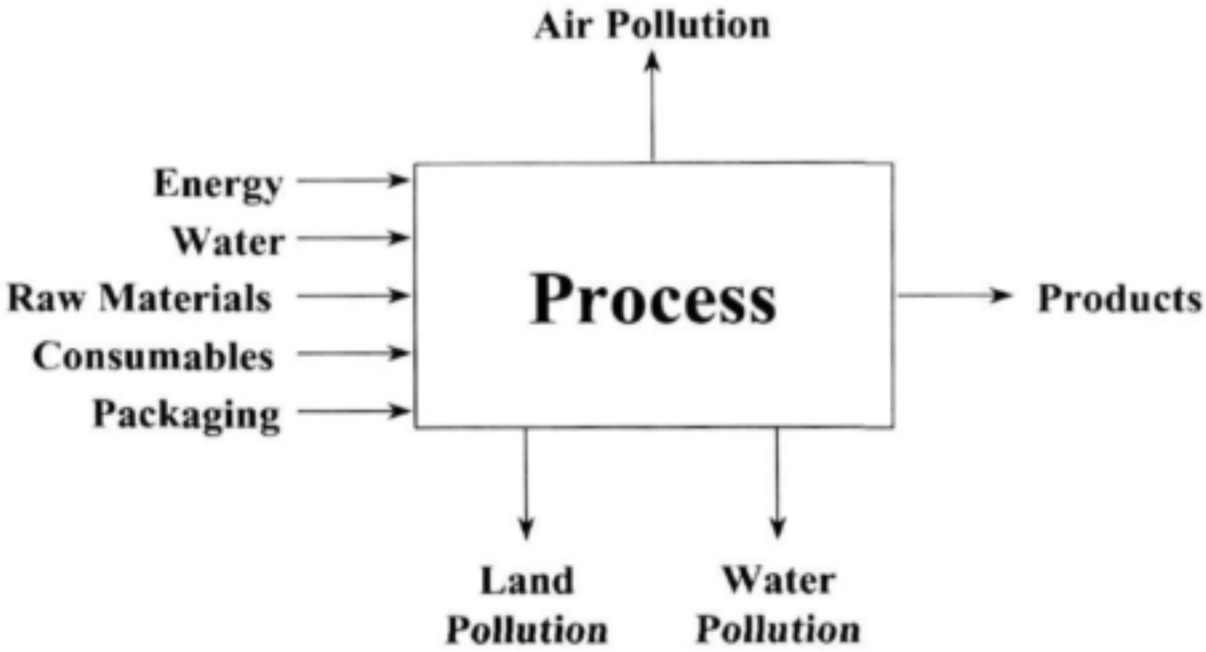
- hazardous materials
- non-hazardous materials
- water
- energy
- raw materials
- all waste emissions
- other resources

It is NOT a once-off activity, but an ON-GOING programme

Trainer Note:

That is, it is a technique that can be applied to all inputs to, and outputs from, a process.

The Process Model



Trainer Note:

This diagram shows pictorially what was said on the previous slide. It indicates the inputs and outputs of a process. Anything that does go into the product is considered as waste.

Waste minimisation is important because it:

- reduces operating costs
- reduces risk of liability
- reduces end-of-pipe treatment
- improves process efficiency
- enhances public image
- protects health and environment
- improves employee moral

Waste minimisation makes good business sense

Trainer Note:

Remember, waste is not only materials that are excess to requirements, but represent a loss of company profits.

Scope to Save

Raw Materials	1 to 5 %
Packaging	10 to 90 %
Consumables	10 to 30 %
Ancillary materials	5 to 20 %
Electricity	5 to 20 %
Water	20 to 80 %
Effluent	20 to 80 %
Solid Waste	10 to 50 %

Trainer Note:

These are typical percentage savings that can be achieved by implementing waste minimisation on-site.

How is it done ?

- Waste minimisation is achieved through

  source reduction by making

  process and **product** changes

Product changes include:

- increasing product life
- designing for less environmental impact

Process changes include:

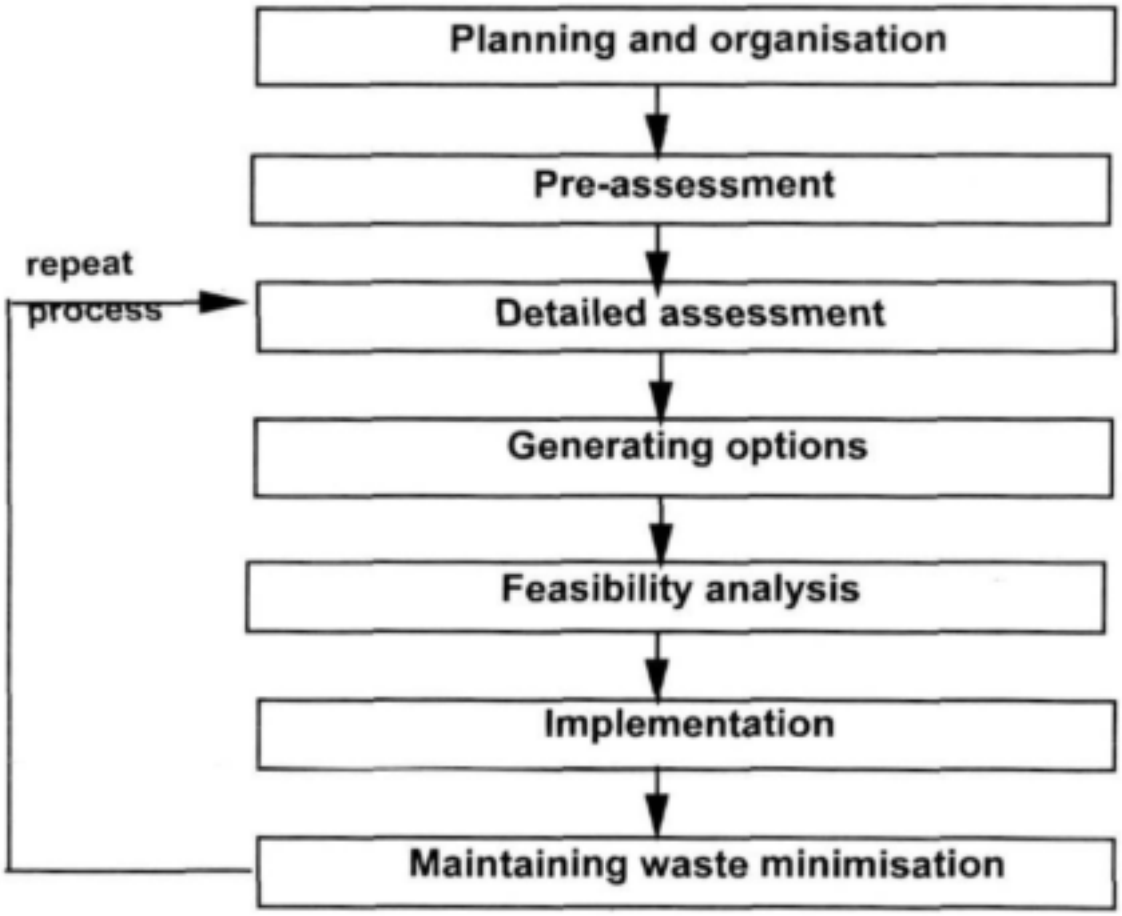
- improved operating practices
- improved housekeeping
- change in raw materials
- change in technology
- in-house reuse or recycling

End-of-pipe treatment is only considered
AFTER
source reduction

Where to start?

- Main stages:
  - planning and organisation
  - pre-assessment
  - detailed assessment
  - generate options
  - feasibility analysis
  - implementation
  - maintaining the programme

How it fits together:



Trainer Note:

Waste Minimisation is a methodical approach to reducing waste at source. This is the accepted approach to implementing a waste minimisation programme. Each stage will be discussed separately

Planning and organisation:

- obtain management commitment
- set up a project team
- set overall goals
- identify and overcome barriers
- conduct a pre-assessment

Trainer Note:

Obtaining management commitment is the most important step in implementing a waste minimisation programme. Without support from the top, the programme will not succeed as people have to be given the time and resources to undertake waste minimisation activities.

Who should be on the project team?

- Representatives from:
  - management
  - environmental department
  - quality assurance and control
  - design and process engineering
  - production and maintenance
  - legal department
  - finance department
  - health and safety
  - operators and
  - external consultants

Trainer Note:

The size of the project team will differ depending on the size of the company. In small companies there may be only 2 team members, while in larger companies, the team may consist of all the above people. A good team is important in order that all relevant information is collected.

Barriers to waste minimisation

- Economic
  - insufficient funds or cash flow
- Technical
  - concerns about changes in product quality
- Regulatory
- Cultural
  - fear of change
  - poor communication

Trainer Note:

These are some of the common barriers encountered when beginning a waste minimisation programme. With good internal communication and good understanding of the benefits of waste minimisation, these barriers can be overcome.

Pre-assessment

- obtain overall company information
- draw process flow diagrams
- identify all sources of wastes
- assign costs to all wastes
- evaluate wastes and emissions
- identify areas for detailed assessment

Trainer Note:

The pre-assessment involves obtaining overall information for the site. Once all waste streams have been identified, quantified and a cost assigned to them, those areas that require further investigation can be identified. This may be based on the quantity of waste produced, the hazardous nature of the waste, or the value of he waste.

Detailed assessment

- construct detailed mass and energy balances
- include:
  - water
  - raw materials
  - energy
  - effluent
  - air emissions
  - solid waste
  - products

Trainer Note:

Once the area for detailed investigation has been chosen, a detailed mass and energy balance can be prepared over this section. This will identify where the losses are occurring and highlight areas for improvement.

Generating options

- identify all areas for improvement
- identify all waste minimisation options
  - brainstorming
  - previous case studies
  - literature
- evaluate options
- identify suitable options for implementation

Trainer Note:

Options for improvement can then be identified. This is best done through brainstorming with all team members.

Feasibility analysis

- Analyse options in terms of:
  - Technology
    - will it do the job ?
    - what changes have to be made ?
  - Economics
    - capital and operating costs
    - payback period
  - Environment
    - will it reduce environmental impact ?
    - compliance with regulations ?

Trainer Note:

All options are then evaluated in terms of their technical, economic and environmental feasibility. In some cases, options have to be implemented due to legislative pressure even if they are not found to be economically feasible.

Implementation

- arrange finance
- design
- purchase equipment
- install
- commission

Simple options that require little of no capital investment should be implemented as soon as they are identified

Trainer Note:

The final stage is implementing those options found to be suitable for the company. It must be remembered that simple options that are identified during the course of the assessment phase that are obviously beneficial should be implemented at that time and not only at the end of the feasibility phase.

Maintaining the programme

- set and reassess targets
- evaluate and monitor performance
- once high priority options have been implemented, return to lower priority
- conduct periodic reviews of the programme

Waste minimisation must become entrenched in company policy

Trainer Note:

Maintaining the programme is the most important aspect of waste minimisation. It is not a once-off activity. Those projects that were identified and implemented must be revisited and regular intervals and evaluated to determine if they are still operating the way it was intended. If possible, new targets should be set and the company should strive for best practice. Options that were identified in the assessment phase and were lower on the list of priorities should also be investigated once the top options have been implemented.

What is the purpose of the guide?

To enable the textile industry to become more efficient through minimising wastes and emissions, thereby decreasing costs.

It guides the industry in:

- identifying areas of waste
- constructing mass and energy balances
- identifying suitable waste minimisation options
- determining the feasibility of implementation

Outline of the Guide

- Consists of 2 volumes
  - Volume I : 9 chapters and 8 appendices
  - Volume II : Self-assessment worksheets
- It guides a company through a waste minimisation survey by means of worksheets specifically designed for the textile industry.

Worksheets

- Divided into 5 main sections :
  - Identifying the scope for savings (A)
  - Planning and organisation (B)
  - Pre-assessment (C)
  - Detailed assessment
    - batch processes (D)
    - continuous processes (E)
    - printing (F)
    - kitchens (G)
    - energy (H)
  - Feasibility analysis (I)

Trainers Note:
Some completed worksheets are provided in Volume II to serve as an example as to the methodology of using the guide.

Worksheets A

- aimed at management
- quick reference to savings that can be achieved
- highlight areas for improvement
- determines key performance indicators
- enables benchmarking

Trainers Note:

This first set of worksheets are designed to be used as an indication of the savings in water, energy and caustic that are possible based on best practice figures. Its aim is to show management the benefits of waste minimisation, and, in this way, get them on board for the programme.

Worksheets B

- Planning and Organisation
  - determines commitment to programme
  - establishes project team
  - prepares policy statement
  - identifies goals of survey
  - conducts a SWOT analysis
  - identifies interested and affected parties

Worksheets C

- Pre-assessment:
  - obtains information on:
    - process routes
    - chemicals and dyes
    - sources of wastes
    - cost of wastes
  - identifies areas for further investigation

Worksheets D

- Detailed assessment: **batch processes**
  - used for jigs, jets, yarn etc.
  - obtain information on:
    - recipes
    - production
- guides company in calculating waste produced
- provides suggestions for minimising waste

Worksheets E

- Detailed assessment: **continuous processes**
  - washing, mercerising etc.
  - obtains information on :
    - production, recipes, flows etc.
  - calculates water use, effluent production and energy discharged to drain
  - assigns costs to waste streams
  - identifies suitable waste minimisation options

Worksheets F

- Detailed assessment: **printing**
  - determines:
    - paste wasted from drums, screens and pipes
    - waster used in blanket, screen and drum washing
    - mass of chemicals and dyes on fabric
  - identifies waste minimisation options

Worksheets G

- Detailed assessment: **kitchens**
  - guide to calculating waste from size, dye and print kitchens
  - determines:
    - water used to wash floors and mixing tanks
    - water used to prepare recipes
    - solid waste
    - chemicals and dye to drain
    - waste minimisation options

Worksheets H

- Detailed assessment: **Energy**
  - determines:
    - cost of compressed air
    - wastes due to leaks
    - cost of refrigeration
    - costs of steam generation, distribution and use
    - possible savings through waste minimisation

Worksheets I

- Feasibility analysis
- determines if an option is technically and economically feasible
- calculates capital and operating costs
- calculates savings
- determines payback

How the Guide can help the Textile Industry

- reduced operating and effluent treatment costs
- reduced environmental impact
- compliance with legislation
- aid in complying with ISO 14000

The company will become more efficient and globally competitive