BOOSTING BEST AVAILABLE TECHNIQUES IN THE MEDITERRANEAN PARTNER COUNTRIES
Best Available Techniques (BAT) for the textile industry in Morocco

Study carried out by Istituto di Management - Scuola Superiore di Studi Universitari e di Perfezionamento Sant’Anna (SSSUP, Italy), Moroccan Cleaner Production Center (CMPP, Morocco)

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Chapter 1  Introduction
This chapter clarifies the concept of ‘Best Available Techniques’ and its use/interpretation within the EU legislative framework. It subsequently describes the general framework of this BAT study and addresses, among other things, the main objectives and the working procedure of the study.

Chapter 2  Socio-economic and environmental-legislative framework of the sector
This chapter provides a socio-economic review of the textile sector. Its socio-economic importance is assessed by means of the number and sizes of the companies involved, the employment rate and some financial indicators (turnover, added value, profit, investments). These data allow the economic strength and viability of the sector to be determined, which is important for assessing the viability of the proposed measures. Furthermore, the main legal provisions which apply to the textile industry are listed.

Chapter 3  Process description
This chapter gives a general overview and description of the processes and methods used in the textile sector. For each of the process steps, the associated environmental issues are described. Important sub-processes are dyeing and finishing processes, etc.

Chapter 4  Available environmentally friendly techniques
In this chapter the various measures which are or can be implemented in the textile industry to prevent or reduce the environmental impacts are explained. The available environmentally friendly techniques are discussed considering Dyeing and Finishing processes. This selection could be justified by two main reasons: the environmental relevance of these phases, the characteristics of the Moroccan textile sector composed of many companies belonging to these types of processes.

When needed, technique descriptions are further elaborated on in separate technical data sheets (Annex 2). Vertical, horizontal and general techniques are proposed, all of them are detailed in technical data sheets.

Chapter 5  Selection of the best available techniques
This chapter evaluates the environmentally friendly measures described in chapter 4, with regard to their environmental impact, their technical and their economic viability. The techniques selected, are considered BAT for the sector as a whole.

Chapter 6  Recommendations
In this chapter the value of the BAT report is described and recommendations for the future are elaborated.
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ANNEX 1: PARTICIPANTS TO THE BAT STUDY

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ABSTRACT

The BAT selection in this study was based on plant visits, a literature survey, a technical and socio-economic study, cost calculations, and discussions with industry experts and authorities. The formal consultation was organised by means of an advisory committee (Technical Working Group, TWG).

The Technical Working Group members were selected among experts in the textile field belonging to universities, companies, and public administrations, as well as consultants and independent experts.

In order to carry out this study report, the Scuola Superiore di Studi Universitari e di Perfezionamento Sant’Anna (SSSUP), the Moroccan Cleaner Production Center (CMPP) and the TWG members met together several times during the duration of the project discussing, sharing and approving the content of this Report.

TWG members actively contributed to the writing and the drawing up of this report thanks to their knowledge, experiences and expertise.

This study was carried out thanks to a continuous exchange of data, information, opinions and feedback between all the authors of this document.
CHAPTER 1 INTRODUCTION

1.1 Background of this study: the BAT4MED project

1.1.1 Context

The Mediterranean region represents one of the most vulnerable environments in the world, accounting for 60% of the world’s ‘water-poor’ population and 8.3% of global carbon dioxide emissions. The World Bank has estimated that the annual cost of environmental damage in some countries on the southern and eastern coasts of the Mediterranean is above 3% of gross domestic product each year. Despite the more than 30 years of international efforts to protect the sea, the Mediterranean region nowadays remains fragile and continues to deteriorate. Industrial production processes account for a considerable share of the overall pollution in the region.

To combat this ongoing decline and improve co-ordination among already existing initiatives, in 2005 the Euro-Mediterranean leaders decided to join forces and launch Horizon 2020, an initiative to tackle the top sources of Mediterranean pollution by the year 2020. Against the background of this initiative, the European Commission included in the 2010 ‘Work Programme of the Environment (including climate change)’ theme of the Seventh Research Framework Programme a specific topic serving the aims of Horizon 2020: ‘ENV.2010.3.1.4-1 Integrated Pollution Prevention and Control of industrial emissions in the Mediterranean region’. The topic addressed Mediterranean Partner Countries. It aimed at preparing the ground for the implementation of best available techniques (BAT) to respond to particular health and environmental impacts from industrial emissions, with the overall objective of reducing ‘pollution leakage’ due to the displacement of polluting industries. The BAT4MED project, Boosting Best Available Techniques in the Mediterranean Partner Countries, arises within this context.

Furthermore, the pattern of economic growth of the Mediterranean Partner Countries relies increasingly on the ability of their industrial activities to face up to the competitive challenges of the EU markets. In order to be fully integrated in and have access to the EU market in socially acceptable conditions, the industrial production of the MPCs and the products offered must increasingly comply not only with performance and quality standards, but also with environmental quality requirements. The effectiveness and efficiency of the economic relations and commercial flows in the Mediterranean countries in the near future is going to depend also on the environmental performance that the most significant and strategic industrial sectors in the MPCs will be able to guarantee. BAT4MED arises to respond to the need of the Mediterranean Partner Countries to design new prevention-based environmental control systems that will not affect their necessary economic development.

1 UNEP/Plan Bleu ‘A Sustainable Future for the Mediterranean’ (2006)
Chapter 1

1.1.2 Industrial emissions and best available techniques

The EU countries of the Mediterranean region are combating industrial pollution mainly through implementation of the EU Industrial Emissions Directive (IED), published on December 17, 2010 (Directive 2010/75/EC) and in force since January 6, 2011. This Directive builds among others on the former Directive on Integrated Pollution Prevention and Control (IPPC). The latter Directive introduced a regulatory system with an integrated approach to preventing and controlling the environmental pollution caused by industrial activities covered by this Directive. In essence, the policy requires polluting industrial operators to obtain integrated environmental permits to run their industrial facilities. Such permits are based on the application of best available techniques (BAT), being the most effective techniques to achieve a high level of environmental protection, taking into account the costs and benefits.

The IED defines Best Available Techniques as follows:

‘best available techniques’ means the most effective and advanced stage in the development of activities and their methods of operation which indicates the practical suitability of particular techniques for providing the basis for emission limit values and other permit conditions designed to prevent and, where that is not practicable, to reduce emissions and the impact on the environment as a whole:

(a) ‘techniques’ includes both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned;
(b) ‘available techniques’ means those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator;
(c) ‘best’ means most effective in achieving a high general level of protection of the environment as a whole.

In summary, ‘application of the BAT’ means that each operator subject to the integrated environmental permit obligation has to take all preventive measures that are economically and technically viable for his company to avoid environmental damage.

The concept of BAT also represents a significant business opportunity: the adoption of preventative environmental measures reduces the consumption of natural resources (raw materials, energy, water, etc.), reduces waste streams and increases the efficiency of the production process. This in turn may contribute to the increase in competitiveness of industrial facilities.

In accordance with the IED, the European IPPC Bureau draws up and regularly reviews and updates the so-called BAT reference documents (BREFs) for all industrial sectors subject to the Directive and some relevant ‘horizontal’ issues such as ‘Energy
Chapter 1

efficiency’ or ‘Monitoring’

The aim of this series of documents is to accurately reflect the exchange of information which has taken place on best available techniques, the associated developments in industry and policy as well as the monitoring efforts. It provides reference information for the permitting authority to take into account when determining permit conditions. By providing relevant information concerning best available techniques, these documents act as valuable tools to drive environmental performance.

1.1.3 Main aims of the BAT4MED project

The BAT4MED project aims to assess the possibilities for and impact of dissemination of the EU Integrated Pollution Prevention and Control approach to the Mediterranean Partner Countries (MPCs). It intends to promote and support the implementation of best available techniques in the national environmental programmes. In this way, the project wants to contribute to an overall objective of ensuring a higher level of environmental protection in the Mediterranean region.

1.1.4 Sector-based BAT studies

The current BAT study is drawn up within the framework of work package 3 of the project, which focuses on identifying, assessing and selecting the BAT for pollution prevention and control in two key industrial sectors common in three MPCs (Egypt, Morocco and Tunisia). These key industrial sectors were selected according to their ‘environmental benefit potential’ (EBP) in the MPCs. A previous work package concentrated on determining the EBP per industrial sector and ranking the sectors of the three MPCs according to the EBP methodology developed. This resulted in the following two industrial sectors being selected for further study: the dairy industry and the textiles industry.

When possible, the report focused and considered regional and local conditions to determine the economic and technical viability of available environmentally friendly techniques. Unfortunately, information on local conditions was not always available.

The primary objective of drafting these BAT studies is of a more demonstrative nature: the studies are drawn up in a close cooperation between European institutes with specific knowledge on the EU IPPC implementation processes and Egyptian/Tunisian/Moroccan partners from governments, industry and environmental administrations or institutes. This leads to an exchange of knowledge on the potential use of and the most appropriate procedures for drafting a BAT study, adapted to the specific local situation and needs.

As in the EU, such BAT studies may be used by competent authorities as a basis for adapting their environmental legislation and administrative procedures to the current

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2 The BREFs are available online at http://eippcb.jrc.es/reference/ (in English). A French version of most BREFs can be consulted at http://www.ineris.fr/ippc/node/10.
state of techniques, e.g. for setting emission limit values at sector level or determining permit conditions. They are also particularly relevant for operators, as they allow them to be kept informed of the available environmentally friendly and eco-efficient techniques in their sector and support the decision making process when changes to the production processes or plants are required or considered.

1.2 The BAT study for the Moroccan textile industry

1.2.1 Main aims of the study

The principal objectives of the current study are:

- to map the state of play in the textile industry in Morocco by, amongst other things, providing an overview of the number and kind of enterprises, their main inputs and outputs, their competitiveness and their main environmental impacts;
- to describe the processes applied in Moroccan textile plants, the available environmentally friendly techniques and the associated environmental aspects;
- to select from this list of environmentally friendly techniques the best available techniques, based on an assessment of economic, technical and environmental aspects;
- to provide suggestions for further data gathering and research, in order to improve any future BAT evaluations.

1.2.2 Content of the study

The starting point of this study on the best available techniques for the textile industry is a socio-economic review of the sector (Chapter 2). This forms the basis for determining the economic strength and viability of the sector, which in turn enables assessment of the viability of the measures proposed in Chapter 4.

Subsequently the processes are described in detail and for each process step the environmental impacts are determined (Chapter 3).

In Chapter 4 an inventory is made of environmentally friendly techniques applicable to the textile sector, and based on an extensive literature survey and data from suppliers and plant visits. Next, in chapter 5, each of these techniques is evaluated with respect to its environmental benefit as well as to its technical and economic viability. A cost-benefit analysis allows us to select the Best Available Techniques.

General conclusions, recommendations and an evaluation of the report are discussed in Chapter 6.
1.2.3 Procedure and guidance

As a first step for gaining insight into the local circumstances of the textile industry and the techniques and processes applied, four plants were visited. These plants were selected taking into account their current state of the art in using environmentally friendly techniques and their willingness to participate. Company-specific data was gathered on, among others, consumption and emission levels. By means of checklists based upon the candidate best available techniques identified in the BREF: Textiles Industry and the Flemish BAT study of the textile sector, some initial basic differences between the EU and the Moroccan context, the plants and the processes applied were identified.

Furthermore, relevant available documents (BREFs and BAT national guidelines, expert information, pilot projects, sector publications, available company data etc.) and experts were consulted in order to gather more detailed information on the sector as a whole, the processes and techniques applied and the environmental impact, and to ensure that all relevant background information was taken into account.

To support the data collection and to provide scientific guidance during the study a technical working group (TWG) was set up, composed of government and sector representatives as well as independent technical experts. This working group assembled to discuss content related matters (3 November 2011, 3 April 2012 and 13 November 2012). A list of members of the sector working group and extern experts that participated in this study is supplied in Annex 1. The author has taken the utmost account of the remarks of the sector working group. However, this report is not a compromise text, but is consistent with what the author at this moment considers the state of techniques and the corresponding most appropriate recommendations.
CHAPTER 2 SOCIO-ECONOMIC AND ENVIRONMENTAL-LEGISLATIVE FRAMEWORK OF THE SECTOR

In this chapter the socio-economic and environmental-legislative context of the textile sector is outlined and analysed.

Firstly, it is attempted to describe the industry branch and precisely delimit the subject of the study. Then, a kind of barometric indicator level is determined, based on a number of socio-economic characteristics on the one hand, and an estimation of the viability of the sector on the other hand. A third section depicts the most important environmental-legislative matters for the textile sector.

This socio-economic and legislative framework can be important when evaluating candidate BAT. For example, the effects on different environmental media need to be translated to a single score for global environmental impact (on the environment as a whole). This can be based on different aspects, but given the qualitative approach in this report, one of the possible criteria is, for example, weighting of the different environmental media based on priorities set in legislation, based on environmental quality standards for water, air, etc.

2.1 Description and delimitation of the sector

2.1.1 Delimitation and sub-classification of the sector

The Textile & Leather sector is ranked third in the Moroccan industry after chemical-para-chemical industries and the food industries. It is divided into 3 sub-sectors:

- Leather and footwear
- Clothing and linens
- Textile

The socio-economic analysis of this chapter will concern the activities conducted under ‘textile’ sub-sector, including:

- Production of yarn: Blending, Carding, Spinning, Twisting
- Fabric formation: Weaving and Knitting
- Finishing process includes: Pre-treatment, printing, dyeing including washing and drying
- Clothing manufacturing

Thus, the BAT study for the textile industry will focus on the finishing process including pre-treatment, printing, dyeing and washing as being the most polluting activities of the ‘textile’ sector.
2.1.2 The distribution chain

The positioning of the textile companies in the distribution chain is shown in Figure 1.

![Distribution Chain Diagram]

Figure 1. Positioning of the textiles industry in the distribution chain
2.2 Socio-economic characteristics of the sector

This section describes the status of the sector based on a number of socio-economic indicators. These indicators provide a general overview of the sector structure and form a basis for the estimation of the sector viability in the next paragraph.

The economic aspects of the sector have been established based on the updated economic data published by the Ministry of Trade, Industry and New Technologies, between the years 2007 and 2009.

2.2.1 Number and sizes of the companies

The textile sub-sector occupies a privileged position within the textile and leather sector and includes 520 units divided between large, medium and small companies.

2.2.2 Employment

The textile sector employs nearly 200,000 people in Morocco. This makes it the largest industrial employer in the country with 40% of national industrial employment.

2.2.3 Evolution of turnover, added value and profit

2.2.3.1 Turnover

<table>
<thead>
<tr>
<th>Year</th>
<th>Turnover in thousands of MAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>10,590,551</td>
</tr>
<tr>
<td>2008</td>
<td>10,499,748</td>
</tr>
<tr>
<td>2009</td>
<td>8,763,106</td>
</tr>
</tbody>
</table>

Figure 1. Evolution of turnover
To make a comparison between the turnover of textile sector in Morocco and the turnover of textile sector in an European Country, here below are included the turnover values for Italy. In Italy the textile sector is very important and developed: the turnover was 55.021 million euro in 2007; 54.117 in 2008 and 45.187 in 2009. In the next table these values have been expressed in Moroccan MAD in order to better point out the comparison.

Table 2. The turnover of textile sector in Morocco and in Italy

<table>
<thead>
<tr>
<th>Year</th>
<th>Turnover in thousands of MAD (Morocco)</th>
<th>Turnover in thousands of MAD (Italy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>10,590,551</td>
<td>611,564,311.80</td>
</tr>
<tr>
<td>2008</td>
<td>10,499,748</td>
<td>601,516,254.92</td>
</tr>
<tr>
<td>2009</td>
<td>8,763,106</td>
<td>502,258,347.85</td>
</tr>
</tbody>
</table>

2.2.3.2 **Added value**

Table 3. Added value for the period 2007-2009

<table>
<thead>
<tr>
<th>Year</th>
<th>AV in thousands of MAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>2,931,760</td>
</tr>
<tr>
<td>2008</td>
<td>2,735,731</td>
</tr>
<tr>
<td>2009</td>
<td>2,491,787</td>
</tr>
</tbody>
</table>

2.2.3.3 **Profit**

Not available

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2.2.4 Evolution of the investments

Table 4. Investments for the period 2007-2009

<table>
<thead>
<tr>
<th>Year</th>
<th>Investments in thousands of MAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>1,046,266</td>
</tr>
<tr>
<td>2008</td>
<td>988,361</td>
</tr>
<tr>
<td>2009</td>
<td>366,989</td>
</tr>
</tbody>
</table>

2.2.5 Production and price setting

Textiles production is valued at 8.5 billion MAD for 2009 with -11% compared to 2008.

2.2.6 Conclusion

The textile sector is one of the industries that experienced the most growth at national level during the ’90s. The sector plays a strategic role in the Moroccan economy. Nearly 30% of companies operating in the Moroccan industrial sector, generating 40% of employment and about 30% of Moroccan industrial exports.

2.3 Sector viability

2.3.1 Procedure

The viability of an industry branch is determined by its competitive position on the one hand, and by its financial situation on the other.
2.3.2 Competitive position

2.3.2.1 Aim and approach

An excellent instrument for determining the competitive position of a sector is Michael Porter’s ‘Five Forces’ framework. Michael Porter (1980, 1985) identifies five sources of competition: (i) the entry of new competitors, (ii) the threat of substitutes, (iii) the bargaining power of buyers, (iv) the bargaining power of suppliers, and (v) the rivalry among the existing competitors. The essence of the theory, and the way in which these sources of competition can influence BAT determination, has been described in the BREF Economics and Cross-media Effects.

2.3.2.2 Potential entry of new competitors

In 2012, the Moroccan textile industry is recovering from the effects of global recession, boosting overall exports and boosting growth.

Despite a difficult global economy, including important competition of low-cost Asian exporters, the Moroccan textile and clothing rose 4.4% in 2011, with exports worth $2.6 billion.

Despite a decreasing European market, the first eight months of 2011 were marked by the growth of textile exports to the EU (24.2%).

To address the current crisis and support growth in the sector, more and more companies are gathered under export consortia supported by ‘the export Consortia’ initiative, launched by the Ministry of Foreign Trade, in cooperation with the United Nations Industrial Development Organization (UNIDO) and the Italian Government.

2.3.2.3 Threat of substitutes

No data/information are available.

2.3.2.4 Bargaining power of suppliers

Bargaining power of suppliers may vary regarding supplier position in the production chain. Changing chemicals products suppliers is much easier for companies than changing raw material suppliers strained by change of prices, availability and outsourcer’s abroad (international clients). It is often difficult for companies to explain additional costs to suppliers regarding environmental measures, however, some companies applying dyeing process for export products are more oriented toward greening their supply chain.
2.3.2.5  Bargaining power of buyers

Textile companies have on average a dozen customers. For clothing companies’ customers are varying from 3 to 4 while companies producing individual items may have over 20 customers.

Changing customers is a difficult task especially for the export market; this difficulty is observed less in the local market.
In most cases, it is not possible to explain additional costs to customers, i.e. environmental measures.

2.3.2.6  Rivalry among existing competitors

Collaboration between local companies is especially noticed for denim bleaching and dyeing units.
The rivalry between existing competitors varies depending on the destination of the final products; It concerns the quality of the product for the export market while the rivalry in the local market is based on product prices.

2.3.2.7  General conclusion of the competition analysis

Textile products are mainly for export as Moroccan companies have joint ventures with foreign companies.

China has long offered attractive advantages regarding production costs but seems now less profitable than a few years ago.

For example, producing in China was 40 to 45% less expensive for Spanish textile manufacturers. Recently, the margin is hardly exceeding 15%, against a backdrop of rising production costs.

Geographically closest, Moroccan workshops are proposing to European companies affordable workforce, delivery times limited to 5 or 6 weeks, in some cases, 3 to 4 days, and reduced logistics costs for transportation.

2.3.3  Financial ratios

2.3.3.1  Introduction

For assessing the financial situation of the sector a number of financial ratios can be selected that represent each of the four areas of financial health: profitability, value added, solvability and liquidity. By comparing the ratios of the textiles sector with those of industry as a whole, we get an indication of the relative financial health of a
sector. In case the sector faces acute or structural financial problems, this can be an argument to determine techniques with substantial costs to be unaffordable.

2.3.3.2 Financial ratios for the textile industry

No data are available

2.3.4 Conclusive estimation of the viability of the sector

Textile sector has many assets for its development including:

- **Incentive framework**: A concrete development plan of supply, an incentive system that includes fiscal, financial, legal and social incentives package, a large network of free trade agreements with the European Union, The United States of America and the Arab world, giving access to a market of over one billion consumers.

- **Investment platform**: the Moroccan government provides investors with very favourable industrial investment platforms.

- **Production Reactivity**: Thanks to local producers of raw materials, and the future establishment of procurement platforms, Morocco can reduce time delivery to Europe to two weeks (-50% less time than the normal cycle).

- **Responsiveness Delivery**: A geographical proximity to European markets, a ‘Tangiers Med’ Port which allows the Moroccan textile industry to be more reactive.

- **Large production capacity**: a significant production capacity in the sector, estimated at over one billion pieces per year, an industry that operates for 50 years with European and American markets, training institutions ensuring the continuous improvement skills enabling companies to benefit from a skilled workforce and sharp profiles of designers, stylists and engineers develop a skill that is central to the sector strategy: planned training of 2,000 engineers and 30,000 operators in 2015.

- **Good sector organization**: an organization around a professional association (AMITH) which includes among its members more than 90% of exporting companies in the sector, ease of communication and interaction with contractors and international investors.

- **Social and environmental ethics**: Adoption of the social compliance program ‘Citizen Fibre’ This label distinguishes textile companies - Moroccan clothing complying with regulations relating to human resource management and working conditions.

2.4 Environmental-regulatory aspects

In the next paragraph the environmental-regulatory framework of this BAT study is outlined, primarily focusing on Moroccan legislation.
2.4.1 Moroccan legislation

The following paragraph (non-limitative) lists the environmental legislation, relevant for the textiles industry:

**Law 10-95 on Water** published in 1995 aims to establish a national water policy based on a prospective vision that takes into account both the evolution of resources and other national needs for water. It provides legal provisions for rationalization of water use, the generalization of access to water, inter-regional solidarity; reducing disparities between city and countryside as part of a programme to ensure water security throughout the country.

The 3 decrees below are applied to strengthen Law 10-95 and control water pollution:

- Decree of February 1998 on assessment and collection of fees for the use of water from public domains
- Decree of February 1998 related to water quality standards and inventory of water pollution degree
- Decree of January 2005 on spills, discharges, releases, direct or indirect deposits in surface water or groundwater. This decree defines the limit of water pollution in terms of physicochemical, biological or bacteriological.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Limit of pollution discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD$_5$ mg O$_2$/l</td>
<td>300</td>
</tr>
<tr>
<td>COD mg O$_2$/l</td>
<td>600</td>
</tr>
<tr>
<td>Suspended solids mg/l</td>
<td>250</td>
</tr>
</tbody>
</table>

Table 5. Limits of water pollutants

These discharge limit values are not specific to the textile industry, thus they’re applied for the sector waiting for specific values to be established for textile activities.

**Law 11-03 related to Environmental Protection and Enhancement** published in 2003 aims to enact the basic rules and general principles of national policy in the field of protection and enhancement of the environment. These rules and principles are to:

- Protect the environment against all forms of pollution and degradation the origin
- Improving the living conditions and rights
- Define the basic guidelines of the legislative, technical and financial support for the protection and management of the environment
- Establish a specific regime of liability to provide compensation for damage caused to the environment and compensation for victims.

**Law 12-03 on Environmental Impact Assessments** established in 2003 intended to precede the implementation of certain projects by an assessment of their environmental impacts. It aims therefore to establish a link between environmental
Chapter 2

protection and the decision making process so the environmental criteria are taken into account in this process.

Thus it subjects to EIA all projects that may affect the environment taking into consideration their nature, size or impact on the natural environment.

**Law 13-03 on Air Pollution Control** edited in 2003 aims to prevent and fight against the emission of air pollutants likely to harm human health, wildlife, soil, the climate, cultural heritage and the environment in general. It is applied to any person or legal entity subject to public or private law, owning, holding, using or operating buildings, mining, industrial or commercial facilities, agricultural sites, cottage industry, vehicles, motor equipment, combustion apparatus, waste incineration, heating or cooling.

**Law 28-00 on Waste Management and Disposal** passed in 2006 enacts the rules and principles which constitute the basic framework for the entire chain: collection, transport, disposal and treatment. It establishes a rational, modern and efficient waste management industry that respects the requirements of sustainable development and environmental protection. The main contributions of this law on industrial waste management are:

- The introduction of ‘polluter pays principle’ and shared responsibility between the various stakeholders, according to the type of waste (hazardous waste or not)
- Creating landfills depending on the nature of the waste
- Waste management programmes established in each region and at a national level
- Creation of a national hazardous waste management programme
- Establishing a system of control and detection of infractions for hazardous wastes, household and assimilated and for the transportation of hazardous waste
- Implementation of a tiered financial system of penalties depending on the seriousness of the infractions

**Law 13-09 on Renewable Energies** enacted in 2010, institutes a legal framework providing prospects to implement and operate facilities producing electrical energy from renewable resources. To encourage the development of such facilities, a financial system and incentives are under elaboration.

For the implementation of the mentioned laws, decrees are elaborated by the environmental instances.
2.4.2 European legislation

2.4.2.1 Industrial Emissions Directive

Industrial production processes account for a considerable share of the overall pollution in Europe (for emissions of greenhouse gases and acidifying substances, wastewater emissions and waste).

In order to take further steps to reduce emissions from such installations, the Commission adopted its proposal for a Directive on industrial emissions on 21 December 2007.

This proposal was a recast of 7 existing pieces of legislation and its aim is to achieve significant benefits for the environment and human health by reducing harmful industrial emissions across the EU, in particular through better application of Best Available Techniques. The IED entered into force on 6 January 2011 and has to be transposed into national legislation by Member States by 7 January 2013.

The IED is the successor of the IPPC Directive and in essence, it is about minimising pollution from various industrial sources throughout the European Union. Operators of industrial plants engaged in activities covered by Annex I of the IED are required to obtain an integrated permit from the authorities in EU countries. About 50,000 installations were covered by the IPPC Directive and the IED will cover some new activities which could mean a slight rise in the number of installations.

The IED is based on several principles, namely (1) an integrated approach, (2) best available techniques, (3) flexibility, (4) inspections and (5) public participation.

1. The integrated approach means that the permits must take into account the whole environmental performance of the plant, covering e.g. emissions to air, water and land, waste generation, use of raw materials, energy efficiency, noise, prevention of accidents, and restoration of the site upon closure. The purpose of the Directive is to ensure a high level of protection of the environment taken as a whole. Should the activity involve the use, production or release of relevant hazardous substances, the IED requires operators to prepare a baseline report before starting an operation of an installation or before a permit is updated having regard to the possibility of soil and groundwater contamination, ensuring the integrated approach.

2. The permit conditions including emission limit values (ELVs) must be based on the best available techniques (BAT), as defined in the IPPC Directive. BAT conclusions (documents containing information on the emission levels associated with the best available techniques) shall be the reference for setting permit conditions. To assist the licensing authorities and companies in determining the BAT, the Commission

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4 Source: European Commission – DG Environment: 
organises an exchange of information between experts from the EU Member States, industry and environmental organisations. This work is co-ordinated by the European IPPC Bureau of the Institute for Prospective Technology Studies at the EU Joint Research Centre in Seville (Spain). This results in the adoption and publication by the Commission of the BAT conclusions and BAT Reference Documents (the so-called BREFs). In February 2012, a guidance document was published to lay down rules concerning the collection of data and on the drawing up of BAT reference documents and their quality assurance (2012/119/EU). This guidance was also used as a basis when drawing up these reports.

3. The IED contains certain elements of flexibility by allowing the licensing authorities to set less strict emission limit values in specific cases. Such measures are only applicable where an assessment shows that the achievement of emission levels associated with BAT as described in the BAT conclusions would lead to disproportionately higher costs compared to the environmental benefits due to
   (a) geographical location or the local environmental conditions or
   (b) the technical characteristics of the installation.
The competent authority shall always document the reasons for the application of the flexibility measures in the permit including the result of the cost-benefit assessment.

Moreover, Chapter III on large combustion plants includes certain flexibility instruments (Transitional National Plan, limited lifetime derogation, etc.)

4. The IED contains mandatory requirements on environmental inspections. Member States shall set up a system of environmental inspections and draw up inspection plans accordingly. The IED requires a site visit to take place at least every 1 to 3 years, using risk-based criteria.

5. The Directive ensures that the public has a right to participate in the decision-making process, and to be informed of its consequences, by having access to
   (a) permit applications in order to give opinions,
   (b) permits,
   (c) results of the monitoring of releases and
   (d) the European Pollutant Release and Transfer Register (E-PRTR). In E-PRTR, emission data reported by Member States are made accessible in a public register, which is intended to provide environmental information on major industrial activities. E-PRTR has replaced the previous EU-wide pollutant inventory, the so-called European Pollutant Emission Register (EPER).

A short summary of the IED is also available at the EUROPA website.\(^5\)

2.4.2.2 Urban Waste Water Directive\(^6\)

Directive 91/271/EEC concerns the collection, treatment and discharge of urban waste water and the treatment and discharge of waste water from certain industrial sectors.


\(^6\) http://europa.eu/legislation_summaries/environment/water_protection_management/l28008_en.htm
Its aim is to protect the environment from any adverse effects caused by the discharge of such waters.

Industrial waste water entering collecting systems and the disposal of waste water and sludge from urban waste water treatment plants are subject to regulations and/or specific authorisation by the competent authorities.

The Directive establishes a timetable, which Member States must adhere to, for the provision of collection and treatment systems for urban waste water in agglomerations corresponding to the categories laid down in the Directive. The main deadlines are as follows:

- 31 December 1998: all agglomerations of more than 10,000 ‘population equivalent’ (p.e.) which discharge their effluent into sensitive areas must have a proper collection and treatment system;
- 31 December 2000: all agglomerations of more than 15,000 p.e. which do not discharge their effluent into a sensitive area must have a collection and treatment system which enables them to satisfy the requirements in Table 1 of Annex I;
- 31 December 2005: all agglomerations of between 2,000 and 10,000 p.e. which discharge their effluent into sensitive areas, and all agglomerations of between 2,000 and 15,000 p.e. which do not discharge into such areas must have a collection and treatment system.

Annex II requires Member States to draw up lists of sensitive and less sensitive areas which receive the treated waters. These lists must be updated regularly. The treatment of urban water is to be varied according to the sensitivity of the receiving waters.

The Directive lays down specific requirements for discharges from certain industrial sectors of biodegradable industrial waste water not entering urban waste water treatment plants before discharge to receiving waters.

Member States are responsible for monitoring both discharges from treatment plants and the receiving waters. They must ensure that the competent national authorities publish a situation report every two years. This report must also be sent to the Commission.

Member States must set up national programmes for the implementation of this Directive and must present them to the Commission.

The Directive also provides for temporary derogations.
2.4.2.3  *Emission Trading Scheme (ETS) Directive*[^7]

Launched in 2005 with the Directive 2003/87/EC, the EU ETS is now in its third phase, running from 2013 to 2020. The EU emissions trading scheme (EU ETS) is a cornerstone of the European Union’s policy to combat climate change and its key tool for reducing industrial greenhouse gas emissions cost-effectively.

The EU ETS works on the 'cap and trade' principle. A 'cap', or limit, is set on the total amount of certain greenhouse gases that can be emitted by the factories, power plants and other installations in the system. The cap is reduced over time so that total emissions fall. In 2020, emissions from sectors covered by the EU ETS will be 21% lower than in 2005.

Within the cap, companies receive or buy emission allowances which they can trade with one another as needed. They can also buy limited amounts of international credits from emission-saving projects around the world. The limit on the total number of allowances available ensures that they have a value.

After each year a company must surrender enough allowances to cover all its emissions, otherwise heavy fines are imposed. If a company reduces its emissions, it can keep the spare allowances to cover its future needs or else sell them to another company that is short of allowances. The flexibility that trading brings ensures that emissions are cut where it costs least to do so.

2.4.2.4  *The Waste Framework Directive*[^8]

The Directive 2008/98/EC establishes a legal framework for the treatment of waste within the Community. It aims to protect the environment and human health through the prevention of the harmful effects of waste generation and waste management. It applies to waste other than:

- gaseous effluents;
- radioactive elements;
- decommissioned explosives;
- faecal matter;
- wastewater;
- animal by-products;
- carcasses of animals that have died other than by being slaughtered;
- elements resulting from mineral resources.

In order to better protect the environment, the Member States should take measures for the treatment of their waste in line with the following hierarchy which is listed in order of priority:

[^7]: http://ec.europa.eu/clima/policies/ets/index_en.htm
• prevention;
• preparing for reuse;
• recycling;
• other recovery, notably energy recovery;
• disposal.

Member States can implement legislative measures with a view to reinforcing this waste treatment hierarchy. However, they should ensure that waste management does not endanger human health and is not harmful to the environment.

2.4.2.5 Water protection and management: the Water Framework Directive

With Directive 2000/60/EC the European Union has established a framework for the protection of:
• inland surface waters;
• groundwater;
• transitional waters;
• coastal waters.

This Framework-Directive has a number of objectives, such as preventing and reducing pollution, promoting sustainable water usage, environmental protection, improving aquatic ecosystems and mitigating the effects of floods and droughts.

Its ultimate objective is to achieve ‘good ecological and chemical status’ for all Community waters by 2015.

According to this Directive Member States have to identify all the river basins lying within their national territory and assign them to individual river basin districts. River basins covering the territory of more than one Member State will be assigned to an international river basin district.

Member States are to designate a competent authority for the application of the rules provided for in this Framework-Directive within each river basin district.

2.4.2.6 REACH Regulation: Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals

REACH is the European Community Regulation n. 1907/2006 on chemicals and their safe use. It deals with the Registration, Evaluation, Authorisation and Restriction of Chemical substances. The law entered into force on 1 June 2007.

The aim of REACH is to improve the protection of human health and the environment through the better and earlier identification of the intrinsic properties of chemical

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10 http://ec.europa.eu/environment/chemicals/reach/reach_intro.htm
substances. At the same time, REACH aims to enhance innovation and competitiveness of the EU chemicals industry. The benefits of the REACH system will come gradually, as more and more substances are phased into REACH.

The REACH Regulation places greater responsibility on industry to manage the risks from chemicals and to provide safety information on the substances. Manufacturers and importers are required to gather information on the properties of their chemical substances, which will allow their safe handling, and to register the information in a central database run by the European Chemicals Agency (ECHA) in Helsinki. The Agency acts as the central point in the REACH system: it manages the databases necessary to operate the system, co-ordinates the in-depth evaluation of suspicious chemicals and is building up a public database in which consumers and professionals can find hazard information.

The Regulation also calls for the progressive substitution of the most dangerous chemicals when suitable alternatives have been identified.
CHAPTER 3 PROCESS DESCRIPTION

In this chapter, the processes that are characteristic for the textile industry are described and their environmental impact is assessed.

The description aims at providing a general overview of the applied process steps and their environmental impacts. This serves as a background for listing the environmentally friendly techniques which could be adopted to reduce the sector’s environmental impact (chapter 4).

The process details and the sequence of the different process steps, in practice may vary from company to company. Not all possible process variants can be outlined in this chapter. Moreover, the true processes might be somewhat more complex than described herein.

This chapter in no way aims at judging whether certain process steps are BAT or not. Consequently, the fact that a process is or is not mentioned in this chapter, does not imply that the process is or is not considered a BAT.
3.1 Processes for the industry

3.1.1 Production of yarn

Textile fibres are converted into yarn by grouping and twisting operations used to bind them together. The processes leading to spinning vary depending on whether the fibres are natural or synthetic. These fibres go through a series of preparation steps before they can be spun into yarn, including opening, blending, carding, combing, and drafting.

We note that some of these steps may be optional depending on the type of yarn and spinning equipment used (natural fibres such as cotton and wool, synthetic fibres).

The main steps used to form yarn are summarized and illustrated in the following figure.

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Figure 4. The yarn process
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**Blending** operation consist into combining fibres of different origins, length, thickness, or colour is performed to impart such desirable characteristics as strength or durability, to reduce cost by combining expensive fibres with less costly types, or to achieve special colour or texture effects.

**Carding** aims to separate individual fibres, causing many of them to lie parallel and removing most of the remaining impurities. Cotton, wool, waste silk, and man-made staple are subjected to carding. Carding produces a thin sheet of uniform thickness that is then condensed to form a thick, continuous, untwisted strand. When very fine yarns are desired, carding is followed by combing, a process that removes short fibres, leaving a sliver composed entirely of long fibres, all laid parallel and smoother and more lustrous than uncombed types.

**Spinning** is a process of drawing out fibres from a mass and twisting them together to form a continuous thread or yarn. Common industrial spinning techniques include ring spinning, open-end (rotor) spinning, and air-jet spinning.

**Twisting**, in yarn production, binds fibres or yarns together in a continuous strand, accomplished in spinning or playing operations. The direction of the twist may be to the right, described as Z twist, or to the left, described as S twist. Single yarn is formed by twisting fibres or filaments in one direction.

### 3.1.2 Fabric formation

The major methods for fabric manufacture are weaving and knitting. Fabrics are formed from weaving by interlacing one set of yarns with another and formed from knitting by using hooked needles to interlock one or more sets of yarns through a set of loops.

The figure below shows fabric formation processes for flat fabrics, such as sheets and apparel.
3.1.3 Finishing process

This operation helps to enhance the appearance, durability, and serviceability of fabrics by converting unfinished goods (woven, knit) into finished consumer goods through several water-intensive finishing process stages.

These stages, shown in the figure below, involve treating goods with chemical baths (preparation, dyeing, printing and finishing) and often require additional washing, rinsing, and drying steps.

We note that some of these steps are optional depending on the style of fabric being manufactured.
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Figure 6. The finishing process

**Desizing** is the process of removing the size material from the warp yarns in woven fabrics. It can be done by many ways such as acid steep, rot steep, enzymatic, etc. Desizing, irrespective of what the desizing agent is, involves impregnation of the fabric with the desizing agent, allowing the desizing agent to degrade or solubilise the size material, and finally to wash out the degradation products. Sizing agents are selected on the basis of type of fabric, environmental friendliness, ease of removal, cost considerations, effluent treatment, etc.

The enzymatic desizing is dominating because of their eco-friendliness and also because of its characteristics that is it acts at specific sites only at definite pH, temperature and concentration. Starch is used mainly as the ingredient in desizing. **Scouring** removes substances that have adhered to the fibre during production of the yarn or fabric, such as dirt, oils, and any sizing or lint applied to warp yarns to facilitate weaving.
Bleaching is a process of whitening fabric by removal of natural colour, such as the tan of linen, is usually carried out by means of chemicals selected according to the chemical composition of the fibre. Chemical bleaching is usually accomplished by oxidation, destroying colour by the application of oxygen, or by reduction, removing colour by hydrogenation. Cotton and other cellulosic fibres are usually treated with heated alkaline hydrogen peroxide; wool and other animal fibres are subjected to such acidic reducing agents as gaseous sulphur dioxide or to such mildly alkaline oxidizing agents as hydrogen peroxide. Synthetic fibres, when they require bleaching, may be treated with either oxidizing or reducing agents, depending upon their chemical composition. Cottons are frequently scoured and bleached by a continuous system.

Mercerization is the chemical treatment applied to cotton fibres or fabrics to permanently impart a greater affinity for dyes and various chemical finishes. Mercerizing also gives cotton cloth increased tensile strength, greater absorptive properties, and, usually, a high degree of lustre, depending on the method used. The treatment consists of immersing the yarn or fibre in a solution of sodium hydroxide (caustic soda) for short periods of time, usually less than four minutes. The material is then treated with water or acid to neutralize the sodium hydroxide.

Dyeing of a textile fibre is carried out in a solution, generally aqueous, known as the dye liquor or dye bath. The dye must not fade rapidly on exposure to light. The process of attachment of the dye molecule to the fibre is one of absorption; that is, the dye molecules concentrate on the fibre surface.

Printing is the process of decorating textile fabrics by application of pigments, dyes, or other related materials in the form of patterns. The four main methods of textile printing are block, roller, screen, and heat transfer printing. In each of these methods, the application of the colour, usually as a thickened paste, is followed by fixation, usually by steaming or heating, and then removal of excess colour by washing. Printing styles are classified as direct, discharge, or resist.

Finishing includes all the mechanical and chemical processes employed to improve the acceptability of the product. The objective of the various finishing processes is to make fabric from the loom or knitting frame more acceptable to the consumer. Finishing processes include preparatory treatments used before additional treatment, such as bleaching prior to dyeing; treatments, such as glazing, to enhance appearance; sizing, affecting touch; and treatments adding properties to enhance performance, such as preshrinking.

3.1.4 Jeans washing

Jeans washing is an operation that removes part of the indigo dye used to dye cotton jeans.

This operation is performed at a temperature of almost 60°C with pumice stone or enzymes with the addition of auxiliary products.

Water used for washing jeans requires a slight softening and heating.

Two types of jeans washing are used:
Chemical washing:

- **Bleaching**: in the process a strong oxidative bleaching agent like sodium hypochlorite or KMnO₄ is added during the washing with or without stone addition. The discoloration produced is usually more apparent depending on the strength of the bleach liquor quality, temperature and treatment time. It is preferable to have strong bleach with short treatment time.

- **Enzyme wash**: an environmentally friendly wash. It involves the application of organic enzymes that eat away at the fabric, i.e. the cellulose. When the desired colour is achieved, the enzyme can be stopped by changing the alkalinity of the bath or its temperature. Post treatment includes final ringing and softening cycle.

- **Acid wash**: It is done by tumbling the garments with pumice stones pre-soaked in a solution of sodium hypochlorite or potassium permanganate for localized bleaching resulting in a non-uniform sharp blue/white contrast. In this wash the colour contrast of the jeans fabric can be enhanced by optical brightening. The advantage of this process is that it saves water as addition of water is not required.

Mechanical washing:

- **Stone wash**: In the process of stone washing, freshly dyed jeans are loaded into large washing machines and tumbled with pumice stone or volcanic rock to achieve a soft hand and desirable look. Variations in composition, hardness, size, shape and porosity make these stones multifunctional. The process is quite expensive and requires high capital investment. Pumice stone give the additional effect of a faded or worn look as it abrades the surface of the jeans like sandpaper, removing some dye particles from the surfaces of the yarn.

- **Micro sanding**: A fabric finishing process in which fabrics are sanded (real sandpaper) to make the surface soft without hair. Can be performed before or after dyeing. In this fabric treatment process, a series of cylindrical rolls in a horizontal arrangement, either wrapped with an abrasive paper or chemically coated with an abrasive are used to create a soft, sueded hand. The jeans are pulled over the face of the sand rollers creating a raised surface finishing. Some colour reduction is experienced.
3.2 Environmental impact of the textile processes

3.2.1 Water use

Water is used for washing and cleaning activities and steam generation.

In order to give some quantitative information on water use, here are included data on two Moroccan textile companies that were audited during the BAT4MED project.

Performance indicators on water use were also calculated.

The data included in Table 6 are only an example of the amount of water use generated by companies. For this reason, this information does not constitute a sampling that shows an overview of the sector on this aspect.
Chapter 3

Table 3. Example of water use of textile Moroccan companies

<table>
<thead>
<tr>
<th>Company</th>
<th>Sources of water</th>
<th>Water use</th>
<th>Amount used m³/year</th>
<th>Yearly production (kg)</th>
<th>Performance indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Textile company n. 1</td>
<td>Tap water</td>
<td>Knitting, pre-treatment, dyeing, washing and drying</td>
<td>Tap water: 600</td>
<td>135,000</td>
<td>1.09 m³/kg</td>
</tr>
<tr>
<td></td>
<td>Ground water</td>
<td></td>
<td>Ground water: 146,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Textile company n. 2</td>
<td>Tap water</td>
<td>Pre-treatment, printing, dyeing, washing and drying,</td>
<td>2,400-3,000</td>
<td>170,000</td>
<td>0.01-0.02 m³/kg</td>
</tr>
</tbody>
</table>

3.2.2 Wastewater

The wastewater emissions generated by the textile industry include cleaning water, process water, cooling water, and water generated by steam production. The amount of water used varies widely, depending on the specific processes operated and the production capacity.

For example, the average annual wastewater flow of a company producing 135t of finished items is about 105,800 m³.

In order to give some additional information on wastewater flows, here is included data on a Moroccan textile company that was audited during the BAT4MED project. The data included in Table 7 are only an example of the amount of wastewater generated by a company. For this reason, this information does not constitute a sampling that shows an overview of the sector on this aspect.

The following data is referred for 3,200,000 items per year:

Table 4. Example of wastewater generated by a Moroccan textile company

<table>
<thead>
<tr>
<th>Process step</th>
<th>Quantities generated annually</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dying, reverse osmosis effluent</td>
<td>99,000 m³/year (1/3 reverse osmosis effluent)</td>
</tr>
<tr>
<td>Washing</td>
<td>6,800 m³/year</td>
</tr>
</tbody>
</table>

The large volumes of wastewater generated by the process are generated by the operations:

**Desizing**: it is one of the largest sources of wastewater pollutants. In this process, large quantities of sizing agents used in weaving processes are discharged

**Pre-treatment**: generate wastewater containing natural and synthetic polymers and a range of other potentially toxic substances. Pollution from bleaching is not a major
concern. In most cases, scouring removes impurities in the fibres, so the only by-product of the peroxide reaction is water.

**Dyeing:** This operation generates a large portion of the effluents. The primary source of wastewater in dyeing operations is spent dye bath and wash water. Such wastewater contains by-products, residual dye, and auxiliary chemicals. Additional pollutants include cleaning solvents.

The wastewaters are characterized by the following:
- High temperature
- traces of chemicals
- coloration aspects due to dyes from printing and dyeing operations
- important concentration of salt, thus, a high pH

The effluents emitted during textiles process are the following:

<table>
<thead>
<tr>
<th>Process</th>
<th>Wastewater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibre preparation</td>
<td>Almost no wastewater generated</td>
</tr>
<tr>
<td>Yarn spinning</td>
<td>Almost no wastewater generated</td>
</tr>
<tr>
<td>Weaving</td>
<td>Almost no wastewater generated</td>
</tr>
<tr>
<td>Knitting</td>
<td>Almost no wastewater generated</td>
</tr>
<tr>
<td>Desizing</td>
<td>BOD from water-soluble sizes; synthetic size; lubricants; biocides; anti-static compounds</td>
</tr>
<tr>
<td>Scouring</td>
<td>Disinfectants and insecticide residues; NaOH; detergents, oils; lubricants; spent solvents</td>
</tr>
<tr>
<td>Bleaching</td>
<td>Hydrogen peroxide, sodium silicate or organic stabilizer; high pH</td>
</tr>
<tr>
<td>Mercerizing</td>
<td>High pH; NaOH</td>
</tr>
<tr>
<td>Dyeing</td>
<td>Metals; salt; surfactants; toxics; organic processing assistants; cationic materials; colour; BOD; COD; acidity/alkalinity and other chemicals</td>
</tr>
<tr>
<td>Printing</td>
<td>Suspended solids; colour; metals; heat; BOD</td>
</tr>
<tr>
<td>Finishing</td>
<td>BOD; COD; suspended solids; toxics; and other chemicals</td>
</tr>
<tr>
<td>Product fabrication</td>
<td>Almost no wastewater generated</td>
</tr>
</tbody>
</table>
3.2.3 Solid wastes

Solid wastes include fabric and yarn scraps, yarn, fabric and packaging waste.

Cutting room waste generates a high volume of fabric scraps that can be reduced by increasing fabric utilization efficiency in cutting and sewing.

The wastes generated during textiles process are:

<table>
<thead>
<tr>
<th>Process</th>
<th>Solid waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibre preparation</td>
<td>Fibres and packaging</td>
</tr>
<tr>
<td>Yarn spinning</td>
<td>Packaging wastes; sized yarn, cleaning and processing waste</td>
</tr>
<tr>
<td>Weaving</td>
<td>Packaging, yarn and fabric scrape, used oil</td>
</tr>
<tr>
<td>Knitting</td>
<td>Packaging, yarn and fabric scrape</td>
</tr>
<tr>
<td>Desizing</td>
<td>Packaging, yarn waste, cleaning materials, maintenance wastes containing solvents</td>
</tr>
<tr>
<td>Scouring</td>
<td>Little or no residual waste generated</td>
</tr>
<tr>
<td>Finishing</td>
<td>Fabric scraps, packaging waste</td>
</tr>
<tr>
<td>Product fabrication</td>
<td>Fabric scraps</td>
</tr>
</tbody>
</table>

Depending on the textile process, the nature of solid waste may differ. However, it is important to distinguish between textile specific and non-specific waste.

<table>
<thead>
<tr>
<th>Textile specific waste</th>
<th>Textile non-specific waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton dust</td>
<td>Packaging waste: paper &amp; cardboards, plastic, metal</td>
</tr>
<tr>
<td>Yarn scraps</td>
<td>Solvents</td>
</tr>
<tr>
<td>Fabric scraps</td>
<td>Used oil</td>
</tr>
<tr>
<td>Printing paste waste</td>
<td>Electrical and Electronic Equipment Waste</td>
</tr>
<tr>
<td>Chemicals packaging waste (dyestuffs, pigments, auxiliary products...)</td>
<td></td>
</tr>
<tr>
<td>Chemical residues (dyes, pigments and auxiliary products)</td>
<td></td>
</tr>
</tbody>
</table>
3.2.4 Air emissions

Textile operations involve numerous sources of air emissions. Operations that represent the greatest concern are weaving, knitting, finishing, and dyeing operations.

Textile usually generates nitrogen and sulphur oxides from boilers and they’re often classified as major pollution sources.

Air emissions emitted by the process are as follows:

<table>
<thead>
<tr>
<th>Process</th>
<th>Air emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibre preparation</td>
<td>Almost no air emissions generated</td>
</tr>
<tr>
<td>Yarn spinning</td>
<td>Almost no air emissions generated</td>
</tr>
<tr>
<td>Weaving</td>
<td>Almost no air emissions generated</td>
</tr>
<tr>
<td>Knitting</td>
<td>Almost no air emissions generated</td>
</tr>
<tr>
<td>Desizing</td>
<td>Vocs</td>
</tr>
<tr>
<td>Scouring</td>
<td>Vocs</td>
</tr>
<tr>
<td>Bleaching</td>
<td>Almost no air emissions generated</td>
</tr>
<tr>
<td>Mercerizing</td>
<td>Almost no air emissions generated</td>
</tr>
<tr>
<td>Dyeing</td>
<td>Vocs</td>
</tr>
<tr>
<td>Printing</td>
<td>Solvents, combustion gases;</td>
</tr>
<tr>
<td>Finishing</td>
<td>Vocs</td>
</tr>
<tr>
<td>Product fabrication</td>
<td>Almost no air emissions generated</td>
</tr>
</tbody>
</table>

3.2.5 Energy consumption

Energy is basically related to:

- Electricity consumption, as a common power source for machinery, cooling and temperature control systems, lighting, office equipment, etc.,
- Thermal energy generated by fuel consumption for steam production by boilers,

Energy consumption is relatively high in the fields of dyeing and finishing, fibre production, spinning, weaving and clothing manufacturing.
As in paragraph 3.2.1 data on an audited Moroccan textile company were included as an example, also in this case data on energy use in two audited Moroccan textile companies are included.

Performance indicators on energy consumption were also calculated.

The additional information represents an example of the energy use of textile companies. For this reason, this information does not constitute a sampling that shows an overview of the sector on this aspect.

**Table 5. Example of energy use of two textile Moroccan companies**

<table>
<thead>
<tr>
<th>Company</th>
<th>Electricity kWh/y</th>
<th>Fuel oil kg/y</th>
<th>Yearly production (kg)</th>
<th>Performance indicator: electricity/production</th>
<th>Performance indicator: fuel oil/production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company n. 1</td>
<td>2,282,000</td>
<td>1,056,000</td>
<td>135,000</td>
<td>16.90 kWh/kg</td>
<td>7.82 kg/kg</td>
</tr>
<tr>
<td>Company n. 2</td>
<td>11,000,000</td>
<td>1,500,000</td>
<td>170,000</td>
<td>64.67 kWh/kg</td>
<td>8.82 kg/kg</td>
</tr>
</tbody>
</table>

The use of renewable energy sources is not common, though; energy cost (MAD/kWh) in Morocco is higher comparing to Tunisia for example. Most companies are aware of this fact, some companies achieved improvements to reduce their energy consumption and be more competitive. Some implemented actions concern:

- Improvement of electric power factor to decrease electricity bill
- Optimization of lighting: replacement of incandescent lamps with fluorescent energy saving lamps
- Installation of speed variators on air compressors
- Insulation of hot surfaces: steam pipes and valves
- Recovery of steam condensate and adjustment of burners for optimal combustion, etc.

In northern Morocco (area of Tangiers and Tetouan), some textile companies are switching to biomass boilers using pomace as an alternative energy source instead of fuel or propane. This action reduces significantly the thermal energy annual bill.
In this chapter the various measures and techniques which can be implemented in the textile industry to reduce or even better to prevent environmental nuisance are described. These environmentally friendly techniques are called “candidate BAT”. The focus of the BAT sector report at hand, and thus the candidate BAT, is on specific processes: pretreatment and dyeing processes. This selection could be justified by two main reasons: the environmental relevance of these phases and the characteristics of the Moroccan textile sector composed of many companies using these types of processes. The candidates BAT are discussed per thematic aspect. For each candidate BAT the following aspects are addressed (based on the guidance 2012/119/EU, and adjusted according to needs in this report):
- description of the technique;
- applicability;
- achieved environmental benefits (Cross-media effects included);
- economics, to determine economic viability;
- driving force (s) for implementation;
- reference literature.

The candidate BAT were identified via intensive literature survey, technical audits, discussions with operators, (con) federations, industry experts and representatives of authorities participating in the TWG.

This chapter concentrates on local issues. A more extensive description of each of the candidate BAT is available on http://www.bat4med.org, in the form of technical data sheets.

The techniques of the database have a more detailed description with respect to those included in the BAT report. Moreover, the database is available in English and French language.

This chapter’s information forms the basis for the BAT evaluation of chapter 5. Consequently, in this chapter it is not intended to decide whether or not a certain technique can be considered a BAT. The fact that a technique is discussed in this chapter, in other words, does not necessarily mean that the technique is a BAT. In this chapter, each technique will be discussed without prejudging whether it meets all the BAT criteria.
4.1 Techniques for textile sector

This Chapter provides a description of the environmentally friendly techniques that can be implemented in the textile sector. Before starting the description of the techniques, it is necessary to clarify some issues.

Firstly it is important to consider that this chapter doesn’t represent an exhaustive list of techniques that can improve the environmental performance of the textile sector. This chapter contains only a summary of some techniques collected and selected from various sources (such as the textile BREF, scientific articles, international projects, and EU technical reports) by the partners of the BAT4MED project. For the consultation of a larger collection of environmental techniques the readers are invited to consult the database developed during the BAT4MED project (www.bat4med.org).

Secondly this chapter contains the techniques linked to specific processes of the textile industry. During the project, the Technical Working Group (TWG) (Moroccan experts from the textile sector) decided to focus on processes for (or linked to) pretreatment and dyeing. This is justified by two main reasons: the high environmental relevance of these processes and the large number of companies in Morocco using them.

Finally this chapter’s information forms the basis for the BAT evaluation of chapter 5. Consequently, in this chapter it is not intended to decide whether or not a certain technique can be considered a BAT. The fact that a technique is discussed in this chapter, in other words. does not necessarily mean that the technique is a BAT.

It should be pointed out that using a BREF approach, techniques with a limited technical applicability, can be considered ‘emerging techniques’.

In this chapter the techniques will be discussed according to a specific classification in classes and sub-classes decided by the mentioned TWG.
Figure 8. Green indicates the processes selected by the Moroccan Technical Working Group Members

In the table below the names of the techniques that will be described in this chapter and their classification are summarized.
### Table 6. Classification of techniques analysed in chapter 4

<table>
<thead>
<tr>
<th>Processes</th>
<th>Sub-classes</th>
<th>Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sizing</td>
<td>Recovery of sizing agents by ultrafiltration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Selection of sizing agents with improved environmental performance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Use of techniques that allow reduced load of sizing agents on the fibre (compact spinning)</td>
</tr>
<tr>
<td></td>
<td>Desizing</td>
<td>Minimizing sizing agent add-on by pre-wetting the warp yarns</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Application of the oxidative route for efficient, universal size removal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Omitting the use of detergents in after washing of cotton dyed with reactive dyes</td>
</tr>
<tr>
<td></td>
<td>Mercerising (and caustification)</td>
<td>Recovery of alkali from mercerizing</td>
</tr>
<tr>
<td></td>
<td>Pre-treatment</td>
<td>Minimizing consumption of complexing agents in hydrogen peroxide bleaching</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dry bleaching using ozone instead of wet washing using chlorine or hydrogen peroxide</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Substitution for sodium hypochlorite and chlorine-containing compounds in bleaching operations</td>
</tr>
<tr>
<td></td>
<td>Bleaching</td>
<td>One-step desizing, scouring and bleaching of cotton fabric</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Optimization of cotton warp yarn pre-treatment</td>
</tr>
<tr>
<td></td>
<td>Other measures</td>
<td>Man-made fibre preparation agents with improved environmental performance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Selection of biodegradable/bio eliminable complexing agents in pre-treatment and dyeing processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bacterial cellulose production from cotton-based waste textiles: Enzymatic saccharification enhanced by ionic liquid pre-treatment</td>
</tr>
<tr>
<td></td>
<td>Efficient measures in dyeing</td>
<td>Alternative process for continuous (and semi continuous) dyeing of cellulosic fabric with reactive dyes</td>
</tr>
<tr>
<td></td>
<td>process</td>
<td>Minimization of dye liquor losses in pad dyeing techniques</td>
</tr>
<tr>
<td></td>
<td></td>
<td>After treatment in PES dyeing.</td>
</tr>
<tr>
<td></td>
<td>Dyeing</td>
<td>Airflow jet dyeing machines with the use of air, either in addition to or instead of water and Soft-flow dyeing machines with no contact between the bath and the fabric</td>
</tr>
<tr>
<td></td>
<td>Use of less pollutant dyes</td>
<td>Direct re-use of dye baths and auto-control of the process online</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Equipment optimisation in batch dyeing.</td>
</tr>
<tr>
<td></td>
<td>Other measures</td>
<td>Dispersing agents with higher bio eliminability in dye formulations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dyeing with sulphur dyes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Silicate-free fixation method for cold pad batch dyeing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exhaust dyeing of cellulosic fibres with high-fixation polyfunctional reactive dyestuffs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exhaust dyeing with low-salt reactive dyes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dyeing without water and chemicals</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pH-controlled dyeing techniques.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adoption of an enzymatic treatment to remove the non-fixed dyestuff not only from the fibre, but also from the exhausted dye bath</td>
</tr>
</tbody>
</table>
## Chapter 4

### Processes

<table>
<thead>
<tr>
<th>Sub-classes</th>
<th>Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaust dyeing of polyester and polyester blends with carrier-free dyeing techniques or with use of environmentally optimised carriers</td>
<td>Use of non-carrier dyeable PES fibres</td>
</tr>
<tr>
<td>Treatment of mixed wastewater with about 60% water recycling</td>
<td></td>
</tr>
<tr>
<td>Recycling of textile wastewater by treatment of selected streams with membrane techniques</td>
<td></td>
</tr>
<tr>
<td>Application of physical-chemical processes and cross-flow filtration</td>
<td></td>
</tr>
<tr>
<td>Water purification tertiary treatment using photo-oxidation</td>
<td></td>
</tr>
<tr>
<td>Purification of industrial and mixed wastewater by combined membrane filtration and sonochemical technologies</td>
<td></td>
</tr>
<tr>
<td>Appropriately treat industrial wastewater by implementing a combination of suitable waste purification techniques</td>
<td></td>
</tr>
<tr>
<td>Removal of disperse dyes from textile wastewater using bio-sludge</td>
<td></td>
</tr>
<tr>
<td>Anaerobic degradation of textile dye bath effluent using Halomonas sp</td>
<td></td>
</tr>
<tr>
<td>Colour removal of dyes from synthetic and real textile wastewater in one- and two-stage anaerobic systems</td>
<td></td>
</tr>
<tr>
<td>Integrating photobiological hydrogen production with dye-metal bio removal from simulated textile wastewater</td>
<td></td>
</tr>
<tr>
<td>Textiles wastewater treatment using anoxic filter bed and biological wriggle bed-ozone biological aerated filter</td>
<td></td>
</tr>
<tr>
<td>Evaluation of the efficacy of a bacterial consortium for the removal of colour, reduction of heavy metals, and toxicity from textile dye effluent</td>
<td></td>
</tr>
<tr>
<td>Biosorption of reactive dye from textile wastewater by non-viable biomass of Aspergillus niger and Spirogyra sp</td>
<td></td>
</tr>
<tr>
<td>Use of Chlorella vulgaris for bioremediation of textile wastewater</td>
<td></td>
</tr>
<tr>
<td>Chemical coagulation/flocculation technologies for removal of colour from textile wastewaters</td>
<td></td>
</tr>
<tr>
<td>Up flow anaerobic sludge blanket reactor in removal of colour and reduction of COD in real textile wastewater</td>
<td></td>
</tr>
<tr>
<td>Potential of combined fungal and bacterial treatment for colour removal in textile wastewater</td>
<td></td>
</tr>
<tr>
<td>Electrochemical oxidation for the treatment of textile industry wastewater</td>
<td></td>
</tr>
<tr>
<td>Removal of reactive dyes from wastewater by adsorption on coir pith activated carbon</td>
<td></td>
</tr>
<tr>
<td>Utilization of modified silk cotton hull waste as an adsorbent for the removal of textile dye (reactive blue MR) from aqueous solution</td>
<td></td>
</tr>
<tr>
<td>Biological and oxidative treatment of cotton textile dye-bath effluents by fixed and fluidized bed reactors</td>
<td></td>
</tr>
<tr>
<td>Biosorption of anionic textile dyes by nonviable biomass of fungi and yeast</td>
<td></td>
</tr>
<tr>
<td>Oxidation techniques (thermal incineration, catalytic incineration), Condensation techniques (e.g. heat exchangers), Absorption techniques (e.g. wet scrubbers), Particulates separation techniques (e.g. electrostatic precipitators, cyclones, fabric filters), Adsorption techniques (e.g. activated carbon adsorption)</td>
<td></td>
</tr>
</tbody>
</table>

---

51
4.2 Pre-treatment process

This paragraph discusses some pretreatment process techniques.
A sub-paragraph is included on pretreatment processes, and in particular:

- Sizing
- Desizing
- Scouring
- Washing
- Mercerising (and caustification)
- Bleaching
- Integrated measures in the pre treatment
- Other measures

4.2.1 Sizing

Sizing is a phase of the pretreatment process. With the scope to lubricate and protect the warp yarn during the weaving phase, sizing agents (in the form of water solutions or water dispersions) are applied after warping.

4.2.1.1 Ref. Datasheet 2.C.1: Recovery of sizing agents by ultra-filtration

a. Description of the technique
Sizing agents protect the warp yarn during the weaving process and should be eliminated during textile pre-treatment. Water-soluble synthetic agents can be recovered from washing liquor by ultrafiltration. The washing liquor is pumped under pressure through diaphragms in the UF method. The far smaller molecules of the washing water pass through the diaphragms, while the macromolecules of the size are held back in the process. Thus, the separation of the size substance and water occurs. After the ultrafiltration, the recovered sizing agent can be reused for sizing. The washing water is returned to the washing process, thus forming a closed recycling cycle that enables the textile mill to eliminate most of the sizing agent out of the wastewater. As regards recycling operation, the sizing agent should not exhibit any change in its structure during the desizing process. Size recovery and reuse can only be possible with the sizing agents that can be desized without any viscosity loss from the woven fabric. The sizing agents should be resistant to the mechanical and thermal stresses of the recovery process. Heat stability deserves particular attention for recycling of sizing agents because the molecules of the sizing agents are exposed to temperatures of 80°C or more for a relatively long time in the vat and in the dryer of the storage tanks before and after the UF. When mixed sizes are recovered, it should be ensured that the components are readily compatible and have approximately the same solubility.

b. Applicability, operational data and driving force for implementation
This technique could be followed only for some kind of sizing agents: water-soluble synthetic sizing agents such as PVA, polyacrylates and carboxymethyl cellulose. The
recovery of sizing agents requires some particular conditions: stock and recovered size should be maintained under sterile conditions when stored and mixed with virgin size. There are some limits in the application of this technique. They can depend for example by the fact that auxiliaries applied to the yarn are not only sizing agents, but also waxes, antistatic agents, etc. Other limitations can be found when the same concentrate is re-used for different kind of yarns. The minting effect can only be realized with non-desized fabric. For these reasons, re-use of the concentrate is typically applied in integrated companies with uniform production. Another problem to consider is the transport distances. Long-distance shipments determine negative environmental effects.

Fibres should be removed before ultrafiltration. The objective of this phase is to minimize scaling and fouling. The operation and management of ultrafiltration units for recovery of sizing agents requires both skilled staff with and appropriate maintenance.

The positive effects on wastewater and the costs reduction are the main driving forces to implement this technique.

The first plant for recovery of polyvinyl alcohol went into operation in 1975 in the USA. Meanwhile there are two plants that have been in operation in Germany for many years and various plants are now in operation in Brazil, Taiwan and USA.

c. Environmental benefit

The main environmental advantage deriving from this technique is the reduction of wastewater pollution. COD of wastewater from finishers of woven fabric is reduced. About the 80-85% of sizing agents could be recovered. Moreover the energy consumption is reduced and also the quantity of sludge to be disposed. The technique allows the reduction of organic load from textile mills.

d. Economic aspects

Many aspects should be considered: the cost of ultrafiltration, the recipe and overall process and treatment costs. Synthetic sizing agents are more expensive than starch-based sizing agents. Other savings could derive by the higher weaving efficiency and the reduced cost of pre-treatment and wastewater treatment.

In Morocco this technique requires high investment and high maintenance costs. For this reason, the financial help of State or international agencies could be necessary.

e. Reference literature


4.2.1.2 Ref. Datasheet 3.D.1: Selection of sizing agents with improved environmental performance

a. Description of the technique

Techniques such as pre-wetting and a targeted selection of sizing agents may contribute significantly to the reduction of the environmental impact of the sizing phase.

Environmentally optimised sizing agents should be:

- highly efficient with low add-on
- completely and easily removed from the fabric
• readily biodegradable or bioeliminable
Modified starches, some galactomannans, polyvinyl alcohol, some polyacrylates and latest generation-polyacrylates satisfy this requirement. These high efficiency synthetic sizes allow a reduction in size add-on without any decline in weaving efficiency. New generation-polyacrylates are easy to wash out and can be removed with little water and without additional auxiliaries. Except for filament polyester and some specific treatment (cotton) they can be applied as almost universal sizing agents for all kinds of fibres.

b. **Applicability, operational data and driving force for implementation**
The application of optimised sizing recipes is technically usable for all sizing departments but it is difficult for commission finishers to influence the up-stream weaving and, in general, for non-integrated mills. Modified starches can be removed with water (less easy than modified polyacrylates), without need for enzymatic or oxidative desizing. They can be eliminated biologically but they form sludge that is difficult to dispose of. In alkaline conditions polyvinyl alcohol is difficult to remove. In mid-range pH conditions it is easy to wash and can be recovered. When there are specific system conditions such as adaptation of the activated sludge, temperatures above 15°C and particularly low food to micro-organism ratios polyvinyl alcohol is biodegradable. In alkaline conditions, PVA gives problems with settlement. Environment protection and a less COD load in water are the main driving forces for the implementation of this technique. Moreover, EU Eco-label, OSPAR and other European initiatives encourage the use of this technique. In addition, this technique permits the reduction of size consumption by 1/3 or even more.

In **Morocco** the selection is also based on performance regarding breakage rate in weaving, price of sizing agent and environmental performance.

c. **Environmental benefit**
Significant reduction of the COD-load in natural waters. Savings can be obtained in chemicals, water and energy consumption too.

d. **Economics**
In most cases, biodegradable/bioeliminable combinations of sizing agents are no more expensive than conventional ones. In **Morocco** the applicability depends also by the price of substituting sizing agents.

e. **Reference literature**
4.2.1.3  Ref. Datasheet 2.A.2: Use of techniques that allow reduced load of sizing agents on the fibre (compact spinning)

a. **Description of the technique**
With the technique of compact spinning the fibre strands are compressed after the draft system through pneumatic devices. Yarn manufactured by means of the compact spinning system compared with classical yarn is characterized by:
- better smoothness,
- higher lustre,
- abrasion fastness better by 40-50%,
- hairiness lower by 20-30%, as measured with the use of the Uster apparatus,
- hairiness lower by 60%, as measured with the use of the Zweigle apparatus,
- tenacity and elongation at break,
- higher by 8-15%, and smaller mass,
- irregularity.

b. **Applicability, operational data and driving force for implementation**
This technique is applicable to pure cotton yarns. Positive aspects derived from compact spinning include a yarn with higher quality and the possibility of creating new effects/designs.

c. **Environmental benefit**
The compact spinning technique allows a compact yarn with better running properties and less thread breakage during weaving. This allows reduction in wastewater load in desizing.

d. **Economic aspects**
The additional costs in yarn manufacturing could be counterbalanced by cost savings generated by the higher weaving efficiency and reduced size add-on. Moreover lower costs in finishing could be obtained.

e. **Reference literature**

4.2.2  Desizing

Desizing is used to remove from woven fabric sizing compounds previously applied to the warp and is usually the first wet finishing operation performed on woven fabric. Desizing techniques are different depending on the kind of sizing agent to be removed.

4.2.2.1  Ref. Datasheet 2.A.1: Minimizing sizing agent add-on by pre-wetting the warp yarns

a. **Description of the technique**
The pre-wetting technology consists of running the warp yarn through hot water before the sizing process.

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11 In Morocco three sizing agents are used: starch, wax and PVA.
The warp yarn is dipped into the hot water, and then a squeeze roller removes the excess of water before the sizing phase. Pre-wetting allows applying a lower amount of size can be applied to the fibre.

b. **Applicability, operational data and driving force for implementation**
The technique can be applied to all kind of cotton yarns and blends of cotton/PES and viscose, and to medium and coarse yarns. Application is possible for batches of more than 5000 m.

Taking into account operation results, a reduction of the size add-on of about 20-50% is possible. The percentage depends on the kind of yarn processed.

Considering some aspects about this technique, sizing agents savings, increase of weaving efficiency and reduction of waste water load are driving forces for its implementation.

It is an additional operation that requires investment.

c. **Environmental benefit**
The reduction of sizing agents on the yarn allows a lower load of these agents discharged in water during pretreatment.

d. **Economic aspects**
Sizing equipment with pre-wetting boxes is more expensive than sizing equipment without a pre-wetting section.

A comparison between sizing with and without pre-wetting shows cost savings, an increase in sizing machine speed and an increase in weaving efficiency.

e. **Reference literature**

4.2.2.2 **Ref. Datasheet 2.D.3: Application of the oxidative route for efficient, universal size removal**

a. **Description of the technique**
H₂O₂ generates free radicals which degrade all sizes and remove them from the fabric when pH is over than 13. This process provides a clean, absorbent and uniform base for subsequent dyeing and printing.

The oxide radical anion O²⁻ is the predominant form above pH 13. It is highly reactive, but it will attack non-fibrous material (sizing agents, etc.) rather than cellulose.

It is recommended to first remove the catalyst that is not evenly distributed over the fabric (e.g. iron particles, copper, etc.).

One possible process sequence could be: removal of metals (pre-treatment lines equipped with metal detectors), oxidative desizing (peroxide and alkali), scouring (alkali), demineralization (alkaline reductive/extractive), bleaching (peroxide and alkali), rinsing and drying.

b. **Applicability, operational data and driving force for implementation**
The technique is particularly suitable for commission finishers (independently of their size), who need to be highly flexible because their goods do not all come from the same source.
Size and the cellulose have similar molecular structure and therefore an attack of the cellulose polymer from non-selective OH* is possible. To avoid damage to the fibre when removing starch-like size, it is essential to add hydrogen peroxide at pH >13. These operating conditions minimize OH* radicals, which are responsible for cellulose damage.

Applicable in Morocco for lightly dyed fabrics.

c. Environmental benefit

The proposed technique allows significant environmental benefits: water and energy consumption along with improved treatability of the effluent.

Hydrogen peroxide is also being used as an active substance for bleaching; it is advantageous to combine alkaline bleaching with scouring to save water, energy and chemicals.

Because of the action of free radicals generated by activation of hydrogen peroxide, the size polymers are highly degraded. The process produces shorter and less branched molecules, which are easier to wash out with a smaller amount of water.

The pre-oxidation of size polymer is also advantageous at wastewater treatment level (improved treatability).

d. Economic aspects

The steps and liquors are combined so that the use of resources is optimised at overall minimal cost.

e. Reference literature


4.2.3 Scouring (washing)

Scouring is aimed at the extraction of impurities present on the raw fibre or picked up at a later stage such as: pectins, fat and waxes, proteins, inorganic substances, such as alkali metal salts, calcium and magnesium phosphates, aluminium and iron oxides, sizes, residual sizes and sizing degradation products. Scouring can be carried out as a separate step of the process or in combination with other treatments.

4.2.3.1 Ref. Datasheet 2.A.4: Omitting the use of detergents in after washing of cotton dyed with reactive dyes

a. Description of the technique

Experiences from several textile companies and literature show that detergents do not improve removal of hydrolysed reactive dyestuffs from the fabric. Some dye houses already omitted the use of detergents in rinsing after reactive dyeing. In many cases fastness of goods is better after hot rinsing than after rinsing with detergents.

b. Applicability, operational data and driving force for implementation

It is possible to obtain a high level of fixation and positive wash-off properties of new low-salt polyfunctional reactive dyes, without the need of detergents.

Tests carried out with rinsing at 90 – 95°C have shown that rinsing is more effective and faster at high temperatures. About 30% more unfixed hydrolysed reactive dyestuff
is rinsed out after 10 minutes of rinsing at 95°C than at 75°C. Problems could arise from accidental stoppages of machinery. Many plants in Europe have applied this technique. In particular, a few examples of plants applying this technique are in Denmark: Kemotextil A/S, Sunesens Textilforædling ApS, Martensen A/S. The driving force for the implementation of this technique is the reduction of costs for chemicals and waste water treatment.

c. Environmental benefit
The main environmental benefits are the lower consumption of detergents and the reduced load in wastewater, and lower consumption of chemicals used to destroy reactive dyes by free radical treatment processes is an advantage.

d. Economic aspects
Economic savings are linked with the chemicals (mainly detergents) consumptions and with the wastewater treatment activities. However, in Morocco this technique requires skills and technology transfer.

e. Reference literature

4.2.4 Mercerising (and caustification)

Mercerising is used to improve the tensile strength, dimensional stability and lustre of cotton.
Mercerising can be carried out on yarn in hanks, woven and knitted fabric through one of the following different treatments:
  - mercerising with tension
  - caustification (without tension)
  - ammonia mercerising.

Sometimes scoured wool contains vegetable impurities. Sulphuric acid is the chemical substance used to destroy these vegetable particles and the process is called carbonising.

4.2.4.1 Ref. Datasheet 2.C.2: Recovery of alkali from mercerising

a. Description of the technique
In the mercerising phase cotton yarn is treated in a solution of caustic soda. Then the caustic soda is removed with rinsing. The rinsing water can be concentrated by evaporation for recycling.

b. Applicability, operational data and driving force for implementation
The higher number of stages for evaporation, the more often the heat is re-used, the lower the steam consumption and also the running cost are. The described technique can be applied to new and existing installations. Coloured alkali can be recovered and decontaminated for re-use. The main driving forces should be the lower alkali content of wastewater and costs related to caustic soda.

In Morocco mercerizing is not a common process in textile plants.
Chapter 4

4.2.5 Bleaching

After scouring, cotton becomes more hydrophilic. However, the original colour stays unchanged due to coloured matter that cannot be completely removed by washing and alkaline extraction.

When the material has to be dyed in dark colours it can be dyed directly without bleaching, while it is obligatory when the fibre has to be dyed in pastel colours or when it will need to be printed subsequently. In some cases, even with dark colours a pre-bleaching step may be needed, but this is not a full bleaching treatment.

Wool is bleached with hydrogen peroxide. An additional reductive bleaching is indispensable for achieving high levels of whiteness. In the oxidative bleaching step, hydrogen peroxide is applied in the presence of alkali and stabilisers.

4.2.5.1 Ref. Datasheet 2.A.3: Minimizing consumption of complexing agents in hydrogen peroxide bleaching

a. Description of the technique

The use of hydrogen peroxide in bleeding, could determine the presence of oxygen species (e.g. O₂**, OH*/O*-, etc.) of differing reactivity in water. The formation of OH* radical causes damage to the fibre. This problem can be prevented through the use of complex formers that inactivate the catalyst (stabilisers). Complexing agents contain N- and P-, and have low biodegradability. The massive use of sequestering agents can be avoided by the removing of OH*. This reduces fibre damage without the need for complexing agents. The hydroxyl radical OH* is removed by hydrogen peroxide, forming the true bleaching agent. In these circumstances hydrogen peroxide has the role of scavenger and the reaction product is the bleaching agent itself.

b. Applicability, operational data and driving force for implementation

This technique can be applied to existing and new plants. The application of hydrogen peroxide needs fully automated equipment. The pre-cleaning of heavily soiled fabric is an alternative to acid demineralization when is carried out in more alkaline conditions, using non-hazardous reducing agents. The technique described in this section is provided directly by some auxiliary’s suppliers. With the help of dynamic simulation
models they are able to prepare a recipe that is suitable for the specific substrate, equipment used, etc. under defined process conditions.

c. **Environmental benefit**
This technique allows bleaching of cellulose in full, without damages to fibre. This is possible by not using of hazardous sequestering agents, and because of the minimal consumption of peroxide, and the pre-oxidation of the removed substances.

d. **Economic aspects**
Lower peroxide consumption is possible. Also a decrease in organic load is possible. Cost savings are achieved.

e. **Reference literature**

### 4.2.5.2 Ref. Datasheet 2.B.8: Dry bleaching using ozone instead of wet washing using chlorine or hydrogen peroxide

a. **Description of the technique**
This operation consists of placing the garments (jeans) in a dry rotary washing machine. The machine is connected to an ozone generator.

This technique is used for many purposes:
- bleaching lightly the fabric by using ozone instead of wet washing using chlorine or hydrogen peroxide.
- cleaning indigo redeposits on fabric.
- fired colour of jeans to gray.

b. **Applicability, operational data and driving force for implementation**
The use of this technique requires the installation of an ozone generator and some small modifications in the washing machine. On the other hand, this technique cannot substitute the use of chlorine or peroxide entirely because in some cases the use of chlorine or peroxide is indispensable to obtain effects. The duration of the operation varies from 15 to 60 minutes and depends on the kind of garment and the type of required effect.

This technique allows a time saving of circa 60%, compared to conventional bleaching followed by squeezing and draining steps. Environmental and economic benefits are the main driving forces for the implementation of this technique.

c. **Environmental benefit**
Environmental benefits consist in no use of water and chemicals, and no production of wastewater.

d. **Economic aspects**
Savings can derive by both process water purchase price, chemicals purchase price, time cost and effluent disposal costs.

e. **Reference literature**
Technical audit carried out in GTS company, GTT company (Tunisia).
4.2.5.3  Ref. Datasheet 3.D.3: Substitution for sodium hypochlorite and chlorine-containing compounds in bleaching operations

a. Description of the technique
Sodium hypochlorite was for a long time one of the most widely used bleaching agents in the textile finishing industry. And it is still in use also for cleaning dyeing machines or as a stripping agent for recovery of faulty dyed goods. Hydrogen peroxide is however now the preferred bleaching agent for cotton and cotton blends as a substitute for sodium hypochlorite.

When a single-stage process using only hydrogen peroxide cannot achieve the high degree of whiteness required, a two-stage process with hydrogen peroxide (first step) and sodium hypochlorite (second step) can be applied, in order to reduce AOX (adsorbable organic halides) emissions. There is also increasing support for peroxide bleach under strong alkaline conditions, which achieves a high degree of whiteness after careful removal of catalysts by a reduction/extraction technique. The additional advantage claimed is the possible combination of scouring and bleaching.

b. Applicability, operational data and driving force for implementation
This technique is applicable to every installation. Hydrogen peroxide is used for bleaching cotton and cotton blend knitted fabric. It is used also for woven fabric made of most cellulosic and wool fibres and most of their blends. Exceptions are flax and other bast fibres. Particular attention needs to be paid to the combination or sequence of pre-treatment operations and to the mixing of streams containing hypochlorite or chlorine. It is important to avoid mixing hypochlorite bleach waste water with certain other streams and mixed effluents, in particular from desizing and washing, even when the right sequence of pre-treatment and bleaching is adopted. The formation of organohalogens is possible in combined process streams.

For chlorine bleach, handling and storage of sodium chlorite needs particular attention because of toxicity and corrosion risks. Machinery and equipment need to be inspected frequently because of the high stress to which they are subjected.

In general, according to the source, the main driving forces are the chlorine-free bleached textiles required by the market and the law requirements regarding wastewater discharge.

c. Environmental benefit
No presence of hazardous AOX such as trichloromethane and chloroacetic acid in the effluent.

d. Economic aspects
This technique is no more expensive than old one. The two-stage bleaching process is two to six times more expensive than the conventional one.
If chlorine dioxide is used as bleaching agent an investment could be needed for equipment resistant to the highly corrosive conditions in existing installations.

e. Reference literature
Chapter 4

4.2.6 Integrated measures in the pre-treatment

The techniques described in this paragraph consist in integrated pretreatment process measures.


a. Description of the technique
In presence of cotton woven fabric and its blends with synthetic fibres, the standard pre-treatment process includes: desizing, scouring and bleaching. The new Flash Steam procedure (possible thanks to new auxiliaries’ formulations and automatic dosing and steamers) allows that telescopes desizing, alkaline cracking (scouring) and pad-steam peroxide bleaching are integrated in one unique step.

b. Applicability, operational data and driving force for implementation
Companies with new machinery for this process are able to apply the described technique. The big advantage is that in a range of 2-4 minutes loom-state goods are brought to a white suitable for dyeing. The sequence of the Flash Steam peroxide bleach is:
   1. application of the bleaching solution
   2. steam 2-4 min.
   3. hot wash off.
The productivity increase is the main driving force for the technique implementation.

c. Environmental benefit
The single integrated process allows water and energy consumption reductions.

d. Economic aspects
In order to assess the cost feasibility of the technique, in Morocco it could be necessary carry out an economic study. In Morocco important savings are achieved.

e. Reference literature

4.2.6.2 Ref. Datasheet 2.D.2: Optimization of cotton warp yarn pre-treatment

a. Description of the technique
In white cotton production, cotton yarn is bleached before weaving. The traditional process includes five steps (wetting/scouring, alkaline peroxide bleaching and three subsequent rinsing steps). The last rinsing water is re-used for making the first bath. The conventional process can be improved through the combination of wetting, scouring and bleaching in only one step and performing rinsing in two steps, re-using the second rinsing bath for making the bleaching/scouring bath.
The energy consumption of the process is reduced by heat recovery. The heat from scouring/bleaching bath is recovered and used for heating the fresh water for the first rinsing.

The bath is cooled to 80°C. The cooled scouring/bleaching bath is collected in a tank together with the warm rinsing water deriving by the first rinsing step. Before being drained, the stream is used to heat water from the second rinsing step.

b. **Applicability, operational data and driving force for implementation**

Even if the quality of yarn has to be considered in order to make sure that process can be applied, this technique could be applied both to new and existing installations. In the case of heat recovery, space for additional tanks is necessary.

The operating conditions of the optimized process are illustrated in the table. It also contains the calculation of COD input and output.

**Table 7. Operating conditions of the optimized process**

<table>
<thead>
<tr>
<th>Process input and operating conditions</th>
<th>Quantity</th>
<th>Spec. COD</th>
<th>COD-load per kg of yarn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wetting/scouring/bleaching</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Conditions: pH ca. 12, 110°C, 10 min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Recipe</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- NaOH 38%Bé (33 %)</td>
<td>3.5 g/l</td>
<td>-</td>
<td>0.6 g O₂/kg</td>
</tr>
<tr>
<td>- H₂O₂:35 %</td>
<td>3.0 g/l</td>
<td>-</td>
<td>24.2 g O₂/kg</td>
</tr>
<tr>
<td>- Sequestrant and stabiliser</td>
<td>1.0 g/l</td>
<td>85 mg O₂/g</td>
<td>3.9 g O₂/kg</td>
</tr>
<tr>
<td>- Surfactant</td>
<td>1.9 g/l</td>
<td>1610 mg O₂/g</td>
<td></td>
</tr>
<tr>
<td>- Optical brighteners</td>
<td>0.15 wt-%</td>
<td>2600 mg O₂/g</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tot. from auxil. 28.7 g O₂/kg</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Extracted from cotton 70.0 g O₂/kg</td>
</tr>
<tr>
<td>First rinsing</td>
<td>3000 mg O₂/l</td>
<td></td>
<td>18.7 g O₂/kg</td>
</tr>
<tr>
<td>• Conditions: 70°C, 15 min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second rinsing</td>
<td>1000 mg O₂/l</td>
<td></td>
<td>6.2 g O₂/kg</td>
</tr>
<tr>
<td>• Conditions: 70°C, 15 min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>124 g O₂/kg</td>
<td></td>
</tr>
</tbody>
</table>

Source: [179, UBA, 2001]


Both economic and environmental benefits are the main driving forces for the implementation of this technique.

c. **Environmental benefit**

With the described technique it is possible to obtain a reduction of 50% of water consumption in respect to the conventional process. Also a reduction of wastewater is achieved.

Moreover, energy and chemicals consumption can be reduced.

d. **Economic aspects**

Savings in time, water, chemicals and energy make the process highly economic. The process requires tanks, heat exchangers, pipes and control devices for energy recovery from wastewater. New equipment for pre-treatment are not required.

e. **Reference literature**
Chapter 4


4.2.7 Other measures

Other techniques of pretreatment process – not indicated in previous paragraphs – are described in this paragraph.

4.2.7.1 Ref. Datasheet 3.A.2: Man-made fibre preparation agents with improved environmental performance

a. Description of the technique

Auxiliaries as coning oils are very important in man-made fibre production but they are the main cause of pollution in the downstream processes. After pretreatment operations, these compounds are in wastewater and exhaust air of finishing mills. These preparation agents are mineral oils in particular but they have many disadvantages. Alternatives to mineral oils are preparation agents based on:

A. polyether/polyester or polyether/polycarbonates
B. special polyol esters
C. special steric hindered fatty acid esters.

b. Applicability, operational data and driving force for implementation

These agents can be applied on PES, PA 6.6, PA 6, CV and their blends with PES or CV. The applicability of low-emission preparation agents depends on the kind of fibre and the end-use of the final product.

Yarn producer

Some machine parts must be composed of high-grade steel to avoid potential corrosion problems. Equipment cleaning must be done after use to avoid compatibility problems between polyether/polycarbonate-based products and conventional hydrophobic preparation systems.

Fabric producer

The equipment has to be cleaned thoroughly (especially in the case of polyester/polycarbonate-based auxiliaries) due to the compatibility problems.

Finishing mill

Processes in pretreatment need to be adjusted to the new preparation systems. Sometimes (e.g. with polyester-/polyethercarbonate-based auxiliaries) washing steps in pretreatment can be easier or skipped.

The main driving force for implementation of the technique are water saving and the minimization of off-gas loads (accordance with national regulations).

In Morocco the applicability of this technique depends on the availability of preparation agents.

c. Environmental benefit

This technique reduces odour in workplace and organic volatile compounds in the exhaust air.
It lowers consumption of water, energy and chemicals. Moreover optimized products have a high biodegradability compared to mineral oil-based preparation agents.

d. Economic aspects

Yarn producer
Low-emission auxiliaries are more expensive than conventional ones.

Finishing mill
No need of exhaust-air cleaning equipment. Reduction of investment, maintenance, and disposal costs are achieved thanks to simplified wastewater treatment and prevention of oil-contaminated wastes. Moreover water saving can be achieved by reducing or omitting the water step.

In Morocco the applicability of this technique depends on the price of preparation agents.

e. Reference literature


4.2.7.2 Ref. Datasheet 3.D.4: Selection of biodegradable/bio eliminable complexing agents in pre-treatment and dyeing processes

a. Description of the technique

In order to eliminate the damaging effect of hardening alkaline-earth cations and transition-metal ions in aqueous solutions complexing agents are used, in pre-treatment processes (e.g. catalytic destruction of hydrogen peroxide), but also during dyeing operations.

The most important complexing agents are polyphosphates (e.g. tripolyphosphate), phosphonates (e.g. 1-hydroxyethane 1,1-diphosphonic acid) and amino carboxylic acids (e.g. EDTA, DTPA, and NTA).

But their often low biodegradability/bio eliminability and their feature to form stable complexes with metals, which may lead to remobilisation of heavy metals is a problem.

Alternatives to the use of complexing agents are polycarboxylates or substituted polycarboxylic acids, hydroxy carboxylic acids and some sugar-acrylic acid copolymers.

b. Applicability, operational data and driving force for implementation

The complexing agents described in this section can be used in continuous and discontinuous processes. The effectiveness of the various products has, however, to be considered when replacing conventional complexing agents by more environmentally-friendly ones.

The use of the optimized products mentioned above does not imply major differences with respect to conventional complexing agents.

In Morocco the selection of complexing agents is based on specifications from clients and price.

c. Environmental benefit

The reduction of eutrophication in the receiving water, the improvement of biodegradability of the final effluent and the reduction of risk of remobilisation of the heavy metals from sediments are the environmental benefits.
Chapter 4

d. Economic aspects
There are not obvious differences in price between conventional complexing agents and more environmentally friendly ones, but in some case higher quantities of complexing agents may be necessary.

e. Reference literature

4.2.7.3 Ref. Datasheet 2.C.7: Bacterial cellulose production from cotton-based waste textiles: Enzymatic saccharification enhanced by ionic liquid pre-treatment

a. Description of the technique
This technique consists in using [AMIM]Cl (1-Allyl-3-methyl- imidazolium chloride) to dissolve cotton-based waste textiles as a pre-treatment prior to enzymatic hydrolysis. The dissolution of cotton in [AMIM]Cl increased with temperature and time; however, the yield of regenerated cotton cloth obtained after the 130 °C pre-treatment was relatively low.

After 4 h, the yields of reducing sugar from pre-treated and untreated cotton cloth were 22.4% and 4.0%, respectively. After hydrolysis for 24 h, the yield of reducing sugar from untreated cotton was only 12.1%, whereas that of pre-treated cotton was 81.6%. This indicates that the pretreatment with [AMIM]Cl is a very efficient approach to increase the hydrolytic rate of cotton cloth so the enzymatic saccharification of cotton materials can be improved by pretreatment with [AMIM]Cl or [BMIM]Cl (1-butyl-3-methylimidazolium chloride).

b. Applicability, operational data and driving force for implementation
The technique can be applied to new and existing installations. The cotton-based materials employed in the study were used/old undyed 100% cotton T-shirts. N-methylimidazole was purchased from Luer Chemical Trading Co. Ltd. (Shanghai, China) and allyl chloride was obtained from Sinopharm Chemical Reagent Co. Ltd. (Shanghai, China). The cellulose preparation was from Bo Li Biological Products Co. Ltd. (Wuxi, China).

Costs savings are the main driving force for implementing this technique.

c. Environmental benefit
The main environmental benefit consists of savings in natural resources by using some kind of industrial/agricultural waste.

d. Economic aspects
The technique allows obtaining costs savings compared to traditional methods.

e. Reference literature
Feng Hong, Xiang Guo, Shuo Zhang, Shi-fen Han, Guang Yang, Leif J. Jönsson; Bacterial cellulose production from cotton-based waste textiles: Enzymatic saccharification enhanced by ionic liquid pre-treatment; Bioresource Technology 104 (2012) 503–508.
4.3  Dyeing

Textile dyeing involves the use of a number of different chemicals and auxiliaries for the dyeing process. Some of them are process-specific, while others are also used in other operations. Some auxiliaries are already contained in dyestuff, but more commonly auxiliary agents are added at a later stage to the dye liquor. Due to substances used in this process, dyeing is a very polluting process in the textile sector.

4.3.1  Efficient measures in dyeing process

This paragraph discusses some techniques to achieve greater efficiency in the dyeing process.

4.3.1.1  Ref. Datasheet 2.A.5: Alternative process for continuous (and semi-continuous) dyeing of cellulosic fabric with reactive dyes

a.  Description of the technique

This technique consists in a continuous dyeing process for cellulose fibres that uses selected reactive dyestuffs. This technique does not need other resources (e.g. urea, sodium silicate, salt). The traditional auxiliaries are replaced by operating with controlled steam content during drying. After the application of the dye liquor to textile, and after a passage through air, the fabric is fed to the dryer. The fixation requires a low fabric temperature, a weak alkali and only 2 minutes. This is possible since reactive dyes are used.

b.  Applicability, operational data and driving force for implementation

The technique can be used for small and large batches. The process is applicable to a huge kind of fabrics. The fabric quality improves with this technique. It is possible to observe a soft handle and improved coverage of dead cotton. Moreover, fabrics could have an improved penetration, due to the presence of humidity. The maximum performance could be achieved with a right choice of fabric pre-treatment and well-engineered selected dye formulations. The referenced technique is available commercially under the name of Econtrol®, which is a registered trademark of DyStar. Plants in Spain, Belgium (UCO-Sportswear), Italy, Portugal, China, Turkey, India, Pakistan and Korea are operating with the Econtrol® process. This technique is applicable in new installations.

c.  Environmental benefit

Savings of urea, salt and sodium silicate are achieved and also the alkalinity of wastewater decreases. The elimination of urea determines a lower amount of nitrogen and its compounds in wastewater. The absence of salt allows a lower salt load in the effluent. The reduction of energy consumption and chemical consumption are other environmental benefits linked with this technique.

d.  Economic aspects

The cost for the investment in new hot-flue is high. This cost is counterbalanced by high savings in energy, chemicals and other auxiliaries. The technique allows a higher productivity that can help compensating the higher costs.
**Chapter 4**

**e. Reference literature**

4.3.1.2 *Ref. Datasheet 2.B.1: Minimization of dye liquor losses in pad dyeing techniques*

a. **Description of the technique**
Reduction of dye liquor losses in pad dyeing processes can be obtained through the impregnation step in a nip or by the minimization of the capacity of the dip trough. Also systems that control the dosage of the input raw materials allow reduction of losses. In this case dyestuff solution and auxiliaries are dosed. Losses reduction could be achieved also through the dosage of the padding liquor based on the measurement of the pick-up. In this case the dyestuff solution is prepared just in time based on on-line measurement of the pick-up.

Taking into account the characteristics of Moroccan textile industry, this technique is usually applied in large companies.

b. **Applicability, operational data and driving force for implementation**
All indicated techniques are applied for new and existing continuous and semi continuous dyeing ranges. This technique is not suitable for light fabrics (below 220 g/m) or fabric with good wettability. In Europe and countries outside Europe, there are about 40 plants successfully operating the described technique. A good maintenance is requested for a good performance of the equipment. Also the precision of dosage systems and pick-up measurement should be checked with a specific periodicity.

c. **Environmental benefit**
The technique allows a reduction of the residues of unused liquor. The preparation of the dyestuff solution based on on-line measurement of the pick-up determines a reduction of the residual dye liquor in tanks. In addition the consumption of water is reduced than to this technique.

d. **Economic aspects**
Investment costs for an automated dosage system are high, but could be partially counterbalanced by annual savings. Moreover, advantages are derived by lower quantity of wastewater needing treatment.

e. **Reference literature**

4.3.1.3 *Ref. Datasheet 2.B.2: After treatment in PES dyeing*

a. **Description of the technique**
This technique increases the wash fastness that is a typical problem in dyeing PES fibres and PES blends using disperse dyestuffs. This phase removes the non-fixed disperse dyes from the fibre. Two approaches exist. The first consists in using reducing agent based on a short-chain sulphinic acid that can be added in the exhausted acid
dye bath. The reducing agent can be metered automatically. It is characterized by a low toxicity and by biodegradability.

The second technique uses disperse dyes that can be cleared in alkaline medium by hydrolytic solubilisation instead of reduction.

b. **Applicability, operational data and driving force for implementation**

In the case of the first approach, only the quantity of reducing agent necessary to reduce the dyestuff is consumed. The consumption of the reducing agent by the oxygen should be minimized. To this purpose the use of nitrogen to remove oxygen from the liquor and the air in the machine, is an effective technique. In presence of alkali-clearable disperse dyes there is no need for levelling agents, dispersing agents and detergent. The quantity of dye used is lowered.

The first approach is used in all kinds of dyeing machines. In case of blends with elastane fibres the application is limited.

In the case of the second approach alkali-clearable dyes are applied for PES and PES/cotton blends.

Taking into account what is mentioned above the drivers to implement this technique are: a higher productivity and costs savings and a better environmental performance.

c. **Environmental benefit**

In the case of the first approach, reducing agent can be applied in the acidic pH range, significant water and energy savings can be achieved. Compared to the conventional process, up to 40% water can be saved. Workplace safety will be improved and odours reduced. In the case of alkali-dischargeable dyes, the use of reducing agents can be avoided and so makes possible a lower oxygen demand in the final effluent. Also lower water and energy consumptions could be obtained.

d. **Economic aspects**

Significant savings can be achieved as a result of higher productivity, reduced consumption of energy, water and chemicals and the lower burden in wastewater.

e. **Reference literature**


4.3.1.4 **Ref. Datasheet 2.B.3: Airflow jet dyeing machines with the use of air, either in addition to or instead of water and Soft-flow dyeing machines with no contact between the bath and the fabric**

a. **Description of the technique**

The airflow jet dyeing technique consists of the use of air, in addition or in substitution of water. In this case the fabric is moved by air, or by steam and air, with no liquid. Dyestuffs, chemicals and auxiliaries are injected in gas stream. Main features of this technique are the bath-less dyeing operation and the separated circuit for liquor circulation with no contact with textile. Soft-flow dyeing machines use water to keep the fabric in circulation. The principle behind this technique is that fresh water enters the vessel via a heat exchanger and arrives at a special interchange zone whilst at the same time the contaminated liquor is channelled to the drain without coming into contact with the fabric or the new bath in the machine.
b. **Applicability, operational data and driving force for implementation**

With respect to conventional jet machines, both techniques require lower inputs: less amount of water, steam and less time. In addition, airflow jet operating requires less auxiliaries and salt. On the other hand, airflow jet operating requires higher electricity than conventional techniques. The first technique could be used for knit and woven fabric and for all types of fibres. Limitations to the use of this technique can be found with wool and wool blends. The technique cannot be used for dyeing linen fabric. These kinds of machines allow high productivity and repeatability. Another driving force are savings in water, chemicals and energy consumption.

c. **Environmental benefit**

Main environmental benefits of airflow jet dyeing technique are less energy use, less chemicals consumption and water savings. Soft-flow dyeing machines generate savings in processing time and less steam and water consumption.

d. **Economic aspects**

This technique can imply new investments in new machineries. In Morocco it can be applied in large companies.

e. **Reference literature**


4.3.1.5 **Ref. Datasheet 2.C.6: Direct re-use of dye baths and auto-control of the process online**

a. **Description of the technique**

The technique foresees the application of a technology for the direct re-use of dye baths, based on a technique of measuring by spectroscopic laser, by means of which the content of each and every one of the colorants and chemical products present in the dye bath will be determined with suitable precision. In this way, using suitable software, the necessary "additions" can be defined precisely, i.e. the residue formula to apply for bath re-use.

For the direct re-use of dyeing baths without sacrificing the exact reproduction of colour, it is necessary to determine precisely the volume of residual bath available, together with the concentrations of the products existing in this. With this data it is possible to discover the quantities needed to be added to the residual bath in order to prepare a new dyeing bath, whether it be to obtain a colour used previously or another, within the limits established by the nature of the colour itself. Of the substances present in the dye, the residual colorants are measured, which are those that suffer variations in concentration during the dyeing process. The measurement can be performed using two methods:

- UV-VIS spectroscope
- RAMAN laser spectroscope

The UV-VIS spectroscope is valid in dyeing processes with a single colorant, but its imprecision increases as the number of colorants increases. Using the RAMAN laser spectroscope, the measurement can be carried out on mixtures of colorants, although the systematic analysis of commercial ranges will enable the establishing of the limits of applicability and the incompatibilities that exist.
b. Applicability, operational data and driving force for implementation

The applicability of the technique is related to different systems for comprehensive control of the dyeing process, including the total direct re-use of residual baths.

c. Environmental benefit


d. Economic aspects

At the technique current level of development, it is difficult to make an evaluation from a cost/benefit point of view, since the following aspects have to be considered:

a. The RAMAN spectroscopy unit used, or any other similar one on the market, still has a very high cost (80,000-100,000 €), due to the fact that it is a quite recently developed measuring technique and has a limited production of apparatus.

b. The applicability to any type of dyeing is not sufficiently established and tested, since the “calibration” data for the colorants does not exist, with the result that the quantities of products and water that might be saved according to the production of a determined industry are not calculable and, as a consequence, neither would the investment recovery time be.

Nevertheless, the rapid advances in optics and electronics suggest the likelihood of a rapid lowering of the cost of RAMAN units, which can in addition be submitted to redesigning or re-engineering for the specific application proposed, in such a way that, at present day costs, if the price of the measuring unit does not exceed 15,000–18,000 euros, and with the most well-established technological aspects (calibration of colourants and auxiliaries), a recovery time of between 2 and 3 years is estimated, from a strictly economic point of view.

e. Reference literature

DYEING BATH REUSE Life project results:
http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.creatpage&s_ref=LIFE03%20ENV/E/000166

4.3.1.6 Ref. Datasheet 2.D.4: Equipment optimisation in batch dyeing

a. Description of the technique

The conservation of water, chemicals and energy and the resulting savings can be obtained by new machines of last generation. New ‘low’ and ‘ultra-low’ liquor ratio (one of the parameters that influence the environmental performance) machines are available for the batch dyeing processes.

These machines can be operated at approximately constant liquor ratio whilst being loaded at a level as low as 60% of their nominal capacity, even small size lots can be dyed at optimal/ nominal liquor ratio and they conserve chemicals as well as water and energy and also achieve higher fixation efficiency. However, the total water consumption is determined by the rinse and wash processes too. In some of these machines the hot exhausted dye liquor and the rinsing waters are kept as separate streams, which allows them to be re-used or at least be treated separately and thermal energy recovered. In order to increase rinsing efficiency mechanical liquor extraction is a possible method for reducing the non-bound water retained by the fabric. Expression, suction and blowing air through the fabric are also all available techniques.
Also a short cycle time permits water and energy saving in dyeing processes. This result can be obtained by pumped drain and fill options, charge tanks (which are used for the preparation of the liquor in parallel with other process operations) combined cooling and rinsing systems, etc. In the latter the cooling water is passed through the machine heat exchanger during the cooling step and is then fed directly into the jet as hot fresh rinse water.

The quantity of rinsing water can be controlled, depending on the end temperature, the desired rate of cooling and, in some machines, also on the desired quality of rinsing.

Further reduction of the cycle times can be achieved by improving the textile/liquor contact to achieve homogenisation of the bath more rapidly.

Additional common features of modern batch dyeing machines include:

- automated systems for chemicals/dyes dispensing and dyeing cycle control,
- automatic controllers to facilitate liquor level and temperature measurement and control,
- indirect heating and cooling systems,
- hoods and doors to reduce vapour losses.

b. Applicability, operational data and driving force for implementation

This technique is applicable for all types of batch dyeing equipment maintaining the same quality standard of the final product. Besides savings in water, chemicals and energy consumption, high productivity and reproducibility are the main driving forces.

c. Environmental benefit

This technology improves the environmental performance in terms of consumption of water, energy, chemicals and reduces water pollution.

d. Economic aspects

The economic aspects depend on the type of new installed machine. In any case the savings in chemicals and energy consumption allow to get back the invested resources.

e. Reference literature


4.3.2 Less pollutant dyes

Dying can in several cases be considered as one of the main the causes/sources for pollution in the textile sector. The use of dyes implies the use of water and energy to fix the dyes during the dyeing process. The companies should remove the non-fixed dyes from the bath if they cause an increase of pollutant load of wastewater. Moreover, being produced by the chemical sector, they cause indirect pollution in the first phases of their life cycle and also in the last phase (use) they cause dangerous packaging waste. For these reasons research on how the company can dye with less pollutant chemicals is very important to reduce pollution by the textile industry.
4.3.2.1  Ref. Datasheet 3.C.1: Dispersing agents with higher bio eliminability in dye formulations

a.  Description of the technique
Dispersing agents are mainly present in disperse, vat and sulphur dye formulations to ensure uniform dispersion throughout the dyeing and printing processes. The lignosulphonates and the condensation products of naphthalene sulphonamic acid with formaldehyde, which are widely applied as dispersing agents, show COD levels as high as 1200 mg/g (lignosulphonates) and 650 mg/g (naphthalenesulphonamic acid condensation products).

Improved dispersing agents that can substitute conventional dispersing agents in the dye formulations, are available:
Option A: partial substitution of conventional dispersing agents with optimized products based on fatty acid esters to date only applicable to liquid formulations of disperse dyestuffs. The tinctorial strength of the dye is also improved.
Option B: it consists in applying dispersing agents based on mixtures of the sodium salts of aromatic sulphonic acids. This technique is applicable to common dispersing agents in powder and granulate formulations.

b.  Applicability, operational data and driving force for implementation
Option A) is used for liquid formulations of disperse dyes only.
Option B) is used for disperse and vat dyes too.
This technique does not imply changes in the process compared to the application of conventional products.
The improvement of the environmental performance is the main driving force.

c.  Environmental benefit
In the case of option A) bio-elimination rates are between 90 and 93%.
For option B) the degree of bio-elimination of the modified dispersing agent is about 70% compared to 20–30% for the conventional one.

d.  Economic aspects
Costs of this kind of dispersing agents are higher than costs of conventional ones.

e.  Reference literature

4.3.2.2  Ref. Datasheet 3.C.2: Dyeing with sulphur dyes

a.  Description of the technique
The classic powder and liquid sulphur dyes can be successfully replaced by:
- pre-reduced dyestuffs (liquid formulations with sulphide content <1%),
- non-pre-reduced sulphide-free dyestuffs (water-soluble in the oxidised form),
- non-pre-reduced sulphide-free stabilised dispersed dyestuffs (in powder or liquid form),
- non-pre-reduced sulphide-free dyestuffs (stable suspension).
All these types of dyestuffs can be used without any sodium sulphide.
The following compounds combinations are in use:
- combination of dithionite and glucose
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- combination of hydroxyacetone and glucose (seldom)
- combination of formamidine sulphinic acid and glucose (seldom).

Hydrogen peroxide is the preferred oxidising agent.

b. **Applicability, operational data and driving force for implementation**

This technique can be used in existing and new dyeing machines.

A typical recipe for cotton dyeing on a jet machine (liquor ratio 1:6 to 1:8; dyeing for 45 min at 95 °C) is given below:

- non-pre-reduced sulphur dye: 10%
- wetting agent: 1 g/l
- caustic soda solution (38 Bé): 15-20 ml/l
- soda ash: 8-10 g/l
- salt: 20 g/l
- glucose: 10-12 g/l
- sodium dithionite: 8 - 10 g/l or hydroxyacetone: 4 - 5 g/l or formamidine sulphinic acid: 4-5 g/l

Driving forces for the implementation of this technique are worker health and safety. Bad smells and presence of sulphides in wastewater that are reduced.

The Moroccan textile companies usually test the sulphur dyes before to use them in dyeing processes in order to check the quality of the final products.

c. **Environmental benefit**

The sulphide content in wastewater is minimized.

d. **Economic aspects**

Stabilised non-pre-reduced sulphide-free dyestuffs are more expensive than sulphur dyes.

e. **Reference literature**


4.3.2.3 **Ref. Datasheet 3.C.4: Silicate-free fixation method for cold pad batch reactive dyeing**

a. **Description of the technique**

Silicate-free highly concentrated aqueous alkali solutions have been developed and used instead of sodium silicate in cold pad-batch dyeing, mainly to increase the pad liquor stability and to avoid selvage carbonization.

It can be easily applied with dosing systems. They are particularly suitable for the cold-pad-batch process.

b. **Applicability, operational data and driving force for implementation**

This technique is applicable for new installation. Additional measures for process optimization and control may be needed in order to guarantee constant conditions for existing installations.

Membrane pumps such as the sera-pumps with 4:1 ratio (alkali solution to dyestuffs solution) are suitable for the application of the product.
The main driving forces are reproducibility, reduction of total process costs, easy handling of the product, no deposits and better washing-off behaviour, possibility of using membrane techniques for wastewater treatment.

c. **Environmental benefit**
Some environmental advantages are achievable: no residues of alkali in the preparation tank, no formation of difficult-to-wash-off deposits on the substrate and on the equipment, no need for additional auxiliaries in the padding liquor to avoid the formation of deposits, lower electrolyte content in the effluent, possibility of using membrane techniques in waste water treatment (no crystallization in filters, pipes and valves and no membrane blocking, which is the case with sodium silicate).

d. **Economic aspects**
The ready-made alkali solutions are more expensive than the conventional fixation methods.
Investment for more efficient process control must be considered but many economics benefits have to be considered too.
The following economic benefits have to be considered:
- investment in advanced dosing systems is lower because only two dosing units are needed instead of three conventional ones,
- no need to change the rubbers of the padder at short time intervals,
- the lower electrolyte content of the liquor makes it easier to wash off. This results in lower energy and water consumption in the washing-off step of the process,
- higher productivity of the padders and washing ranges,
- better reproducibility thanks to monitored process conditions.

e. **Reference literature**

**4.3.2.4 Ref. Datasheet 3.C.5: Exhaust dyeing of cellulosic fibres with high-fixation polyfunctional reactive dyestuffs**

a. **Description of the technique**
Bifunctional (polyfunctional) reactive dyes contain two similar homo or dissimilar hetero reactive systems that offer very high levels of fixation in exhaust dyeing. However, polyfunctional dyes are not necessarily better. Only the right combination of reactive groups makes them superior to conventional monoreactive dyes.

b. **Applicability, operational data and driving force for implementation**
This technique offers particular advantage on the most modern low liquor ratio dyeing machines fitted with multi-task controllers but high fixation reactive dyes can be applied in all types of dyeing machines.
Dye manufacturers introduced small dye ranges each comprising highly compatible dyes with virtually identical behaviour in the dye bath. Each of these compact ranges is geared to specific application segments.
Also dyeing compatibility matrixes are provided.
The reduction of total processing costs and the introduction of legislation restricting colour in the discharged effluent have been the main driving forces.
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4.3.2.5 Ref. Datasheet 3.C.6: Exhaust dyeing with low-salt reactive dyes

a. Description of the technique
Development of innovative dye ranges and application processes permits to need about two-thirds of amounts of salt compared to conventional one to improve exhaustion of dyeing of cellulosic fibres with reactive dyestuffs.
Examples are:
- Cibacron LS (Ciba)
- Levafix OS (Dystar)
- Procion XL+ (Dystar)
- Sumifix HF (Sumitomo)
Most of these dyes are polyfunctional dyes and offer very high level of fixation. Because of the reduced amount of salt needed for their exhaustion, low-salt dyes are more soluble and can be kept in solution at a higher concentration than necessary for low liquor ratio dyeing machines. This offers further possibilities for reducing the overall salt requirement.

b. Applicability, operational data and driving force for implementation
This techniques offer particular advantage in the most modern low liquor ratio dyeing machines but are applicable to existing dyeing equipment too. The lower the salt concentration, the more sensitive the system becomes to any change in parameters that influence exhaustion. To give the dyer the high flexibility needed, dye manufacturers have developed trichromatic combination dyes with high mutual compatibility.
Products with very similar application properties are now available, which makes them little affected by changes in dyeing conditions.
One of the characteristics of advanced reactive dyes is the reciprocal compatibility of dyes that are included in each dye range.
It is good for areas having arid climate conditions and negative water balance and where dye houses discharge directly to fresh water and there is a need to minimize salination effects.
It helps water recycling by decreasing corrosion caused by salt.

c. Environmental benefit
Positive effects on effluent salinity and smooth running of waste water treatment units are obtained.
d. **Economic aspects**
Depending on the special circumstances but low-salt reactive dyes are significantly more expensive than conventional reactive dyes.

e. **Reference literature**

4.3.2.6 - *Ref. Datasheet 3.C.7: Dyeing without water and chemicals*

a. **Description of the technique**
This technique consists in using carbon dioxide (CO₂) for dyeing of textile-materials instead of water to achieve a water free dyeing process. The dyeing process is completely waterless, using recycled carbon dioxide. When CO₂ is heated to above 31°C and pressurised to above 74 bar, it becomes ‘supercritical’, a state of matter that can be seen as an expanded liquid, or a heavily compressed gas. One characteristic of a supercritical fluid is a high (liquid-like) density that enables dissolution of compounds. In dyeing, CO₂ is heated to 120°C and pressurised to 250 bars. The CO₂ penetrates synthetic fibres, thereby acting as a swelling agent during dyeing and enhancing the diffusion of dyes into the fibres. In particular the glass-transition temperature of the fibres is lowered by the penetration of the CO₂ molecules into the polymer. This accelerates the process for polyester by a factor of two. Finally, the CO₂ is able to transport the necessary heat from a heat exchanger to the fibres. During the dyeing of polymer fibres, CO₂ loaded with dyestuff penetrates deep into the pore and capillary structure of fibres. This deep penetration provides effective coloration of these materials, which are intrinsically hydrophobic. The process of dyeing and the act of removing the excess dye can be carried out in the same plant (the dye can be easily separated from CO₂). During the dyeing, the CO₂ is circulated through a heat exchanger, through a vessel where the dye is dissolved and through a vessel where the dye is delivered to the textile. After the dyeing cycle the CO₂ is gasified, so that the dye precipitates and the clean CO₂ can be recycled by pumping it back to the dyeing vessel. This technique is available since the year 2011.

b. **Applicability, operational data and driving force for implementation**
The first production machine started operation at Thailand’s Tong Siang Co Ltd, part of the Yeh Group: the Yeh Group was the first textile mill to implement a new waterless dyeing process. The Yeh Group is pioneering this revolutionary new process. The Yeh Group is a worldwide supplier of innovative fabrics and finished garments that use the latest technologies in custom performance fabrics.
This technique will dye batches of between 100 and 125kg of fabric in an open width of 60 or 80 inches.

Supercritical CO₂ may act as both a solvent and a solute. Supercritical fluids have higher diffusion coefficients and lower viscosities than liquids, as well as the absence of surface tension, allowing better penetration into materials.
Costs savings and improvement of environmental performance are the main driving forces.
c. **Environmental benefit**
Many environmental benefits are achieved by using this technique. In particular: elimination of water consumption and wastewater discharges, elimination of wastewater treatment process, reduction in energy consumption, reduction in air emissions. Surfactants and auxiliary chemicals in dyes are eliminated, dye utilization is very high with very little residue dye. Unused dye can be recaptured.

d. **Economic aspects**
Water and energy costs savings.

e. **Reference literature**
http://www.dyecoo.com/

4.3.3 **Other measures**

This category summarises techniques not included in the previous sections but which are important if considered in the context of the paragraph concerning the dyeing process.

4.3.3.1 **Ref. Datasheet 1.B.2: pH-controlled dyeing techniques**

a. **Description of the technique**
At a low pH the dye becomes attracted to the fibre through coulombic interactions, which furnishes additional bonding forces that cannot be broken by thermal agitation. At iso-pH the dye moves very quickly and with a low energy through the fibre. The pH-controlled dyeing is characterized by the fact that in the temperature-controlled dyeing the process is controlled by the dye bath consumption and thermal migration of the dye. Instead, with a pH-controlled profile the dyeing process is controlled by the adsorption of the dye onto the ionic fibre.

b. **Applicability, operational data and driving force for implementation**
The pH-controlled process is applicable to fibres with ionic behaviour (e.g. wool, polyamide, silk, etc.). This technique is applied in uni-dyeing processes, and also to dyeing acrylic fibres with basic dyes. It is also used for all kind of fibres with “neutral pH-dyeable” reactive dyes. pH steering during batch dyeing can be carried out by fitting the machine with dosing systems for acids and alkalis. With this method becomes difficult a punctual control of the pH profile. This technique is limited to machines where the goods and liquor are well mixed. Another alternative technique is the generation of a pH-buffer during the dyeing process. Though this technique is very expensive, it tends to be preferred by textile companies because there is no need to measure the pH in a fully contained system. Savings in energy and time are the main driving forces for the implementation of this technique.

c. **Environmental benefit**
The iso-thermal dyeing allows that the use of special organic levelling agents or retarders can be avoided.
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With pH-controlled dyeing energy consumption and time are lower than with temperature-controlled process. A reduction of energy is possible since dye bath do not need to be heated from room temperature up to the migration temperature. Time is reduced because the heating and cooling phases are shorter. Moreover hot spent bath can be recycled.

d. Economic aspects
The bath does not need to be warmed up and cooled down according to a preset temperature profile. The resulting saving in processing time is therefore one major economic advantage of this technique. Additional benefits in terms of time and energy savings can be achieved when the hot spent dye bath is recycled.

e. Reference literature

4.3.3.2 Ref. Datasheet 3.B.1: Adoption of an enzymatic treatment to remove the non-fixed dyestuff not only from the fibre, but also from the exhausted dye bath

a. Description of the technique
This technique consists in using an enzymatic treatment to remove the non-fixed dyestuff not only from the fibre but also from the exhausted dye bath.

b. Applicability, operational data and driving force for implementation
The technique is only applicable to exhaust dyeing with reactive dyestuffs at this time. The steps of the enzymatic treatment are given below (batch process):

- filling with fresh water (50°C)
- addition of a buffer for adjusting the pH
- control of pH (addition of acetic acid, if necessary)
- addition of the enzymatic compound (0.25 g/l)
- running: 10 min
- draining

Cost-saving prospective and improved quality (higher fastness) of the final product are the main driving forces for the implementation of the technique.

c. Environmental benefit
This technique achieves water, energy and detergent consumption savings.

d. Economic aspects
Water, energy consumption savings and reduced process time are the economic benefits.

e. Reference literature
Ref. Datasheet 3.D.7: Exhaust dyeing of polyester and polyester blends with carrier-free dyeing techniques or with use of environmentally optimised carriers

a. Description of the technique
Exhaust dyeing of single polyester and polyester blends can be carried out either in autoclaves at high temperature (HT-dyeing at 130°C, which is usually applied for pure PES and wool-free PES blends) or at normal dyeing temperatures (95°C–100°C, which is applied for PES/wool blends) with the help of so-called carriers. Carriers are absorbed to a great extent onto the PES fibre. They improve fibre swelling and encourage colourant migration. In dyeing and rinsing a significant amount of carriers is emitted to wastewater. The fraction that remains on the fibre may be emitted to air during subsequent drying, heat setting and ironing.

Active substances used in carrier formulations include:
- chlorinated aromatic compounds (mono-chlorobenzene, trichlorobenzenes etc.)
- o-phenylphenol
- biphenyl and other aromatic hydrocarbons (trimethyl benzene, 1-methyl naphtalene etc.)
- phthalates (diethylhexylphthalate, dibutylphthalate, dimethylphthalate)

The application of HT-dyeing processes avoids the use of carriers. It is still necessary to use carriers when dyeing polyester blends and, in particular, polyester/wool blends due to the sensitivity of the wool substrate to high temperatures. In these cases, hazardous carriers can be replaced by chlorine-free substances with improved toxicological and environmental characteristics. New carriers are based on:
- benzylbenzoate
- N-alkylphthalimide

b. Applicability, operational data and driving force for implementation
Carrier-free dyeing at high temperature can be applied to all PES qualities, provided that HT dyeing equipment is used. Application to PES blends depends on the sensitivity to high temperature of the fibres in the blend, being particularly critical for PES/WO blends. Dyeing with optimised carriers is applicable to all PES blends. In the case of benzylbenzoate carriers, applied concentrations range between 2.0 and 5.0 g/l (dyeing at boiling temperature; average liquor ratio).

Limit values enforced by environmental legislation on workplace safety have been one of the main driving forces in the process of elimination/substitution of halogenated and other hazardous carriers.

Moreover, prescriptions regarding dye carriers are required by eco-label schemes for textile product.

c. Environmental benefit
In the case of HT-dyeing processes, wastewater and off-gas are carrier-free. Odour nuisance is negligible. Water savings could also be obtained.

d. Economic aspects
Optimised carriers described in this section cost approximately the same as traditional carriers.
In Morocco costs can result by the intensive use of energy.

e. Reference literature

4.3.3.4 Ref. Datasheet 3.D.8: Use of non-carrier dyeable PES (PTT) fibres

a. Description of the technique
Any special processing steps or carriers to accelerate the dyeing process is used to dye or print standard disperse dyestuff of fibres made from polytrimethylene terephthalate (PTT) because this is a non-carrier dyeable PES-fibres.

b. Applicability, operational data and driving force for implementation
PTT fibres are easy to process and to manufacture. They can be used with all machinery making little modifications. They may have extensive applications in carpeting, textiles and apparel, engineering thermoplastics, non-woven, films and mono-filaments given their performance. Disperse dyes are the advised dye class for PTT, for dark shades in particular. Basic dyes can also be used, but only for light shades. Dyeing equilibrium for a medium shade depending on the dyes chosen and it is obtained in 30 to 60 minutes. From 30 to 45 minutes holding time at 100°C permits good dye utilization without compromising productivity. The strict limits required by environmental legislation and the leading voluntary eco-label schemes are the main driving forces.

c. Environmental benefit
This technique permits environmental benefits in the dyeing process compared to conventional ones, such as:
- No emissions of carriers in the workplace and in the environment
- Energy saving compared with PET dyed under high-pressure-high-temperature (HT) conditions

d. Economic aspects
Less cost of dyeing is achieved thanks to low dyeing temperature and the broad dyeing pH allowance. Moreover, environmental costs associated with the presence of carriers are avoided.

e. Reference literature

4.4 End of pipe techniques
Even if the preventive measures should have a higher attention in the identification of techniques to reduce the impact of any industrial sector, the end of pipe techniques have still a high relevance in textile sector for several reasons. Firstly, there are still some chemicals that can’t be substitute in the process with other more eco-friendly without quality products alteration. This aspect means the presence of some pollutants in the process that can be removed only at the end of it. The second reason
is linked with the importance of water as input in the textile process. Several finishing activities of the sector need water and so cause wastewater. There are some research that are carrying out experimentations related for example to apply the dyeing process without water, but these are still not so disseminated and with some issues to solve from the technical and economic viability point of view. Finally the water is not important for the sector but also as resource at all. For this reason advanced techniques in the waste water treatment allow the textile companies to obtain an high quality water after the treatment that could be re-used in the process (e.g. first rinsing activities) reducing the water footprint of the textile fabric.

4.4.1 Ref. Datasheet 4.A.1: Treatment of mixed waste water with about 60% water recycling

a. Description of the technique
This is an example that shows how to recycle the treated effluent partially through an on-site treatment of mixed textile water. Before treatment, the hot streams (> 40°C) are subjected to heat recovery. Then the mixed effluent goes through the following steps:

- equalisation (about 20 hours equalisation) and neutralisation
- activated sludge treatment in a special system consisting of loop reactors (dry matter content in the reactors: about 35 g/l) and clarifiers. In this system the biodegradable compounds are completely removed (< 5 mg/l). Lignite coke powder improves and stabilises biodegradation efficiency. Organic compounds and oxygen (buffer function) are temporarily adsorbed by lignite; moreover, micro-organisms growing on lignite powder can be enhanced in the system
- adsorption stage: 0.8 - 1 kg/m³ of lignite coke powder (with a specific surface of 300 m²/g) is added to remove dyestuff and other compounds that are hardly or non-biodegradable (the content of dry matter in the reactors is about 40 g/l). The lignite coke powder is recycled thanks to adsorbers and activated sludge loop reactors after sedimentation.
- flocculation/precipitation and the resulting flotation to remove the sludge is a fundamental step. This technique serves to remove the lignite powder (otherwise incomplete) and consist in adding alum sulphate and an anionic polyelectrolyte as flocculants (about 180 g/m³) and an organic cationic flocculants to avoid breaching local limits of colour.
- In order to remove organic compounds and suspended solids a filtration in a fixed bed gravel filter is required. After two-thirds of the flow undergo first a filtration in an activate carbon filter to remove the traces of organic compounds and then a desalination in a reverse osmosis plant. The remaining flow is discharged to the river.

The permeate is mixed with fresh water in the reverse osmosis plant and is used for all finishing processes, whilst the salty concentrate is re-used for the preparation of the brine solution needed for reactive dyeing. The treated wastewater is stocked in a tank and conditioned with ozone (about 2 g/m³) in order to avoid any biological activity. The effluent is colourless and the inorganic and organic charge is very low. Both the sludge from floating and the excess sludge from the activated sludge system are
dewatered in a thickener and decanter. Then it is thermally regenerated in a rotary kiln. The off-gas from the kiln is about 450°C. The flue-gas is subject to post-combustion at 850°C and finally the heat from the final off-gas is recovered by heat exchange (final emitted air temperature is about 120°C).

b. **Applicability, operational data and driving force for implementation**

This technique is applicable to all kinds of textile wastewater. There are no limitations for recycling by using this technique. However, additional treatment (ion exchange and reverse osmosis) is required to remove salt and hardness ions (mainly calcium extracted from cotton). Moreover the recycling of lignite cook is possible without limitations. Ash removed from off-gas after heat recovery has to be considered as hazardous waste. The specific quantity is 5 g/m³ treated effluent. The limitation of groundwater supply is the main driving force.

c. **Environmental benefit**

Reduction of wastewater is achieved and the non-recycled water contains a slow amount of organic compounds residual. Moreover this technique allows about 50% neutral salt saving.

d. **Economic aspects**

The costs are very high but they can be written off over time.

e. **Reference literature**


4.4.2 **Ref. Datasheet 4.A.2: Recycling of textile waste water by treatment of selected streams with membrane techniques**

a. **Description of the technique**

Membrane techniques are applied in several ways. In particular it is used for the treatment of segregated streams to allow water reclamation and re-use closely integrated with the process. It can also be applied to other kinds of effluents, such as the desizing effluents including those resulting from the enzymatic desizing of fabrics treated with starch and modified starch sizes.

The examples below show how membrane techniques could be used:

Plant A) If the company treats woven fabric, cotton in particular, rinsing operations account for most of the wastewater produced. Wastewater from pretreatment (scouring and bleaching) and finishing (residual padding liquors) is discharged to the municipal wastewater treatment plant and it is not treated in the membrane. The first membrane step is an ultrafiltration tubular ceramic module, to enable the removal of all residual particles and polymers. About 90% of the feed can be recycled for most processes. However the re-use of the treated water has to be valued very well.

Plant B) Also this example refers to a company finishing cotton fabric. The measures include:

- a reclamation and re-use of dye bath and first rinsing water after reactive dyeing by treating the highly coloured and salted water with activated carbon. The latter retains the dyestuff and other organic chemicals and delivers clear, hot water with sodium chloride and sodium hydroxide for re-use.
Membrane filtration is used to recovery and re-use of rinsing water after dyeing (e.g. with nanofiltration).

b. **Applicability, operational data and driving force for implementation**
All textile finishing industries can use this technique. Plant A has encountered many problems since 1995, the removal of fibres and particles and the ultrafiltration of chemicals in particular.

The plant treats about 900 m³/week wastewater, 800 of which can be used for all washing/rinsing operations. The plant is operated batch-wise. The concentrate is physico-chemically treated in an external plant. For further optimisation, plans are in hand to treat the concentrate by evaporation (in order to achieve 15% water content) and then it is subject to incineration.

c. **Environmental benefit**
Water saving and a reduction of wastewater discharge are the main benefits.

d. **Economic aspects**
The cost of 10 m³/h membrane equipment is about 1 million euro altogether (plant A).
In Plant B, a payback period of 5 years is reported for recovery and re-use of dye bath by processing with activated carbon. 8 months is the time for membrane treatment and recycling of rinsing water from dyeing.
In Morocco this technique is expensive in terms of investment and maintenance and for this reason applicable for medium and large companies.

e. **Reference literature**

4.4.3 Ref. Datasheet 4.A.3: Application of physical-chemical processes and cross-flow filtration

a. **Description of the technique**
The developed purification system is composed of a sequence of treatments:
- Balance tank, in order to allow the homogenization of the wastewater to be treated;
- Clarification (coagulation + sedimentation or coagulation + flotation) and filtration with sand, aimed at a massive reduction of the pollution load;
- Cross-flow filtration with flat membranes for the complete removal of suspended solids and turbidity;
- Advanced chemical oxidation with ozone, which allows the oxidation of the residual dyestuffs and a disinfection of the water.

b. **Applicability, operational data and driving force for implementation**
The technique has been tested in four different pilot plants - having a high automation degree and in-let flow rates ranging from 5 to 10 m³/h. The prototypes were installed in four textile mills (end-users): a dyeing mill, a finishing mill, a washing mill, a dyeing/finishing mill.
It has been evaluated that a textile wet industry needs 200-500 litres of freshwater in order to produce 1 kg of finished product.
In Morocco this technique can be applied in large companies.
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**c. Environmental benefit**
The obtained removal (%) for the four case-studies is in line with expected values: COD removal: 60%; Total surfactants removal: 50%; Colour removal: 85%; Total suspended solids removal: 95%; Turbidity removal: 90%.
The saving of freshwater, which can be obtained through the reuse of the treated wastewater, represents the most important result of the technique
High level of abatement of wastewater pollutants. Possibility to re-use the water in the process.

**d. Economic aspects**
Operating costs of the prototypes are very interesting, especially if in the near future the cost of the freshwater and of the treatment in centralized plants will increase. At the four case-study sites involved in the project, the operating costs of the system range between 0.78 and 2.37 €/m³; the variation depends on the different optimizations needed at each site.

**e. Reference literature**
PROWATER Life project results: http://www.tecnotex.it/prowater/


**a. Description of the technique**
Application of photo-oxidation techniques for the removal of biodegradable and non-biodegradable organic compounds found in textile wastewater has been developed at semi-industrial scale. This technique can be used as complement to the biological degradation techniques used nowadays in conventional depuration plants. The treatment takes place in a homogenous phase and under acid pH, consisting in the addition of Fe²⁺/H₂O₂ either in the presence of light or in the dark. At the end of the reaction, the iron is eliminated in the form of colloidal particles, which are separated by a physico-chemical treatment that also drag along any suspended particle, completing the efficiency of the treatment.

**b. Applicability, operational data and driving force for implementation**
The Technique of photo-oxidation treatment has been demonstrated at semi-industrial scale, with a 1 m³/h depuration volume, is able to improve the water quality compared to the conventional treatments, so water can be reused and recycled. To demonstrate this, a photo-reactor that works at 1 m³/h volume has been built, in which a photo-oxidation reaction is done to the water through the irradiation of light in the ultraviolet-visible spectre. The chemical process that takes place is photo-Fenton, an advanced oxidation reaction, which achieves the degradation of organic matter. This technique uses H₂O₂ as oxidant and Fe²⁺ salts as catalyst, which are converted into Fe³⁺ in the process. To improve the performance of the reaction, ultraviolet light is used on the dissolution. A very energetic reaction is produced, which allows for the rupture of the covalent bonds of the organic molecules and achieves the biodegradability of the matter.
The advantage of this kind of techniques is that they are little specific. The degradation of organic substrates is derived from its generality, which comprises a high number of
organic compounds with a great variety of functional groups. So this technique can be effective in the treatment of several kinds of effluents.

c. **Environmental benefit**
The first analytics shown that the photo-oxidation treatment can provide reductions of up to 50% in organic pollutant load. Note that in order to separate iron as precipitate, a basic pH (≈ pH 8) is needed because on the contrary, output samples show colour, iron and high turbidity, which entails solids in suspension.

d. **Economic aspects**
Water and chemicals consumption savings.
In Morocco this technique is usually applied only by large companies (i.e. companies with more than 250 employees) because it requires huge investments.

e. **Reference literature**
Fototex Life project results: www.aitex.es/en/home.html

### 4.4.5 Ref. Datasheet 4.A.5: Purification of Industrial And Mixed Wastewater By Combined Membrane Filtration And Sonochemical Technologies

a. **Description of the technique**
Use of ultrafiltration (UF) combined with sonication (US) for the refinement of treated effluent to be reused in wet textile processes.
Membrane processes have the potential to remove dyestuff and allow reuse of the auxiliary chemicals used for dyeing or to concentrate the dyestuffs and auxiliaries and produce purified water. Ultrafiltration (UF) is effective in removing particles and macromolecules. Power ultrasound produces its effect via cavitation bubbles. During cavitation, bubbles collapse, producing intense short term local heating at high pressures.

b. **Applicability, operational data and driving force for implementation**
The technique has not yet been applied on full industrial scale, but has only been tested on a pilot scale on the secondary effluent of the Baciacavallo WWTP which treats part of the effluents of one of the largest textile industries district in Italy. The membrane filtration process was optimized in terms of running time, backwash, chemicals addition and cleaning procedures. The sonication treatment was optimized in terms of hydroxyl radical’s formation rate, frequency, acoustic power, hydrogen peroxide addition, contact time and pH. According to the experimental results the best configuration within the Baciacavallo WWTP was the sonication of non-ozonated wastewater followed by the ultrafiltration. The combined treatment guaranteed the compliance with the target values for wastewater reuse in wet textile industries.
Operating the filtration process under optimized conditions is highly desirable for economical and environmental reasons. Optimal set points assure process stabilization as well as cost reductions in terms of permeate, energy, and chemical savings.
Due to the complexity of a multivariate filtration process it is very difficult to realize the optimal operational settings in real time.
By applying an automated control system it can be ensured that the filtration performance is always stable and optimal in terms of the adjusted parameters.
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Driving forces for the implementation of the technique are the effectiveness of the technique and costs savings.

c. **Environmental benefit**

The combination of the Ultrafiltration technology and Ultrasonic treatment seems to be a promising approach for wastewater purification since the peculiarity of each technology, the physical separation and the sonochemical oxidation, allow reducing the pollution load of the investigated mixed wastewater.

d. **Economic aspects**

Reduction of chemicals consumption.
Reduction of laboratory costs.

e. **Reference literature**

PURI FAST Life project results: http://purifast.tecnotex.it/project.asp

4.4.6 Ref. Datasheet 4.A.6: Appropriately treat industrial wastewater by implementing a combination of suitable waste purification techniques

a. **Description of the technique**

In some cases it is important to treat specific partial flows before they are sent to the central wastewater purification system.

The first purification aims to remove solids and sedimentary matter from wastewater. Secondary purification is about the removal of organic substances and nutrients. The tertiary purification aims to purify wastewater or to remove components from wastewater that are difficult to break down.

Techniques concerning tertiary purification are also used for pre-treating partial flows. Here some wastewater purification techniques:

- Anaerobic purification
- Biological purification
- Dosing active carbon in biological purification
- Membrane bio-reactor
- Chemical precipitation (coagulation-flocculation)
- Micro filtration, ultrafiltration
- Nano filtration, reverse osmosis
- Sand filtration
- Adsorption chemical oxidation
- Ozonisation
- Evaporation
- Incineration

These techniques can be combined together for the wastewater treatment.

b. **Applicability, operational data and driving force for implementation**

As indicated above, these techniques can be combined together. The opportunity to combine together many techniques is one of the driving forces for the implementation.

In Morocco difficult to apply currently: not enough surface on production sites; homogenisation tanks are frequently used to mix wastewater before treatment.
c. **Environmental benefit**
The implementation of a combination of wastewater purification techniques allows to reducing the quantity of impurities affecting environment (soil, ground, water). In some cases, these techniques determine waste, require energy and chemicals. Odour problems can emerge when wastewater purification installations does not function optimally.

d. **Economic aspects**
Costs price for wastewater purification depends on single situation. Type, configuration and size of wastewater purification plant, as also costs, are determined by discharge situation, wastewater load, and the to-be-treated volume.

e. **Reference literature**
Best Available Techniques for the Textile Industry, Flemish Centre for Best Available Techniques –VITO-, 2010, paragraph 4.2.3.


a. **Description of the technique**
Bio sludge from a domestic wastewater treatment plant has adsorption ability on disperse dyes and organic matter. This technique can be applied due to the high absorption ability of bio sludge and to its ability to be reused after washing with a diluted alkali solution. Further increases in dye removal could be achieved with addition of glucose into the systems (e.g. SBR, GAC-SBR systems).

b. **Applicability, operational data and driving force for implementation**
This technique has been tested on two kind of disperse dyes: disperse red 60 and disperse blue 60.
At pH values of 7.8 + 0.2 for SBR and GAC-SBR systems, the dye adsorption capacity of acclimatized bio sludge is about 30% higher than that of non-acclimatized bio sludge. The dye adsorption capacity of resting type of acclimatized bio sludge decreased by about 5-7% with autoclaving.

c. **Environmental benefit**
COD, BOD, TKN (total kjeldahl nitrogen) and dyes reduction in wastewater are possible

d. **Economic aspects**
No data are available

e. **Reference literature**

4.4.8 Ref. Datasheet 4.A.8: Anaerobic degradation of textile dye bath effluent using Halomonas sp

a. **Description of the technique**
This technique provides a reduction of COD and colour of the effluent containing reactive textile dye by microbial method. Anaerobic digestion has the potential to
break down complex refractory organic compounds. In this way compounds may be further degraded aerobically or to completely mineralize. This anaerobic digestion technique uses Halophilic and halotolerant Halomonas bacteria.

b. **Applicability, operational data and driving force for implementation**

The technique could be applied to wastewater produced by azo-reactive dye used by a nearby textile industry. Halophilic and halotolerant bacterial culture Halomonas variabilis and Hamolonas glaciei have been used for degradation in batch-mode static condition. At a constant temperature of 30°C and using a CO₂ incubator, maximum degradation was achieved within 144 hours of experimental run. BOD and COD reduction rate were optimal in the concentration of 1297 mg L⁻¹ for time duration of nearly 100 h. The environmental benefits deriving by the implementation of this technique are the main driving force for implementation.

c. **Environmental benefit**

Reduction of BOD, COD and dyes in wastewater are the main environmental benefits.

**Economic aspects**

No data are available.

d. **Reference literature**


4.4.9 **Ref. Datasheet 4.A.9: Colour removal of dyes from synthetic and real textile wastewater in one- and two-stage anaerobic systems.**

a. **Description of the technique**

This technique consists in decolourisation of the azo dye Congo Red (CR) model compound and real textile wastewater in one- and two-stage anaerobic treatment systems. High colour removals are achieved in both treatment systems even when a very high CR concentration is applied. The two stage anaerobic treatment has a slightly better stability and the acidogenic reactor plays a major role on dye reductions in respect to methanogenic reactor, evidencing the role of fermentative microorganism.

b. **Applicability, operational data and driving force for implementation**

The technique can be applied in synthetic textile wastewater and in real textile wastewater. No differences between the two treatment systems. Colour removal efficiencies were high for both systems. The high percentage of colour removal efficiency is the main driver for the implementation.

c. **Environmental benefit**

COD and dyes removals from wastewater.

**Economic aspects**

No data are available.

d. **Reference literature**

**a. Description of the technique**
This technique has the dual purpose of hydrogen production and biosorption of some toxic dyes and heavy metals present in textile wastewater. To this aim this technique consists in the integration of hydrogen production in photobioreactor with a packed bed biosorption column on lab-scale for removal of certain pollutants.

**b. Applicability, operational data and driving force for implementation**
This technique has been applied to simulated textile wastewater. Sustained and enhanced hydrogen production at average rates of 101 µmol/h/mg Chl a for 15 d was achieved by glucose supplement and anoxic gas sparging using free cyanobacterial biomass. The achieved environmental benefits are the main driving force for the implementation.

**c. Environmental benefit**
Removal of pollutants from wastewater.

**d. Economic aspects**
No data are available.

**e. Reference literature**

4.4.11 Ref. Datasheet 4.A.11: Textiles wastewater treatment using anoxic filter bed and biological wriggle bed-ozone biological aerated filter

**a. Description of the technique**
The refractory pollutants in textile industries cannot easily be degraded by traditional activated sludge process (ASP). Therefore, anoxic hydrolysis-acidification/aerobic biological treatment was regarded as a potential alternative process. In this technique anaerobic filter bed (AFB) was used as the hydrolysis-acidification reactor and BAF (biological aerated filter) was used as the aerobic reactor. Considering the textile wastewater hard-degradation characteristics, secondary aerobic treatment process was applied. The first reactor is defined as the biological wriggle bed (BWB), for the aeration was strengthened by increasing the ratio of aeration and wastewater influent. The second reactor is defined as O3-BAF, for O3 was utilized to remove colour and increase the biodegradability of the influent wastewater. The experiments were carried out in a pilot-scale AFB-BWB-O3-BAF reactor, placed at a textile wastewater treatment plant in China. The textile wastewater was pumped to
the bottom of the AFB by diaphragm pump (phase I). The anoxic effluent flowed by
gravity to the pre-oxic tank, which is a plastic bucket. Aeration was provided by
blower. The effluent of the pre-oxic tank was pumped to the bottom of the BWB
(phase II). The effluent flowed to a middle clarifier which was divided to three parts.
The effects of the three parts were influent, sedimentation and ozonation,
respectively. The effluent of the middle clarifier was pumped to the BAF whose
construction was similar with the BWB reactor (phase III).

b. **Applicability, operational data and driving force for implementation**
The described technique can be applied to new and existing installations
All experiments were performed at 25–33°C. The operating conditions were divided to
three phases (phases I, II and III) according to the variation of the influent flow. Both
reactors were backwashed periodically so that the accumulated suspended solid (SS)
and the excess biomass could be removed. The average COD removal efficiencies were
74.1%, 82.5% and 84.1%, in phases I, II and III, respectively.
Environment protection and a less COD load in water are the main driving forces.

c. **Environmental benefit**
Decrease of COD and SO₄²⁻ load and reduction of pH value in effluent water
d. **Economic aspects**
High costs, also for maintenance.
e. **Reference literature**
Z. Fu, Y. Zhang, X. Wang; Textiles wastewater treatment using anoxic filter bed and
biological wriggle bed-ozone biological aerated filter; Bioresource Technology 102

the removal of colour, reduction of heavy metals, and toxicity from textile
dye effluent

a. **Description of the technique**
This technique is focused on the characterization and decolourization of local textile
mill effluent and RO16 dye by three bacterial consortia at laboratory scale. Enzymes
involved in the degradation of RO16 were assayed and metabolites formed after
degradation was analyzed.
The effluent predominantly contained a mixture of reactive azo dyes viz.
A novel bacterial consortium DAS capable of decolorizing textile effluent was isolated
from soil samples of the textile industry effluent site by an enrichment culture
technique. DAS consists of 3 bacterial strains: SUK1, LBC2 and LBC3 were able to grow
and degrade various textile dyes.
b. **Applicability, operational data and driving force for implementation**
The described technique can be applied to new and existing installations.
A loopful of each microbial culture was inoculated for 24 h in 10 ml culture tubes
containing 5 ml nutrient broth to develop the consortium. A 24-h culture of each
bacterial isolate (5 ml) was added to 250-ml Erlenmeyer flask containing 100 ml of
textile effluent (undiluted). The flasks were further incubated to observe the time
required for the decolourization. Aliquots (3 ml) of the culture media were withdrawn
at different time intervals, centrifuged at 7669g for 15 min to separate the bacterial
cell mass. Decolourization of the textile effluent was analyzed using a UV–Vis spectrophotometer at 490 nm. Costs savings and less toxicity of textile effluent are the main driving forces for the technique implementation.

c. **Environmental benefit**
After inoculation, the COD analysis of the textile effluent supernatant carried out at various time interval, showed a decrease in COD from 6760 mg to about 1440 mg in 48 h incubation. The observed COD reduction of 78% indicates the partial mineralization of textile effluent due to bacterial consortium DAS. Similarly, the BOD reduction was also achieved by this bacterial consortium. Moreover the microorganisms can be very efficient accumulators of the metals. For this reason, the technologies based in the microorganisms are often the alternative treatments, that are viable or helping conventional techniques in the elimination or recuperation of metals. Moreover a less toxicity and genotoxicity is achieved by using this technique.

d. **Economic aspects**
Costs savings compared with traditional methods. In Morocco government funding is requested.
e. **Reference literature**


a. **Description of the technique**
This technique shows the potential of fungus Aspergillus niger and alga Spirogyra sp. as biosorbent for the removal of Synazol reactive dye from multicomponent textile effluent.

b. **Applicability, operational data and driving force for implementation**
The described technique can be applied to new and existing installations. After washing the fungal and algal biomasses with deionised water, they were dried at 80 °C for 20 h. The dried biomasses were ground in a mortar and pestle before use, to obtain larger surface area and were termed as the raw biomasses. Also, the washed biomasses were pre-treated by autoclaving (121°C for 20 min) or gamma radiation (5 kGy, sufficient dose for inactivate fungal biomass) before drying. The pre-treatment of biomasses either with autoclaving or gamma irradiation increased the adsorption capacity for this dye effluent. In all tests, the fungus and alga biomasses were removed from the treated solutions by centrifugation (4000 rpm) for 5 min and the supernatants were collected and analyzed for residual dye concentrations. The efficiency of dye removal was expressed as the percentage ratio of decolorized dye concentration to that of initial one. The percentage of dye removal varies with pH ranges. The maximum percentage of dye removal 42% and 36% for fungus and alga biomasses, respectively, was obtained at pH 3. Temperature is also important, maximum dye removal (44% and 36%) for fungus and alga biomasses, respectively, was obtained at 30°C. Moreover the percentage of dye removal increased and the
maximum dye removal of 84% and 80% was obtained at biomass concentration of 8 g/l for A. niger and Spirogyra sp., respectively. Costs savings and less toxicity of textile dyes are the main driving forces for the technique implementation.

**c. Environmental benefit**
Improvement of water quality of dyes that may be toxic, carcinogenic and even mutagenic.

**d. Economic aspects**
Costs savings compared with traditional methods.

**e. Reference literature**


**a. Description of the technique**
This technique shows the potential application of *Chlorella vulgaris* UMACC 001 for bioremediation of textile wastewater (TW) using four batches of cultures in high rate algae ponds (HRAP).

**b. Applicability, operational data and driving force for implementation**
The described technique can be applied to new and existing installations. Ten microalgae were screened for their ability to grow in TW (Textile Wastewater) and remove colour from the wastewater using flask cultures. Three azo dyes were used, namely Supranol Red 3BW, Lanaset Red 2GA, Levafix Navy Blue EBNA and the textile wastewater (TW) was collected from a garment factory located at Senawang Industrial Estate, Negeri Sembilan (Malaysia). Ten millilitres of exponential cultures, standardised at an optical density at 620 nm (OD620) of 0.2, were inoculated into 90 ml of TW in 250 ml conical flasks in triplicate. The cultures were grown for 10 days in an incubator shaker (150 rpm) set at 25°C, with an irradiance of 40–60 lmol/m²/s on a 12:12 h light–dark cycle. Initial pH of the TW was adjusted to 7.0 prior to inoculation. Pollutants reduction in textile wastewater is the main driving force for the technique’s implementation.

**c. Environmental benefit**
Reduction of pollutants such as COD, NH₄–N and PO₄–P in textile wastewater.

**d. Economic aspects**
No data are available.

**e. Reference literature**

a. **Description of the technique**
   Chemical coagulation and flocculation in wastewater treatment involves the addition of chemicals to alter the physical state of dissolved and suspended solids and facilitate their removal by sedimentation. In some cases the alteration is slight, and removal is affected by entrapment within a voluminous coagulate consisting mostly the coagulant itself. Another result of chemical addition is a net increase in the dissolved constituents in the wastewater. Coagulation is used for removal of the waste materials in suspended or colloidal form that do not settle out on standing or may settle by taking a very long time. In water treatment, coagulation as pre-treatment is regarded as the most successful pre-treatment.

b. **Applicability, operational data and driving force for implementation**
   To improve the efficiency of coagulation process, number of high molecular weight compounds such as polymers from synthetic or natural origin may be recommended. These polymers can function as coagulant itself or in the form of coagulant aids/bioflocculants, depending upon the wastewater and polymer characteristics. In contrast to some traditionally used coagulant such as alum, organic polymers are beneficial because of the lower coagulant dosage requirement, efficiency at low temperature and produce small volume of sludge whereas inorganic polymers and chemical coagulants generally involve higher cost, less biodegradability and toxicity. Less toxicity of textile wastewater is the main driving force

c. **Environmental benefit**
   Improvement of wastewater quality.

d. **Economic aspects**
   No data are available

e. **Reference literature**


a. **Description of the technique**
   This technique regards the UASB (upflow anaerobic sludge blanket) reactor in terms of its efficiency in removing colour and COD in the treatment of RTW (real textile wastewater). Real textile wastewater collected from a textile factory (Pacific Group, Wuxi, PR China) was used. The investigation was carried out in seven experimental stages including reactor start-up. Chemical oxygen demand removal in all experimental stages was over 97% except stage VII where COD removal was about 90%. Low COD removal in stage VII was merely due to the low COD in effluents. Colour removal in all experimental stages was over 92%.

b. **Applicability, operational data and driving force for implementation**
A laboratory scale UASB reactor was used. The flow distributor was placed at the bottom of the reactor to distribute influents evenly from the bottom. The solid–gas–liquid separator was also kept in the upper part of the reactor to prevent the loss of granules from the reactor and for easy release of the gas produced by anaerobic digestion. A peristaltic pump with a constant discharge flow was used to pump the substrate into the reactor. The reactor was operated at 35 ± 3°C in a temperature-controlled room. Total alkalinity, pH, total suspended solids (TSS), total volatile suspended solids (TVSS) and total phosphorus were determined.

c. **Environmental benefit**
Improvement of wastewater quality. COD removal of about 90%.

d. **Economic aspects**
No data are available

e. **Reference literature**


a. **Description of the technique**
Dye decolourization carried out by relatively unspecific fungal oxidative enzymes leading to both decolourization and detoxification in the first step with a subsequent degradation of the degradation products by bacterial communities in the second step is investigated. The aim of the technique was to investigate the degradation potential of the preselected white-rot fungus *I. lacteus* immobilized on polyurethane foam/straw carrier in a trickling filter reactor to decolourize chemically different, model textile dyes and textile dye house wastewater and to prove its applicability in sequential use with a mixed bacterial consortium for decolourization of recalcitrant dyes and textile wastewater and for total organic carbon (TOC) removal. The dye and TOC removal shares of the fungus and mixed bacterial cultures during the sequential use of both cultures were determined.

The results confirmed poor decolourization obtained with mixed bacterial communities where the observed dye removal by the sludge is thought to be mostly through adsorption. The subsequent application of the fungus resulted in an efficient decolourisation.

b. **Applicability, operational data and driving force for implementation**
Three textile colouring bath liquids were used in the experiments. Wastewater I contained anthraquinone dyes Indanthrene Blue FF and Ostanthrene Blue GA; wastewater II contained substantive dyes Solophenyl green BLE 155% and Solophenyl yellow ARLE 154% (Cibafix yellow E-R) and a colour additive Avolan IW (alkyl polyglycol ether); wastewater III contained reactive dyes Bezactive red V-RB, Remazol yellow GR gran. 133% and Remazol bordo B (C.I. Reactive Red 49).

The initial treatment with the fungal culture lasted 3–8 days. Subsequently, the liquid from the 1st step was transferred to the second reactor containing the immobilized bacteria for a 9–12-d treatment.
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Less toxicity in wastewater is the main driving force for the implementation of this technique.

c. **Environmental benefit**
   Improved wastewater quality is the main benefit.

d. **Economic aspects**
   No data are available.

e. **Reference literature**
   Cenek Novotny, Katerina Svobodová, Oldrich Benadaa, Olga Kofronová, Andreas Heissenbergerb, Werner Fuchs; Potential of combined fungal and bacterial treatment for colour removal in textile wastewater; Bioresource Technology 102 (2011) 879–888.


a. **Description of the technique**
   Use of electrochemical oxidation process appears to be a promising alternative to solve the environmental problem generated by the discharge of textile effluent. The results implies that increase of current density lead to reduction in COD, TS (total solids), TDS (total dissolved solids) and TOC (total organic carbon) and at a current density of 28 mA/cm², maximum of 68% COD was reduced. During the treatment process, the colour removal efficiency reached maximum efficiency (96%) within 60 min at the same condition.

b. **Applicability, operational data and driving force for implementation**
   Experiments were carried out in five different pH ranges (7.5, 5.2, 3.5, 2.9, 1.7 and 1.3) at a constant current density of 28 mA/cm². The rate of COD reduction increased significantly (from 22% to 68%) when the pH was decreased from 7.5 to 1.3. Experiments were carried out in a square packed-bed electrochemical reactor. It consists of an axial field configuration with about 0.15 m sides and 0.25 m height in laboratory scale at ambient conditions having dimensions 25 cm x 13.5 cm x 13.5 cm. Graphite rod was used as anode and stainless steel acted as cathode and the gap between the electrodes was kept constant at 6 cm. Experiments were carried out at a fixed potential difference of 8 V. Wastewater was collected from the common effluent treatment plant. The technique has been experimented in Chennai (India).

c. **Environmental benefit**
   Improvement of wastewater quality, reduction of COD and TS.

d. **Economic aspects**
   High costs due to electricity.

e. **Reference literature**

a. **Description of the technique**
Coir pith, a waste material from coir industries, causes a disposal problem. Being resistant to biodegradation it is heaped along road sides. Since the material is rich in lignocellulose, an effective solution to the problem may lie in the use of the material for the preparation of activated carbon used to remove dye in textile effluents. The removal of dyes by CPC (coir pith activated carbon) was found to be a maximum in the acidic pH range of 1–3 and in all cases the dye uptake increased with increasing doses of carbon. The adsorption capacity was not significantly affected by the presence of chloride ion but, increase in sulphate ion concentration beyond 2000 mg/l enhanced the adsorption capacity of carbon. The BDST analysis of absorption of dyes showed linear relationship between bed depth and service time, which could be used successfully for scale-up purposes. Regeneration of the carbon was found to be effective with 1.0 M NaOH and the regenerated carbon was found to be effective up to 3 cycles of operation. Application of the carbon to textile effluent decolourisation studies showed significant removal of colour and COD.

b. **Applicability, operational data and driving force for implementation**
Powdered activated carbons (PAC) are preferred over granular activated carbon (GAC) in liquid phase batch application because of their high adsorption capacity.

c. **Environmental benefit**
Reduction of use hazardous chemicals in textile wastewater treatments plants, re-use of a waste generated by other industries.

d. **Economic aspects**
Costs savings because the exhausted carbon can be regenerated and reused.

e. **Reference literature**


a. **Description of the technique**
In view of the high cost and associated problems of regeneration, there is a constant search for alternate low cost adsorbents to treat textile wastewater. This technique dealt with the removal of commercially used textile dye, reactive blue MR (RBMR) from aqueous solution using carbon prepared from silk cotton hull as an adsorbent (SCHC). The removal increases with time and attains equilibrium within 75 min for all concentrations studied (10–40mg/l) and it increases with increasing carbon dosage while adsorption of dye decreased with increasing pH and the percentage desorption increased with increasing NaOH concentration in the aqueous medium and attained a maximum desorption at 0.6 N NaOH solution.
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b. **Applicability, operational data and driving force for implementation**
The silk cotton hull was collected from Coimbatore, India. The dye used was commercially available textile dye (RBMR) obtained from Diamond Dyes, Mumbai, India. Costs saving and less use of hazardous chemicals are the main driving forces for the implementation of the technique. In Morocco skills are requested to apply this technique.

c. **Environmental benefit**
Minimize hazardous chemicals in textile industries.

d. **Economic aspects**
Costs saving by using this kind of adsorbent. In Morocco skills are requested to apply this technique.

e. **Reference literature**

4.4.21 Ref. Datasheet 4.A.21: Biological and oxidative treatment of cotton textile dye-bath effluents by fixed and fluidized bed reactors

a. **Description of the technique**
Treatability of dye-baths by oxidative and biological methods represents the condition of segregated dye-bath stream treatment and to facilitate the advantages of water segregation and reuse. Hence, the objectives of this technique were assessment of biodegradability of azo dye-baths, determination of the treatability by using a cheap material for adsorption and biofilm attachment media and enhancement of biodegradability by ozone oxidation. Treatment of remazol reactive dye-baths by using brown coal-packed reactors is advantageous to obtain high removal efficiencies that may not be easy to achieve by conventional systems.

b. **Applicability, operational data and driving force for implementation**
For this purpose, samples from defined process lines of remazol dye-bath effluents were collected from two different textile plants (enterprise I and II) in Istanbul, Turkey. The enterprises are classified under the knit fabric dyeing and finishing subcategory, involving cotton, polyester and polyamide products. Two reactors (fixed bed reactor and up-flow fluidized bed reactor) with different configurations were set up and operated to treat various concentrations of dye-bath effluents. Brown coal char (lignite), a low price material, was used in the reactors as a packing medium. The fixed and fluidized bed reactor effluents for enterprise-II had COD concentrations of 124 and 168 mg/l corresponding to 90% and 83% COD removal respectively. The colour reduction efficiency was around 99% for the fixed bed reactor. The efficiency was slightly lower for the fluidized bed reactor.

c. **Environmental benefit**
Improvement of wastewater quality. COD reduction

d. **Economic aspects**
Cost savings achieved by using brown coal char as packing material
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\textbf{a. Description of the technique}

The nonviable biomass of \textit{Aspergillus niger}, \textit{Aspergillus japonica}, \textit{Rhizopus nigricans}, \textit{Rhizopus arrhizus}, and \textit{Saccharomyces cerevisiae} were used for biosorption of textile dyes. The selected anionic reactive dyes were C.I. Reactive Black 8, C.I. Reactive Brown 9, C.I. Reactive Green 19, C.I. Reactive Blue 38, and C.I. Reactive Blue 3. Experiments were conducted at initial dye concentration of 50, 100, 150 and 200 mg/l. \textit{S. cerevisiae} and \textit{R. nigricans} were good bio sorbents at initial dye concentration of 50 mg/l, 1 g\% (w/v) biomass loading and 29 ± 1 °C. \textit{R. nigricans} adsorbed 90–96\% dye in 15 min, at 20 °C and pH 6.0. The data showed an optimal fit to the Langmuir and Freundlich isotherms. The maximum uptake capacity (\textit{Qo}) for the selected dyes was in the range 112–204 mg/g biomass. Adsorption kinetic studies showed \textit{R. nigricans} to be the best adsorbent with 90–96\% adsorption of the selected dyes at the specified conditions: pH 6, 20°C, 120 rpm shaking at 50 mg/l initial concentration of the dye and 1 g\% biomass loading.

\textbf{b. Applicability, operational data and driving force for implementation}

The described technique can be applied to new and existing installations. Powdered nonviable biomass of \textit{R. nigricans}, \textit{Rhizopus arrhizus}, \textit{Aspergillus niger}, \textit{Aspergillus japonica}, and \textit{Saccharomyces cerevisiae} were the selected bio sorbents. These microorganisms are produced in large quantities as unwanted by-products of fermentation industries, which make them an interesting target for examination of their dye biosorption potential. Costs savings and less toxicity of textile effluent are the main driving forces for the technique’s implementation.

\textbf{c. Environmental benefit}

These microorganisms have been found to be excellent bio sorbents of toxic heavy metals and radioactive compounds allowing a reduction of these compounds in wastewater.

\textbf{d. Economic aspects}

Costs savings compared with traditional methods.

\textbf{e. Reference literature}


4.4.23 Ref. Datasheet 4.B.1: Oxidation techniques (thermal incineration, catalytic incineration), Condensation techniques (e.g. heat exchangers), Absorption techniques (e.g. wet scrubbers), Particulates separation techniques (e.g.
electrostatic precipitators, cyclones, fabric filters), Adsorption techniques (e.g. activated carbon adsorption).

a. **Description of the technique**

In textile finishing can be used these off-gas abatement techniques:

- oxidation techniques (thermal incineration, catalytic incineration)
- condensation techniques (e.g. heat exchangers)
- absorption techniques (e.g. wet scrubbers)
- particulates separation techniques (e.g. electrostatic precipitators, cyclones, fabric filters)
- adsorption techniques (e.g. activated carbon adsorption).

These techniques can be used singly or in combination. It depends on the type of air stream and pollutants to be treated. Typical applied systems is described below:

- wet scrubbers
- combination of wet scrubber and electrostatic precipitation
- combination of heat exchanger, aqueous scrubber and electrostatic precipitation
- heat exchangers (used for energy saving in particular, but it is also used for partial condensation of certain pollutants)
- adsorption on activated carbon.

b. **Applicability, operational data and driving force for implementation**

**Oxidation techniques**

The downside of thermal incineration is the high energy consumption for heating the off-gas to at least 750 °C. Another problem is the quality of the gas-air-mixture typical of exhaust air from textile finishing. Catalytic oxidation is used in some mills for treating off-gases derived from singeing operations with full heat recovery.

**Condensation techniques**

This technique allows removing pollutants with high volatility and, in many cases, odour-intensive substances.

**Absorption techniques**

The efficiency of wet scrubbers is in the range of 40 to 60% normally and it depends on process-specific parameters. The application of this technique for water-insoluble pollutants is limited.

**Electrostatic precipitation**

Electrostatic precipitators can precipitate dusts and aerosols with a size between 0.01 and 20 μm even if the maximum efficiency will be attained at around 0.1 μm – 1.5 μm. For this reason manufacturers recommend installing a mechanical filter before the electrostatic filter, which precipitates most of the particles with size > 20 μm. The electrostatic precipitators for particle-sized solid and liquid pollutants have an efficiency between 90% and 95%. Gaseous pollutants and odorous substances cannot be precipitated. In order to improve efficiency, all condensable substances, emitted as aerosols, are removed before reaching the electrostatic precipitator. This can be achieved by heat exchangers or scrubbers. The combination of electrostatic precipitation and heat exchangers or scrubbers is applied successfully in the treatment of fumes emitted from the stenter where the fabric is submitted to thermo fixation and it is particularly advantageous when this operation is done as a first treatment.
step before washing. The off-gas derived from oils and preparation agents present in grey fabric can be treated in four steps:

1) mechanical filtration
2) cooling and condensation
3) ionisation/ electrofiltration
4) collection of the condensates and separation of the oily phase from the aqueous phase in a static decanter.

The oily condensates (mineral oils, silicone oils, etc.) are collected separately and thus recovered by using the dry electrofiltration system. Energy recovery is another benefit of this technique. Recovered energy (35 – 40% of the supplied amount) can be used to preheat the fresh air supplied to the stenter or to heat up process water.

An adjustment of the appropriate operating conditions and an appropriate maintenance of the equipment must be done to achieve high operational reliability. The environmental legislation for air pollution and a better performance in term of odour nuisances is the main driving forces for the implementation of techniques. In Morocco applicable for large companies (due to high costs).

c. **Environmental benefit**

A reduction of VOC (volatile organic carbon), particulates and special toxic substances in the off-gas is achieved. Moreover less odour nuisance is obtained.

d. **Economic aspects**

Oxidation techniques have the highest investment and operating costs. A capital investment for dry electrofiltration (combination of heat exchangers and electrostatic precipitation) is about 70,000 euros for a 10,000 m³/h unit with a payback period of less than 3 years.

e. **Reference literature**


### 4.5 General good management practices for textile sector

#### 4.5.1 Ref. Datasheet G.1: Management and good housekeeping

a. **Description**

Some principles belonging to this practice.

Education/ training of employees for example is very important for environmental management.

Training should be resource- (chemicals, fibres, energy, water), process- and machinery-specific.

Also equipment maintenance and operations audit is important. Machinery, pumps and pipe work (including abatement systems) should be well maintained and free from leaks. Regular maintenance schedules should be established.

Moreover, chemicals storage, handling, dosing and dispensing should be guaranteed. Improved knowledge of chemicals and raw materials used is also important.

The minimization and optimisation of chemicals used should be carried out.
The use of water and energy in an optimal way is also important in order to develop waste minimization options in a process. For this purpose monitoring of the water, heat and power consumption of sub-units of the process are requested. Some measures concern management of waste streams.

b. **Applicability, operational data and driving force for implementation**

These measures are cheap and do not require investment in new equipment, even if the immediate applicability of some of the techniques in existing mills may be limited by considerations of space, logistics and the need for major structural modifications. Some measures, such as the installation of automated dosing systems and process control devices, may be expensive, depending on how sophisticated they are. The main driving force for the implementation of these measures is cost savings, improvement of operational reliability, improved environmental performance and compliance with legislation.

c. **Environmental benefit**

Main benefits are savings in the consumption of chemicals, auxiliaries, fresh water and energy and reduction of solid waste and pollution loads in waste water and off-gas. Workplace conditions can also be improved.

d. **Economic aspects**

These measures are economically viable. Main economic benefits are savings in consumption of energy, fresh water, chemicals, and in the cost of waste water, off-gas cleaning and discharge of solid waste.

e. **Reference literature**


4.5.2 Ref. Datasheet G.2: Input/output streams evaluation/inventory

a. **Description**

In order to consider options and priorities for improving environmental and economic performance, it is important to know quality and quantity of input/output streams. Input/output stream inventories can be drawn up on different levels. The most general level is an annual. Starting from the annual values, specific input and output factors for the textile substrate can be calculated (e.g. litre of water consumption/kg processed textiles).

It is also possible to make input/output assessment at process-level.

b. **Applicability, operational data and driving force for implementation**

The technique is applicable to existing and new installations. Provided that the management of a company is convinced of the benefits of such a tool, there are no limitations in applicability, regardless of the size of the mill. The application of these tools needs qualified staff. Driving forces are: saving on raw materials and production costs. These measures can allow implementing in easier way some kind of environmental management systems.

c. **Environmental benefit**

The evaluation and inventory of input/output mass streams is an essential management tool for the identification of optimisation potential, both environmental and economic.
Chapter 4

4.5.3 Ref. Datasheet G.3: Automated preparation and dispensing of chemicals

a. Description
Automated chemicals dosing and dispensing systems are applied in many companies in the textile industry. There are microprocessor-controlled dosing systems that meter chemicals automatically. Some automated systems are available for just-in-time-preparations of liquors. With on-line measurement of the liquor pick-up and of the quantity of processed fabric, the exact amount of liquor can be prepared and added. Waste water pollution is minimised. Other automated dosing systems allow saving even more chemicals, water and time.

b. Applicability, operational data and driving force for implementation
Typical automated dosing and dispensing techniques can be applied to new and existing installations. Exception is made for sophisticated techniques which are expensive and for this reason can be apply for large installations. Qualified personnel is required for highly automated systems. The main driving forces for implementation are higher reproducibility and productivity along with health and safety requirements defined by legislation.

c. Environmental benefit
Many environmental benefits are achieved: reduction of waste water pollution and wasted chemicals. Positive aspects also for working environment.

d. Economic aspects
Investment costs for the automated dosing of liquid chemicals, depending on the number of machines to be served, liquors to be prepared and chemicals to be used. Costs can vary from EUR 230.000 to EUR 310.000. For powder dyes, the investment is between 250.000 and 700.000 EUR. Cost savings (about 30%) can be derived from a reduction of consumption of chemicals and water, increase of reproducibility and decrease in staff costs.

e. Reference literature

4.5.4 Ref. Datasheet G.4: Optimising water consumption in textile operations

a. Description
Many techniques allow a reduction of water consumption. Controlling water consumption of installation is important. Water use should be monitored and recorded at machine/process level and water meters should be maintained and calibrated.
Chapter 4

Also reducing water consumption is an important approach. This is possible by improved working practices, by reducing liquor ratio, by improving washing efficiency, by combining processes.

Re-using water is also an option to optimise water consumption.

b. **Applicability, operational data and driving force for implementation**

Principles indicated above are applicable at general level.

The following specific water consumption levels are considered achievable:

- Finishing of yarn: 70/120 l/kg
- finishing of knitted fabric: 70/120 l/kg
- pigment printing of knitted fabric: 0,5-3 l/kg
- finishing of woven fabric consisting mainly of cellulosic fibres: 50-100 l/kg
- finishing of woven fabric consisting mainly of cellulosic fibres (including vat and/or reactive printing): < 200 l/kg
- finishing of woven fabric consisting mainly of wool: < 200 l/kg
- finishing of woven fabric consisting mainly of wool (for processes that require high liquor ratio): < 250 l/kg

c. **Environmental benefit**

Savings in energy and water consumption.

d. **Economic aspects**

Investment in new equipment and/or structural modifications are needed.

e. **Reference literature**


4.5.5 **Ref. Datasheet G.5: Insulation of High Temperature (HT) machines**

a. **Description**

Insulation of pipes, valves, tanks and machines is a general principle of good housekeeping practice that should be applied at the general level in all processes.

b. **Applicability, operational data and driving force for implementation**

The applicability is general.

Insulation material may be exposed to water, chemicals and physical shock. For this reason, insulation should be covered or coated with a hard-wearing, chemical/water resistant outer layer.

Savings in energy costs are the main driving force for implementation.

c. **Environmental benefit**

More rational use of energy. Savings up to 9% of the total energy requirement on wet processing machines can be achieved.

d. **Economic aspects**

Payback for heat-insulation of HT dyeing units is indicated here. Reference data for calculation are referred to Europe and are as follows:

- thermal transmission coefficient for stainless steel: 15.1 W/m²K
- thermal transmission coefficient for insulating material: 0.766 W/m²K
- dyeing temperature: 110°C
• room temperature: 30°C  
• HT-dyeing unit (average temperature 110 °C): 10h/d  
• processing time: 230 d/yr  
• gas costs: 0.25 €/m³  
• loss by energy transformation and transport: 15%  
• dyeing unit 1 – front: 17.5 m²  
• dyeing unit 2 – front: 23.5 m²  
• dyeing unit 3 – front 31.6 m²

<table>
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<tr>
<th></th>
<th>Dyeing unit 1</th>
<th>Dyeing unit 2</th>
<th>Dyeing unit 3</th>
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<td>Annual gas savings (EUR/yr)</td>
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<td>Payback period (yr)</td>
<td>4.9</td>
<td>4.6</td>
<td>3.8</td>
</tr>
</tbody>
</table>

e. **Reference literature**  

### 4.6 Horizontal techniques

Some environmental issues are common for many industries. For these issues, standard “horizontal” candidate BAT are selected. The horizontal techniques presented here, are gathered by screening the European horizontal BREF documents (except for the last technique on Energy Efficiency, which has been included from a different source).

Important to notice is that some of the horizontal techniques are clearly linked with the vertical techniques mentioned in the previous paragraphs. Therefore, in this paragraph, only the additional horizontal candidate BAT, i.e. not directly linked with the vertical techniques, are highlighted. For more information on the measures, we refer to the candidate BAT database and the original BREF documents.

The structure as we used for the other techniques above (vertical techniques) will not be kept here. Only specific local issues, e.g. reasons for applicability problems or legislation related to the measure, are added. For further information on the technical viability, environmental benefit and economic viability we again refer to the candidate BAT database.
4.6.1 Best Available Techniques to Industrial Cooling Systems

4.6.1.1 Integrated heat management techniques

*Database references: technique CV1*

Cooling of industrial processes can be considered as heat management and is part of the total energy management within a plant. It’s important to follow an integrated approach to reduce the environmental impact of industrial cooling systems maintaining the balance between both the direct and indirect impacts. Another important aspect is to reduce the level of heat discharge by optimization of internal/external heat reuse. Once the level and amount of waste heat generated by the process is established and no further reduction of waste heat can be achieved, an initial selection of a cooling system can be made in the light of the process requirements.

4.6.1.2 Techniques for reduction of energy consumption

*Database references: technique CV2*

In the design phase of a cooling system, energy consumption can be reduced when:
- Resistance to water and airflow is reduced;
- High efficiency/low energy equipment is applied;
- The amount of energy demanding equipment is reduced;
- ...

In an integrated approach to cooling an industrial process, both the direct and indirect use of energy is taken into account. It is preferred to use a once-through system when possible.

4.6.1.3 Techniques for the reduction of water requirements

*Database references: technique CV3*

In order to reduce water requirements in cooling, several measures can be taken. In general, for new systems, for example it is advised to reduce the cooling demand by optimising heat reuse or a site should be selected for the availability of sufficient quantities of (surface) water in the case of large cooling water demand.

For existing water cooling systems, increasing heat reuse and improving operation of the system can reduce the required amount of cooling water. Other techniques are available to further reduce water requirements, like the application of recirculating systems, application of dry cooling or the optimization of cycles of concentration.
4.6.1.4 Techniques for the reduction of entrainment of organisms

Database references: technique CV4

The adaptation of water intake devices to lower the entrainment of fish and other organisms is highly complex and site-specific. Changes to an existing water intake are possible but costly.

4.6.1.5 Techniques for the reduction of emissions to water

Database references: technique CV5

Whether heat emissions into the surface water will have an environmental impact strongly depends on the local conditions. Prevention and control of chemical emissions resulting from cooling systems have received a lot of attention as well. Measures should be taken in the design phase of wet cooling systems:

- Identify process conditions;
- Identify chemical characteristics of the water source;
- Select the appropriate material for heat exchangers;
- Select the appropriate material for other parts of the cooling system;
- Identify operational requirements of the cooling system;
- Select feasible cooling water treatment.

4.6.1.6 Reduction of air emissions

Database references: technique CV6

Air emissions from cooling towers have not been given much attention yet. Lowering concentration levels in the circulating cooling water will obviously affect the potential emission of substances in the plume. Some reduction techniques are plume emission at sufficient height and with a minimum discharge air velocity at the tower outlet, application of hybrid technique or other plume suppressing techniques, design and positioning of tower outlet to avoid risk of air intake by air conditioning systems, ...

4.6.1.7 Reduction of noise emissions

Database references: technique CV7

Noise emissions have local impact. Noise emissions of cooling installations are part of the total noise emissions from the site. A number of primary and secondary measures have been identified that can be applied to reduce noise emissions where necessary. The primary measures change the sound power level of the source, where the secondary measures reduce the emitted noise level. The secondary measures in particular will lead to pressure loss, which has to be compensated by extra energy input, which reduces overall energy efficiency of the cooling. The ultimate choice for a
technique will be an individual matter, as will the resulting associated performance level. Possible measures include for example application of earth barrier or noise attenuating wall, application of low noise fans, ...

4.6.1.8 Reduction of risk of leakage

Database references: technique CV8

To reduce the risk of leakage, attention must be paid to the design of the heat exchanger, the hazardousness of the process substances and the cooling configuration. The following general measures to reduce the occurrence of leakages can be applied: i) select material for equipment of wet cooling to the applied water quality, ii) operate the system according to its design, iii) select the right cooling water treatment programme and iv) monitor leakage in cooling water discharge by analysing the blow down. Other techniques include among others constant monitoring, the application of welding technology and changing technology to indirect cooling for example.

4.6.2 Best Available Techniques on Energy Efficiency

4.6.2.1 Cogeneration

Database references: technique ENES

Cogeneration can be defined as the simultaneous generation in one process of thermal energy and electrical and/or mechanical energy (Directive 2004/8/EC). There are different types of cogeneration possible, such as combined cycle gas turbines, steam turbine plants, gas turbines with heat recovery boilers, fuel cells, Stirling engines etc. There are significant economic and environmental advantages to be gained from CHP production, due to their high efficiency.

Trigeneration is generally understood to mean the simultaneous conversion of a fuel into three useful energy products: electricity, hot water or steam and chilled water. It is actually a cogeneration system with an absorption chiller that uses some of the heat to produce chilled water.

District cooling is another aspect of cogeneration, where cogeneration provides centralised production of heat, which drives on absorption chillers, and the electricity is sold to the grid. Cogeneration can also deliver district cooling by means of centralised production and distribution of cooling energy.

4.6.2.2 Techniques to optimise the energy efficiency of combustion by relevant techniques

Database references: technique ENE2

The combustion installations discussed here are heating devices or installations using the combustion of a fuel (including wastes) to generate and transfer heat to a given
Energy can be managed by control of the process parameters and control on the combustion side. Some possible techniques to improve energy efficiency in combustion are shortly described below.

- **Reduction of the flue-gas temperature**: one option to reduce possible heat losses in a combustion process. The lower the flue-gas temperature, the better the energy efficiency;

- **Installing an air or water preheater**: the preheater heats the air which flows to the burner. This means flue-gases can be cooled down even more, as the air is often at ambient temperature. A higher air temperature improves combustion, and the general efficiency of the boiler will increase;

- **Recuperative & regenerative burners**: these burners have been developed for direct waste heat recovery through combustion air preheating. A recuperator is a heat exchanger that extracts heat from the furnace waste gases to preheat the incoming combustion air. This will increase combustion efficiency;

- **Reducing the mass flow of the flue-gases by reducing excess air**: excess air can be minimised by adjusting the air flow rate in proportion to the fuel flow rate. Depending on how fast the heat demand of the process fluctuates, excess air can be manually set or automatically controlled;

- **Burner regulation & control**: automatic burner regulation and control can be used to control combustion by monitoring and controlling fuel flow, air flow, oxygen levels in the flue gases and heat demand;

- **Fuel choice**: the type of fuel chosen for the combustion process affects the amount of heat energy supplied per unit of fuel used. The required excess air ratio is dependent on the fuel used and this dependence increases for solids. The choice of fuel is therefore an option for reducing excess air and increasing energy efficiency.

- **Oxy-firing (oxyfuel)**: oxygen is used instead of ambient air is either extracted from air on the site, or more usually, bought in bulk. Energy requirement to concentrate the air is considerable, and should be taken into account in any energy calculations;

- **Reducing heat losses by insulation**: the heat losses through the walls of the combustion system are determined by the diameter of the pipe and the thickness of the insulation. An optimum insulation thickness which relates energy consumption with economics should be found in every particular case;

**Reducing losses through furnace openings**: heat losses by radiation can occur via furnace openings for loading/unloading. Openings include furnace flues and stacks, peepholes used to visually check the process,
Compressed air is air that is stored and used at a pressure higher than atmospheric pressure. It can be used as an integral component in industrial processes or as an energy medium. Compressed air systems (CAS) are important installations from an energy point of view. Optimising these to achieve energy efficiency is important. Again, depending on the specific characteristics of the system (new, refurbishment, old, size, ...) there are different techniques to improve energy efficiency:

- **System design**: nowadays, many existing CASs lack an updated overall design. The implementation of additional compressors and various applications in several stages along the installation lifetime without a parallel redesign from the original system have frequently resulted in a suboptimal performance of a CAS.

- **Variable speed drives**: VSD for compressors find applications mainly when the process air requirements of the users fluctuate. In VSD compressors, the speed of the electric motor is varied in relation to the compressed air demands, resulting in a high level of energy savings.

- **High efficiency motors**: these motors minimise the electrical and mechanical losses to provide energy savings.

- **CAS master control system**: often, CASs are multi-compressor installations. The energy efficiency of such multi-compressor installations can be significantly improved by CAS master controls, which exchange operational data with the compressors and partly or fully control the operational modes of the individual compressors.

- **Heat recovery**: most of the electrical energy used by an industrial air compressor is converted into heat and has to be conducted outwards. In many cases, a properly designed heat recovery unit can recover a high percentage of this available thermal energy and put to useful work heating either air or water when there is a demand.

- **Reducing compressed air system leaks**
- **Filter maintenance**
- **Feeding the compressor(s) with cool outside air**
- **Optimising the pressure level**
- **Storage of compressed air near high-fluctuating uses**

### 4.6.2.4 Techniques to optimise the energy efficiency of Electric motor driven sub-systems

*Database references: technique ENE4*

The energy efficiency in motor driven systems can be assessed by studying the demands of the (production) process and how the driven machine should be operated. This is a systems approach and yields the highest energy efficiency gains. Savings achieved by a systems approach as a minimum will be those achieved by considering individual components and can be 30% or higher. There are at least two different ways to approach the concept of energy efficiency in motor driven systems. One is to look at...
individual components and their efficiencies and ensure that only high efficiency equipment is employed. The other is to take a systems approach.

The following measures may be taken:

- **Energy efficient motors**: energy efficient motors and high efficiency motors offer greater energy efficiency. Additional purchase costs may be up to 20-30% higher, however the energy savings of about 2-8% can be achieved.
- **Proper motor sizing**: often motors are oversized for the real load they have to run. The maximum efficiency however is obtained for the motors of between 60-100% of full load. Therefore proper sizing improves energy efficiency, may reduce line losses due to low power factors and may slightly reduce the operating speed and thus power consumption of fans and pumps.
- **Variable speed drives**: the adjustment of the motor speed through the use of variable speed drives can lead to significant energy savings associated to better process control, less wear in the mechanical equipment and less acoustical noise.
- **Reduce transmission losses**
- **Motor repair**
- **Rewinding**

### 4.6.2.5 Techniques to optimise the energy efficiency of electrical power supply

*Database references: technique ENE6*

Public electrical power is supplied via high voltage grids. The voltage is high to minimise the current losses in transmission. Various factors affect the delivery and the use of energy, including the resistance in the delivery systems and the effects some equipment and uses have on the supply. To increase efficiency, different measures might be taken, such as power factor correction (real power versus apparent power), reduction of harmonics, optimising supply...

### 4.6.2.6 Energy efficiency management

*Database references: technique ENE1*

In order to achieve energy efficiency in a company, mostly an integrated approach combining management systems, process-integrated techniques and specific technical measures is preferred. In this paragraph, the focus will be on techniques to be considered at the level of an entire installation with the potential to achieve optimum energy efficiency. All techniques from this paragraph may be used singly or as combinations with those of the next paragraph.

- All industrial companies can save energy by applying the same sound management principles and techniques they use elsewhere in the business for key resources such as finance for example. These management practices include full managerial accountability for energy use. The management of
energy consumption and costs eliminates waste and brings cumulative savings over time. Some important features for a successful **energy efficiency management system (ENEMS)** are:

- Commitment of top management;
- Definition of an energy efficiency policy;
- Planning and establishing objectives and targets;
- Implementation and operation of procedures;
- ... 

**Planning and establishing objectives and targets.** An important element of an environmental management system is **maintaining overall environmental improvement**, including energy efficiency. Additionally, it was shown that, while there are savings to be gained by optimising individual components (e.g. pumps), the biggest energy efficiency gains are to be made by taking a **systems approach**, starting with the installation, considering the component units and systems and optimising how these interact, and optimising the system. Only then any remaining devices should be optimised.

- Experience shows that, if energy efficiency is considered during the planning and design phase of a new plant, saving potentials are higher and the necessary investments to achieve the savings are much lower, compared with optimising a plant in commercial operation. **Energy efficient design** should therefore be performed.

- Intensifying the use of energy and raw materials by optimising their use between more than one process or system is called **process integration**. This is site- and process-specific.

- **Maintaining the impetus of energy efficiency initiatives** often creates problems. It is important that savings in energy efficiency due to adoption of a new technology or technique are sustained over time.

- **Other:** communication, effective control of processes, maintenance, monitoring and measurement, energy audits and energy diagnosis, pinch methodology, enthalpy and exergy analysis, thermo economics, energy models and benchmarking.

### 4.6.2.7 Energy efficient design (EED)

**Database references: technique ENE7**

In the planning phase of a new plant or installation lifetime energy costs of processes, equipment and utility systems should be assessed. Energy efficiency in the planning phase of a new plant or installation could be improved by considering all of the following:

- a. the energy efficient design (EED) should be initiated at the early stages of the conceptual design/basic design phase, The EED should also be taken into account in the tendering process.
- b. the development and/or selection of energy efficient technologies.
- c. additional data collection may need.
• d. the EED work should be carried out by an energy expert.
• e. the initial mapping of energy consumption should also address which parties in the project organisations influence the future energy consumption, and should optimise the energy efficiency design of the future plant with them.

4.6.2.8 Heat exchangers; monitoring and maintenance

Database references: technique ENE8

Direct heat recovery is carried out by heat exchangers. A heat exchanger is a device in which energy is transferred from one fluid or gas to another across a solid surface. They are used to either heat up or cool down processes or systems. Heat transfer happens by both convection and conduction.

Heat exchangers are designed for specific energy optimised applications. To ensure the smooth operation of the heat exchanger is necessary to carry out monitoring and maintenance activities.

Condition monitoring of heat exchanger tubes may be carried out using eddy current inspection.

This is often simulated through computational fluid dynamics (CFD).

4.6.2.9 Techniques to improve energy efficiency on space heating and cooling

Database references: technique ENE9

A typical HVAC system comprises the heating or cooling equipment, pumps and/or fans, piping networks, chillers and heat exchangers. Studies have shown that about 60% of the energy in an HVAC system is consumed by the chiller/heat pump and the remaining 40% by peripheral machinery. To increase efficiency in HVAC, several elements are to be optimised:

• **Space heating & cooling**: energy savings can be achieved e.g. by reducing the heating/cooling needs or improving the efficiency of the system (through waste heat recovery, heat pumps, etc.);
• **Ventilation**: optimisation of design of a new or upgraded ventilation system is important, but also improving an existing system within an installation;
• **Free cooling**: can be used for cooling in order to increase energy efficiency. It takes place when the external ambient air enthalpy is less than the indoor air enthalpy.

4.6.2.10 Increased process integration

Database references: technique ENE10
Candidate BAT is to seek to optimise the use of energy between more than one process or system, within the installation or with a third party.

4.6.2.11 Lighting

Database references: technique ENE11

Artificial lighting accounts for a significant part of all electrical energy consumed worldwide. In some buildings over 90% of lighting energy consumed can be an unnecessary expense through over-illumination. Thus, lighting represents a critical component of energy use today. There are several techniques available to minimise energy requirements:

- Identification of lighting requirements in each area;
- Analysis of lighting quality and design;
- Management of lighting.

4.6.2.12 Techniques to optimise the energy efficiency of Pumping Systems

Database references: technique ENE12

Pumping systems account for nearly 20% of the world’s electrical energy demand. The energy and materials used by a pumping system depend on the design of the pump, the design of the installation and the way the system is operated. Different steps are important to identify energy saving measures:

- **Inventory and assessment of pumping systems**: the first step is to establish an inventory of the pumping systems in the installations with the key operating characteristics.
- **Pump selection**: the pump is the heart of the system. Its choice is driven by the need of the process which could be, first of all, a static head and a flow rate. The choice also depends on the system, the liquid, the characteristic of the atmosphere etc.
- **Pipe work system**: the pipe work system determines the choice of the pump performance. Its characteristics have to be combined with those of the pumps to obtain the required performance of the pumping installation. The energy consumption directly connected to the piping system is the consequence of the friction loss on the liquid being moved, in pipes, valves and other equipment of the system.
- **Maintenance**: excessive pump maintenance can indicate i) pumps are cavitating, ii) badly worn pumps or iii) pumps that are not suitable for operation.
- **Pumping system control and regulation**: a control and regulation system is important in a pumping system so as to optimise the duty working conditions for the head pressure and the flow. It provides process control, better system reliability, and energy savings.
4.6.2.13 Technique about renewable energy: Biomass Combustion from oil/olive by-product chain

Database references: technique ENE13

This technique capitalizes on the direct combustion of oil and olive by-products. Waste from olives can be transformed in biogas through a biochemical process through microorganism without oxygen (anaerobic process). The biogas is made up by CO₂, CH₄ and other components. The biogas can be used to produce electrical or thermal energy (or both kind) thanks to plants made on the basis of used organic substrates (oil and olive waste). Environmental benefits can derive by the re-use of materials (use of oil and olive waste). Lower pollution and renewable energy production are other positive aspects. Negative environmental aspects: odours from plants, air emissions.

Reference: www.resolive.com (European Project from 7th Framework Programme).

4.6.3 Best Available Techniques on Emissions from Storage

4.6.3.1 Techniques to prevent and reduce gas and liquid emissions (liquid and liquefied gases) from the tanks. General principles

Database reference: technique ESB1

The emissions of liquid and liquefied gases from tanks can be prevented and controlled taking into account various criteria that consider the recipient characteristics, the surroundings and the handling.

Some general measures to do this are:

- **Tank design:** the design or retrofit of an installation for a given substance is a multi-step approach in which elimination is performed starting from all possible storage modes. A proper design should take into account many factors, e.g. physic-chemical properties of the substance, how the storage is operated, what equipment has to be installed, etc.

- **Inspection, maintenance and monitoring:** According to national regulations, there are different approaches to perform inspection work, e.g. official surveillance, surveillance by experts and internal company control (operator). To optimise inspection and maintenance, the application of risk-based tools are gaining attention. Another common aspect of inspections is the monitoring of diffuse emissions to air and the monitoring of leakages. In addition to general inspection techniques, some specific gas-leak detection techniques exist as gas detection systems. This is mainly a safety feature instead of a preventative tool for leakages.
• Location and layout: The location and layout of a storage installation have to be selected with care. Each location – underground, aboveground or in mounds – has different advantages and disadvantages.

4.6.3.2 Prevention and control of gas emissions from storage of liquids and liquefied gases in tanks

Database reference: techniques ESB2 – ESB9

To prevent and control gas emissions occurring during the use of the tanks to store liquids and liquefied gases, several techniques are available. Each of these will shortly be described. For more information we refer to the candidate BAT database.

Emissions minimisation principle in tank storage is a principle that, within a certain time frame, aims to abate all emissions (from air, soil, water, energy consumption and waste) from tank storage, transfer and handling before they are emitted. The environmental benefit lies mostly in the fact that unabated operational emissions from the tanks will become negligible. Although the principle was originally developed for tank terminals, it is also applicable to tank storage in general. The economics depend strongly on the prevention and reduction measures that are currently applied.

Different types of covers might be used to avoid vapours to escape from open storage tanks. Covers considered are floating covers, flexible covers or tent covers and fixed/grid covers. Another possibility is to install a fixed or domed roof on an external floating roof tank. This however is, particularly in retrofit, a high cost option. Significant costs are involved on a site-specific basis.

The tank colour influences the amount of thermal or light radiation absorbed by aboveground tanks and, therefore, the temperature of the liquid and vapour contents inside. A white painted tank has the lowest emission level compared with other paint colours. The application of sunscreens or sunshields around tanks is newer. The idea is that one will reduce/prevent an increase in temperature of the vapour/product within the tank and this in turn will lead to the potential for lower emissions. In order to keep the storage temperature under a certain limit, also during summer conditions, it is advantageous to use all natural possibilities for cooling the tank. This might be done by for example using floating roof tanks.

Other examples of techniques are:
• Roof seals for external and internal floating roofs;
• Internal floating roof (IFR);
• Pressure and vacuum relief valves;
• Closed drain systems;
• Vapour balancing;
• Vapour holders;
• Vapour treatment.
4.6.3.3 Prevention and control of liquid emissions of storage of liquids and liquefied gases

Database reference: technique ESB12

Liquid emissions control measures divide into two main groups: ECM for potential releases to soil from planned activities and those for unplanned releases. Here, only those measures for potential releases from regular operation are considered. Manual draining of tanks can be done successfully with due care and attention. Careful manual draining is still a viable option at many sites, however it can be an extremely time consuming process. Automation is therefore often introduced. Semi-automatic tank drain valves are categorised as such because they need to be reset at the start of each draining operation. Fully automatic tank drain valves are designed to require minimal operator intervention and, as such, are significantly more expensive than semi-automatic systems. A power source at the tank is also needed. Dedicated systems include tanks and equipment that are dedicated to one group of products. This means no changes in products. This makes it possible to install and use technologies specifically tailored to the products stored.

4.6.3.4 Prevention and control of waste from storage of liquids and liquefied gases

Database reference: technique ESB10

Sludge deposition in tanks occurs by the mechanisms of molecular diffusion, gravity and chemical reactivity and depends on operating conditions. Sludge deposition is not usually even and does not necessarily build at the same rate. Reducing sludge can be done in two ways:

- **Tank mixing**: this is the best technology for reducing sludge. The mixer prevents sludge deposition, either by using impeller mixers or jet mixers.
- **Sludge removal**: where sludge in tanks becomes unacceptably high and cannot be reduced by mixing technologies, tank cleaning will be necessary.

4.6.3.5 Operational specific techniques to prevent and reduce emissions (liquid and liquefied gases) from the tanks. Storage modes

Database reference: technique ESB11

**(Vertical) fixed roof tanks (FRT)**: fixed roof tanks are designed as atmospheric tanks, low pressure tanks or so-called ‘high pressure’ tanks. Non-pressure fixed roof tanks are suitable for storage at atmospheric pressure and therefore have open vents. Both low pressure and high pressure fixed roof tanks are provided with pressure/vacuum relief valves, which are fully open at the design pressure/vacuum.

**Aboveground horizontal storage tanks (atmospheric)**: horizontal fixed roof tanks are constructed for both aboveground and underground service and generally have a capacity of less than 150 m³. Horizontal tanks are usually equipped with
pressure/vacuum relief vents (PVRVs), gauge hatches, sample wells and manholes to provide access.

**Mounded storage (pressurised):** mounded storage is the term given to the pressurised storage at ambient temperatures of liquefied petroleum gases in horizontal cylindrical tanks placed at or just below ground level and completely covered with suitable backfill. Several tanks may be placed side-by-side under one ‘mound’.

**Variable vapour space tanks:** variable vapour space tanks are equipped with expandable vapour reservoirs to accommodate vapour volume fluctuations attributable to temperature and barometric pressure changes. The two most common types of variable vapour space tanks are lifter roof tanks and flexible diaphragm tanks.

**Refrigerated storage tanks:** there are three types of refrigerated storage systems:

- single containment
- double containment
- full containment.

The selection of the type of storage system will be considerably influenced by the location, the operational conditions, the adjacent installations, loadings and environmental considerations.

**Underground horizontal storage tanks:** horizontal tanks can be – apart from aboveground – buried or mounded. Underground (buried) storage tanks are often used for the storage of gasoline, diesel and other fuels.

### 4.6.3.6 Incidents and (major) accidents emission control measures for tanks

**Database references: techniques ESB13-ESB14**

Companies should take all measures necessary to prevent and limit the consequences of major accidents. **Safety and risk management system** gives shape to the so called major accident prevention policy. The system includes i) a statement of tasks and responsibilities, ii) an assessment of the risks of major accidents, iii) a statement of procedures and work instructions, iv) plans for responding to emergencies, v) the monitoring of the safety management system and vi) the periodical evaluation of the policy adopted. An important tool is the **risk assessment** that is an organised view at the activities on-site. Incidents and (major) accidents can be prevented and controlled taking into account different measures. Several techniques have to be considered, for example:

- Operational procedures and training;
- Leakage and overfill;
- Corrosion and erosion;
- Instrumentation and automation to prevent overfill;
- Impervious barriers under aboveground tanks;
- ...

In some areas, flammable atmospheres may occur either during normal operation or due to accidental spills or leakages. These **flammable areas** are hazardous and measures to prevent these areas or control the induction of sources of ignition are
required. Fire protection may be necessary. Measures can be provided by for example fire resistant cladding or coatings, firewalls and water cooling systems. Another element is the fire-fighting equipment which depends on the quantity and type of liquid and on the conditions of storage. It can either be dry powder, foam or CO₂ extinguishers. An adequate water supply is needed in cases larger fires might occur. In case of fire water run-off, an adequate interceptor or special draining system may be applied to minimise the risk of contamination of local watercourses, thus containment of contaminated extinguishant.

4.6.3.7 Incidents and (major) accidents emission control measures for storage of packaged hazardous substances in tanks. Safety and risk management

Database references: technique ESB15

The Seveso II Directive (Council Directive 96/82/EC of 9 December 1996 on the control of major accident hazards involving dangerous substances) requires companies to take all measures necessary to prevent and limit the consequences of major accidents. They must, in any case, have a major accident prevention policy (MAPP) and a safety management system to implement the MAPP. Companies holding large quantities of dangerous substances, the so-called upper tiered establishments, must also draw up a safety report and an on-site emergency plan and maintain an up-to-date list of substances.

However, plants that do not fall under the scope of the Seveso II Directive also often apply individual risk management policies.

An important tool is the risk assessment.

Concerning the storage of flammable liquids in tanks, the assessment includes the risks arising from the tank and risks to the tank from external sources.

Incidents and (major) accidents from tanks can be prevented and controlled taking into account different safety and risk measures. For this, several techniques have to be considered:

Operational procedures and training

Low level indicator in external floating roof tanks (EFRT): instrumentation to measure and warn for a low level of the content of a tank is needed to prevent an external floating roof from landing in an emptying mode.

Leakage and overfill: containment refers to additional protection against storage tank releases over and above the inherent protection provided by the tank container itself. Tank farm bunds and cup-tanks are designed to contain large spills from aboveground tanks, such as caused by shell rupture or large overfills. Also underground tanks can be equipped with containment.
4.6.3.8 Incidents and (major) accidents emission control measures for storing containers

Database references: technique ESB16

Operational losses do not occur in storing packaged dangerous materials. The only possible emissions are from incidents and (major) accidents. Three main events have the potential to cause significant harm or damage: fire, explosion and/or release of dangerous substances.

Again, safety and risk management is advisable. Also, adequate construction and ventilation is important.

4.6.3.9 Management tools to reduce emissions from transfer and handling of liquids and liquefied gases

Database references: techniques ESB17, ESB18, ESB20

Emissions might occur when transferring liquids and/or liquefied gases (e.g. in aboveground closed piping transfer systems, aboveground open piping transfer systems, underground closed piping transfer systems, unloading hoses) or during handling. The most significant potential emission sources are filling of piping systems, cleaning of open systems and fugitives in all modes. The use of Emission Control Measures (ECM) is therefore advisable.

Management tools for transfer and handling (general measures) include:
- Operational procedures and training;
- Inspection, maintenance and monitoring (ref. Database ESB17);
- Leak detection and repair (LDAR) programme (ref Database ESB18);
- Safety and risk management (ref. Database ESB20)

4.6.3.10 Techniques to prevent and reduce gas and liquid emissions (liquid and liquefied gases) from the tanks: Emissions minimisation principle in tank storage

Database references: technique ESB19

Description: The principle of ‘emissions minimisation in tank storage’ is that all emissions from the tank storage, transfer and handling will be abated before they are emitted. This includes the following emissions arising from normal operational activities and from incidents:
- emissions to air
- emissions to soil
- emissions to water
- energy consumption
- waste.
4.6.3.11 Techniques to prevent and reduce gas and liquid emissions (liquid and liquefied gases) from the tanks. Considerations on transfer and handling techniques: Piping

Database references: technique ESB21

ECM FOR ABOVEGROUND OPEN PIPING – OPERATIONAL – GAS EMISSIONS
Replacement with closed piping systems
Aboveground closed piping systems are normally designed to transport liquids, refrigerated gases (liquefied), pressurised gases (as liquids) or vapours. Aboveground piping systems are the most common form of handling system within storage facilities.

ECM FOR ABOVEGROUND CLOSED PIPING – INCIDENTS AND (MAJOR) ACCIDENTS
Internal corrosion and erosion
Primarily the selection of the correct construction material would minimise corrosion. Erosion may be controlled by a combination of flow management, corrosion inhibitors, internal lining and frequent pigging.

INSPECTION, MAINTENANCE AND MONITORING
Risk and Reliability Based Maintenance (RRM)
The application of risk-based tools for the optimization of maintenance and inspection activities following the trend in worldwide industry to move away from a time based maintenance approach to a condition based maintenance approach.
In-service and out-service inspections
Inspections can be categorized as regular in-service inspections or as regular out-of-service inspections.

4.6.3.12 Techniques to prevent and reduce gas and liquid emissions (liquid and liquefied gases) from the tanks. Considerations on transfer and handling techniques: Vapour treatment

Database references: technique ESB22

ECM FOR THE LOADING AND UNLOADING OF TRANSPORTERS
Vapours displaced during the loading of road tankers, rail tankers and ships may be freely vented to atmosphere, or as an alternative for products where the vapours have a significant negative environmental effect, may be ‘balanced’ back to the tank from which the product is being delivered, or treated in a vapour treatment system. Vapour balancing and treatment are also ECM for tank filling.
Vapour balancing for the loading and unloading of transporters
Vapour balancing can be used for both the loading and unloading of transporters. The balancing principle requires vapour tight pipe work between the storage tank and the transporter. A vapour connection system is required at the loading point to connect the facility and the transporter. This would result in air being drawn into the tank and effective vapour balancing not being achieved.
Vapour treatment for the loading of transporters
Vapour treatment requires the vapours to be collected during the loading of a transporter and fed to a vapour treatment system via pipe work.

4.6.3.13 Techniques to prevent and reduce gas and liquid emissions (liquid and liquefied gases) from the tanks. Considerations on transfer and handling techniques: Valves and fittings

Database references: technique ESB23

Valves and fittings
Valves are part of both the tank and the transfer system. Leaking losses are higher from dynamic equipment (compared to static equipment) and from older equipment.

Some valves are more likely to leak than others. Valves which are operated frequently, such as control valves, may wear quickly and allow emission paths to develop.

All except the relief valve and check valve are activated through a valve stem. This stem requires a seal to isolate the product inside the valve from the atmosphere.

Because they open and close frequently, control valves are more prone to leakage than shut-off valves. Using rotating control valves can help reduce fugitive emissions.

High quality packed valves are available that have very low fugitive emissions. To achieve low emissions, these valves use improved packing systems, are built according to stringent tolerances, and are carefully assembled.

It is common practice that valves (fittings) are easily accessible and operated and that they are appropriate for the technical purpose.

ECM FOR PRODUCT HANDLING SYSTEMS – OPERATIONAL – GAS EMISSIONS
The main sources of fugitive emissions in a storage transfer and handling system are valve stems, flanges, connections and open ends, sampling points and pump seals. Technical ECM for each of these potential sources is described as follows:

High quality equipment
In many cases, using better quality equipment can result in reductions of emissions.

Elimination of open-ended lines and valves
Open-ended lines occur at the outlets from drains or sampling points. They are typically fitted with a valve, which is normally closed. All drains that are not operated on a regular basis are normally fitted with a cap, blind flange or plug. If they need to be operated regularly, they are fitted with a second valve.

Bellows valves
Bellows valves have no stem emissions as this type of seal incorporates a metal bellows that forms a barrier between the valve disc and body.
Chapter 4

Valves with a diaphragm
In this type of valve, a diaphragm is used to isolate the working parts of the valve from the liquid in the main body.

Rotating control valves
Using rotating control valves instead of rising stem control valves reduces emissions to air.

Variable speed pumps
Using variable speed pumps instead of rising stem control valves reduces emissions to air.

Double walled valves
Double-wall valves are available. These valves are approved standard valves with an outer secondary containment which hermetically encapsulate all critical parts that represent a potential point for leakage or emission.

Pressure and thermal relief valves
Relief valves are fitted to transfer systems to avoid a build up of pressure due to solar heat absorption or in emergency situations. Thermal relief valves are designed for credible fire cases as well as thermal expansion due to ambient effects. Similar relief systems are used for liquids that can be subject to decomposition and cannot be blocked between two closed valves.

Seal-less pumps
To isolate the interior of the pump from the atmosphere all pumps, except canned motor and diaphragm pumps, require a seal at the point where the shaft penetrates the housing.
In seal-less canned motor pumps, the cavity housing, the motor rotor and the pump casing are interconnected. As a result, these pumps are not suitable in transferring substances containing particles.

4.6.3.14 Techniques to prevent and reduce gas and liquid emissions (liquid and liquefied gases) from the tanks. Considerations on transfer and handling techniques: Pumps and compressors

Database references: technique ESB24

Pumps
Pumps are used to displace all types of products under atmospheric, pressurised or refrigerated conditions.

Compressors
Compressors have many similar features to pumps and are used to displace gases or refrigerated products.
Seals for pumps
The products transferred can leak at the point of contact between the moving pump shaft and the stationary casing. To isolate the interior of the pump from the atmosphere all pumps, except the seal-less types require a seal at the point where the shaft penetrates the housing.
Seal for compressors
Sealing technologies can be employed in low velocity compressors.
Chapter 4

ECM FOR PRODUCT HANDLING SYSTEMS – OPERATIONAL – GAS EMISSIONS
The main sources of fugitive emissions in a storage transfer and handling system are valve stems, flanges, connections and open ends, sampling points and pump seals. Technical ECM for each of these potential sources is described as follows:

**High quality equipment**
In many cases, using better quality equipment can result in reductions of emissions.

**Elimination of open-ended lines and valves**
Open-ended lines occur at the outlets from drains or sampling points. They are typically fitted with a valve, which is normally closed.

**Bellows valves**
Bellows valves have no stem emissions as this type of seal incorporates a metal bellows that forms a barrier between the valve disc and body.

**Valves with a diaphragm**
In this type of valve, a diaphragm is used to isolate the working parts of the valve from the liquid in the main body. The diaphragm may also be used to control the flow. However, emissions will occur if the diaphragm fails.

**Rotating control valves**
Control valves open and close frequently and are, therefore, more prone to leakage than shut-off valves. Using rotating control valves instead of rising stem control valves reduces emissions to air.

**Variable speed pumps**
Control valves open and close frequently and are, therefore, more prone to leakage than shut-off valves. Using variable speed pumps instead of rising stem control valves reduces emissions to air.

**Double walled valves**
Double walled valves are available which are approved standard valves with an outer secondary containment. These valves are a necessary item in all monitored double wall systems and can be attached to either pipes or tanks with welded or flanged connections.

**Pressure and thermal relief valves**
Relief valves are fitted to transfer systems to avoid a build up of pressure due to solar heat absorption or in emergency situations. Thermal relief valves are designed for credible fire cases as well as thermal expansion due to ambient effects.

**Seal-less pumps**
To isolate the interior of the pump from the atmosphere all pumps, except canned motor and diaphragm pumps (with magnetic drive), require a seal at the point where the shaft penetrates the housing.
In seal-less canned motor pumps, the cavity housing, the motor rotor and the pump casing are interconnected

**Improved single seals for pumps**
The technologies employed include highly sophisticated finite elements and other modelling techniques in the optimisation of component shapes, computational fluid dynamics, specialised material developments, improved tribological properties rubbing
face surface profile adjustments and pre-set packaged assemblies to eliminate fitting errors.

**Dual unpressurised seals for pumps**

The simple sophistication of a single seal (which contains the process fluid) is to include a second mechanical seal outboard of this primary seal.

**Seals for compressors**

The issues with seals in compressors are similar to pumps.

**Improved sampling connections**

Sampling points can be fitted with a ram type sampling valve or with a needle valve and a block valve to minimise emissions.

### 4.6.3.15 Incidents and (major) accidents emission control measures for tanks. Safety and risk management

*Database references: technique ESB25*

**Description**

The Seveso II Directive (Council Directive 96/82/EC of 9 December 1996 on the control of major accident hazards involving dangerous substances) requires companies to take all measures necessary to prevent and limit the consequences of major accidents. They must, in any case, have a major accident prevention policy (MAPP) and a safety management system to implement the MAPP. Companies holding large quantities of dangerous substances, the so-called upper tiered establishments, must also draw up a safety report and an on-site emergency plan and maintain an up-to-date list of substances.

The safety management system gives shape to the MAPP. However, plants that do not fall under the scope of the Seveso II Directive also often apply individual risk management policies.

Incidents and (major) accidents from tanks can be prevented and controlled taking into account different safety and risk measures. For this, several techniques have to be considered:

**Operational procedures and training**

**Low level indicator in external floating roof tanks (EFRT):** instrumentation to measure and warn for a low level of the content of a tank is needed to prevent an external floating roof from landing in an emptying mode, potentially causing damage and loss.

**Leakage and overfill:** containment refers to additional protection against storage tank releases over and above the inherent protection provided by the tank container itself.

**Corrosion and erosion:** corrosion is one of the main causes of equipment failure. Corrosion is generally avoided by the selection of resistant construction materials and proper construction methods.

**Operational procedures and training to prevent overfill:** clear operational procedures undertaken by the operators are the first level of protection against overfilling.

**Instrumentation and automation to prevent overfill:** to prevent the overfilling of a tank, high level instrumentation is required. This can be a level gauge with alarm settings and/or auto closing of valves.
Chapter 4

Instrumentation and automation to detect leakage: four different basic techniques can be used to detect leaks. These are:

- **Release prevention barrier system (RPBS):** where a double tank bottom or impervious barriers are installed, any leakage from the tank bottom can be lead to the perimeter of the tank.

- **Inventory checks:** these checks are either based on the level of the product in the tank (level check), or the mass of the product in the tank under static conditions (mass check), both known as the *static volumetric methods*, or the difference between the volumes of product pumped in and out of the tank over long periods compared to the change in the stored volume, known as the *enhanced inventory check*.

- **Acoustic emissions method:** this method detects a leak by listening for the characteristic noises created by a leak from the bottom of a static tank.

- **Soil vapour monitoring:** this method depends on the testing of vapours either diffusing or being drawn with a vacuum pump from the soil below a tank.

**Risk-based approach for emissions to soil below tanks:** the risk-based approach for emissions to soil from an aboveground flat-bottom and vertical, storage tank containing liquids with a potency to pollute soil, is that soil protection measures are applied at such a level that there is a ‘negligible risk’ for soil pollution because of leakage from the tank bottom or from the seal where the bottom and the wall are connected.

**Tank bunds and liner systems:** whereas double bottoms or impervious liners under a tank protect against the small but persistent leak, a tank farm bund (or dike) is designed to contain large spills, such as that caused by a shell rupture or a large overfill.

The bund consists of a wall around the outside of the tank (or tanks) to contain any product in the unlikely event of a spill.

**Laminated concrete containment under aboveground tanks:** for chlorinated hydrocarbon solvents (CHC), concrete containment requires the application of surface protection, allowing the covering of capillary cracks, to render it impervious.

**Aboveground double wall tanks:** the double wall is normally applied in combination with a double tank bottom and leak detection for the storage of flammable and non-flammable substances and substances that are non-hazardous up to very hazardous to surface water. **Cup-tanks:** with a cup-tank, a second tank is built around a single wall tank with a distance of about 1.5 m. The cup has the same strength as the tank itself and is constructed to contain all of the liquid stored.

**Aboveground double wall tank with monitored bottom discharge:** in preventing emissions to soil and/or surface water, the two alternative systems used are the ‘single wall tank in a pit or bund’ or ‘double wall tank equipped with a leak detection device’

**Underground double wall tanks:** tanks containing gasoline (with MBTE) or other fuels are normally double walled (or single walled with containment) and equipped with a leakage detector.

**Underground single wall tanks with secondary containment:** an alternative to the double wall tank is to equip the single wall tank with a secondary containment with additional leak detection to monitor liquid ingress into the containment. The secondary containment is coated with an impermeable material to prevent leaks.
In this chapter, the environmentally friendly techniques of chapter 4 are evaluated with respect to their environmental benefit, their technical and their economic viability. It is also suggested whether or not a discussed technique can be regarded as a BAT for the textile industry.

The BAT selected in this chapter are considered BAT for the textile sector. This does not imply that every single company belonging to the sector is capable of applying each of the selected techniques without experiencing any significant problems. For drawing company-level conclusions, the company specific circumstances always need to be taken into account.

The BAT selection in this chapter is not to be considered as a separate matter, but should be viewed in the global context of this study. That is, the discussion of the environmentally friendly techniques in chapter 4 should always be taken into account.
5.1 Evaluation of the available environmentally friendly techniques

In Table 15 the available environmentally friendly techniques discussed in chapter 4 are tested according to a number of criteria. This multi-criteria analysis allows for judging whether or not a technique can be considered a Best Available Technique. The criteria are not only related to the environmental media (water, air, soil, energy, noise/vibrations), but also cover the technical viability and the economic aspects. In that way, an integrated assessment, consistent with the BAT definition (cf. Chapter 1) is allowed for.

The following aspects are qualitatively evaluated and reflected in the table:

**Technical viability**
- **proven**: indicates whether the technique has a proven use in industrial practice ("-": not proven, "+": proven);
- **technical applicability**: indicates whether the technique is general applicable or not ("+": applicable, "+/-": applicable under certain circumstances, "+/": not applicable). Limiting circumstances need to be clearly described;
- **safety and working conditions**: indicates whether the technique, when properly applying the appropriate security measures, is expected to lead to an increased risk of fire, explosions or accidents in general and thus affecting the safety and working conditions ("-": increased risk, "0": no increased risk, "+": reduced risk);
- **quality**: indicates whether the technique is expected to influence the quality of the end product ("-": reduced quality; "0": no quality effect; "+": increased quality);
- **global**: estimates the global technical viability of the technique for the sector as a whole ("+": if all the above aspects are "+" or "0"; "+/": if at least one of the above aspects is "+").

**Environmental benefit**
- **water use**: reuse of waste water and reduction of the total water use;
- **wastewater**: addition of polluting substances to the water as a result of the operation of the facility (BOD, COD, nutrients, other emissions to water);
- **energy**: energy savings, use of renewable energy sources and energy reuse;
- **air/odour**: addition of polluting substances to the atmosphere as a result of the operation of the facility (dust, NOX, SOX, NH3, VOC, other emissions to air);
- **waste**: prevention and control of waste flows
- **use of raw and auxiliary materials**: influence on the amount and the kind of raw/auxiliary materials (e.g. chemicals) used;
- **soil**: addition of polluting substances to soil and groundwater as a result of the operation of the facility
- **global**: estimated influence on the environment as a whole.
- **noise/vibrations**
Per technique, for each of the above criteria a qualitative assessment is carried out in which:

- “-”: negative effect;
- “0”: no/negligible impact;
- “+”: positive effect;
- “+/−”: sometimes positive, sometimes negative effect.

The single score for global environmental benefit is determined based on the individual scores, using different criteria. Due to the qualitative approach used in this study, a possible criteria is the weighting of the different environmental scores based on priorities set in legislation, based on environmental quality standards for water, air, etc. (see Chapter 2 for the legislative and socio-economic framework). In this study, this weighting is part of the expert judgement by the TWG members involved, but is seldom explicitly described.

**Economic viability**

- “+”: the technique reduces the costs;
- “0”: the technique has a negligible impact on the costs;
- “−”: the technique increases the costs, but the additional costs are considered bearable for the sector and reasonable compared to the environmental benefit.
- “−−”: the technique increases the costs, the additional costs are not considered bearable for the sector or reasonable compared to the environmental benefit.

Finally in the last column it is decided whether the considered technology can be selected as Best Available Technique (BAT: ‘yes’ or BAT: ‘no’). When this decision is highly dependent on the company and/or the local circumstances, the technique gets a score of ‘Yes’, but with a clear description of the specified conditions.
Important remarks for using Table 15:

Whenever using the table below, keep the following remarks in mind:

The table should not be considered as a separate matter, but should be viewed in the global context of the study. That is, the discussion of the environmentally friendly techniques in chapter 4 should always be taken into account.

The evaluation of the different criteria is, among other things based on:
- The operators’ experience with the technique;
- BAT-selections carried out in other (foreign) comparable studies;
- The sector working group’s advice (expert judgement);
- The author’s considerations.
Where needed, footnotes are inserted for additional clarification. The meaning of the criteria and the scores is explained in section 5.1.

The BAT conclusions in the table are based on discussion in the Technical Working Group. The final BAT conclusions and conditions can differ from these in other MPCs. These differences are explained (made clear) by the individual scores for the technical viability, environmental benefit and economic viability and accompanying footnotes in the BAT evaluation matrix. When determining/setting the scores, the local situation in the MPC was taken into account. Differences in scores, like differences in environmental scores, might also be caused by differences in background and focus of the members of the TWG in the different MPCs. However, these smaller differences (often not at all contrary) will not directly influence the final BAT conclusion.

The assessment of the criteria is indicative and not necessarily applicable in each individual case. Thus, the appreciation in no way relieves the operator from the responsibility to investigate if e.g. the technique is technically viable in his/her specific situation, if it does not hamper safety, causes unacceptable environmental nuisance or entails excessive costs. Additionally, for the assessment of each technique it is supposed that appropriate safety/environment protection measures were taken.

The table should not be considered as a separate matter, but should be viewed in the global context of the study. That is, the discussion of the environmentally friendly techniques in chapter 4 should always be taken into account.

The table assesses in a general way if the discussed environmental techniques are to be considered BAT for the textile sector. The scoring is thus purely a qualitative scoring, not a score compared to a certain reference situation as you might do for a single company. The resulting evaluation does therefore not necessarily mean that every company belonging to the sector is capable of applying each of the selected techniques. The company’s specific circumstances should always be taken into account.
Table 8. Evaluation of the available environmentally friendly techniques and selection of the BAT

General measures

The scoring in this table is purely based on a qualitative evaluation and thus not compared with a reference situation. The scores merely indicate what overall effect a technique is expected to have.

<table>
<thead>
<tr>
<th>Technique</th>
<th>Technical viability</th>
<th>Environmental benefit</th>
<th>Economic viability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proven</td>
<td>Applicability</td>
<td>Safety and working conditions</td>
</tr>
<tr>
<td>G1</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>G2</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>G3</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>G4</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>G5</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

12 Investment in new equipment and/or structural modifications are needed.
### Pretreatment process

#### Sizing

The scoring in this table is purely based on a qualitative evaluation and thus not compared with a reference situation. The scores merely indicate what overall effect a technique is expected to have.

<table>
<thead>
<tr>
<th>Technique</th>
<th>Technical viability</th>
<th>Environmental benefit</th>
<th>Economic viability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proven</td>
<td>Applicability</td>
<td>Safety and working conditions</td>
</tr>
<tr>
<td>2.C.1 Recovery of sizing agents by ultra-filtration</td>
<td>+</td>
<td>-/+</td>
<td>0</td>
</tr>
<tr>
<td>3.D.1 Selection of sizing agents with improved environmental performance</td>
<td>+</td>
<td>-/+</td>
<td>+</td>
</tr>
<tr>
<td>2.A.2 Use of techniques that allow reduced load of sizing agents on the fibre (compact spinning)</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

---

13 There are some technical limitations. These limitations depend on the use of other auxiliaries, such as waxes and antistatic agents. Other limitations can be found when the same concentrate is re-used for different kind of yarns.

14 According to the TWG Members, in Morocco, this technique is not economically viable due to high investment and operational (maintenance) costs.

15 For commission finishers and in general for non-integrated mills, it is difficult to influence up-stream weaving.

16 According to the TWG Members, in Morocco, the economic viability depends on the price of substituting sizing agents.

17 Restrictions: This technique has a limited technical applicability and a limited economic viability.
Pretreatment process

Desizing

The scoring in this table is purely based on a qualitative evaluation and thus not compared with a reference situation. The scores merely indicate what overall effect a technique is expected to have.

<table>
<thead>
<tr>
<th>Technique</th>
<th>Technical viability</th>
<th>Environmental benefit</th>
<th>Economic viability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proven</td>
<td>Applicability</td>
<td>Safety and working conditions</td>
</tr>
<tr>
<td>2.A.1 Minimizing sizing agent add-on by pre-wetting the warp yarns</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>2.D.3 Application of the oxidative route for efficient, universal size removal</td>
<td>+</td>
<td>+19</td>
<td>+</td>
</tr>
</tbody>
</table>

18 This technique increases the costs, but the additional costs are considered bearable for the sector and reasonable compared to the environmental benefit.
19 In Morocco the technique is applicable for lightly dyed fabrics.
Pretreatment process

Scouring (washing)

The scoring in this table is purely based on a qualitative evaluation and thus not compared with a reference situation. The scores merely indicate what overall effect a technique is expected to have.

<table>
<thead>
<tr>
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<th>Technical viability</th>
<th>Environmental benefit</th>
<th>Economic viability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proven</td>
<td>Applicability</td>
<td>Safety and working conditions</td>
</tr>
<tr>
<td>2.A.4 Omitting the use of detergents in after washing of cotton dyed with reactive dyes</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

20 According to the TWG members, in Morocco, this technique requires additional skills and technology transfer.
### Pretreatment process

**Mercerising (and caustification)**

The scoring in this table is purely based on a qualitative evaluation and thus not compared with a reference situation. The scores merely indicate what overall effect a technique is expected to have.

<table>
<thead>
<tr>
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<th>Technical viability</th>
<th>Environmental benefit</th>
<th>Economic viability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proven</td>
<td>Applicability</td>
<td>Safety and working conditions</td>
</tr>
<tr>
<td>2.C.2 Recovery of alkali from mercerizing</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
</tbody>
</table>

21 The investment cost and payback time depends on different factors: the plant size and the purification technique used. In Europe the investment cost can vary from 200,000 to 800,000 euros.
Pretreatment process

Bleaching

The scoring in this table is purely based on a qualitative evaluation and thus not compared with a reference situation. The scores merely indicate what overall effect a technique is expected to have.

<table>
<thead>
<tr>
<th>Technique</th>
<th>Technical viability</th>
<th>Environmental benefit</th>
<th>Economic viability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2.A.3</strong></td>
<td>Minimizing consumption of complexing agents in hydrogen peroxide bleaching</td>
<td>+ + + 0 +</td>
<td>0 + 0 0 0 0 + + +</td>
</tr>
<tr>
<td><strong>2.B.8</strong></td>
<td>Dry bleaching using ozone instead of wet washing using chlorine or hydrogen peroxide</td>
<td>+ + 0 + +</td>
<td>+ + 0 0 0 0 + + +</td>
</tr>
<tr>
<td><strong>3.D.3</strong></td>
<td>Substitution for sodium hypochlorite and chlorine-containing compounds in bleaching operations</td>
<td>+ + + 0 +</td>
<td>0 + 0 0 0 0 + +</td>
</tr>
</tbody>
</table>

---

22 Two stage bleaching is expensive, but if the bleaching is carried out in one stage the costs are no higher than the costs for conventional methods.
Pretreatment process

Integrated measures in pre treatment

The scoring in this table is purely based on a qualitative evaluation and thus not compared with a reference situation. The scores merely indicate what overall effect a technique is expected to have.

<table>
<thead>
<tr>
<th>Technique</th>
<th>Technical viability</th>
<th>Environmental benefit</th>
<th>Economic viability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proven</td>
<td>Applicability</td>
<td>Safety and working conditions</td>
</tr>
<tr>
<td>2.D.1</td>
<td>One-step desizing, scouring and bleaching of cotton fabric</td>
<td>+</td>
<td>-/+</td>
</tr>
<tr>
<td>2.D.2</td>
<td>Optimization of cotton warp yarn pre-treatment</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

23 Only companies with new machinery are able to apply this technique. According to the TWG members, in Morocco, a technical study on the productive process is needed to prove the applicability of this technique to textile installations (e.g. to verify whether the textile machine can support the one-step process).

24 Restriction: BAT for all textile companies with new machinery,
**Pretreatment process**

**Other measures**

*The scoring in this table is purely based on a qualitative evaluation and thus not compared with a reference situation. The scores merely indicate what overall effect a technique is expected to have.*

<table>
<thead>
<tr>
<th>Technique</th>
<th>Technical viability</th>
<th>Environmental benefit</th>
<th>Economic viability</th>
<th>BAT?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proven</td>
<td>Applicability</td>
<td>Safety and working conditions</td>
<td>Quality</td>
</tr>
<tr>
<td>3.A.2</td>
<td>Man-made fibre preparation agents with improved environmental performance</td>
<td>+/-25</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>3.D.4</td>
<td>Selection of biodegradable/bioeliminable complexing agents in pretreatment and dyeing processes</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

---

25 The applicability depends on the kind of fibre. This technique is applicable for polyester, polyamide and viscose fibres.

26 According to the TWG members, in Morocco, prices vary depending on the kind of preparation agents used.

27 Restriction: The applicability of this technique is limited.
### Chapter 5

<table>
<thead>
<tr>
<th>Technique</th>
<th>Technical viability</th>
<th>Environmental benefit</th>
<th>Economic viability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proven</td>
<td>Water use</td>
<td>Raw/auxiliary materials</td>
</tr>
<tr>
<td></td>
<td>Applicability</td>
<td>Wastewater</td>
<td>Global</td>
</tr>
<tr>
<td></td>
<td>Safety and working</td>
<td>Energy</td>
<td>Cost feasibility and cost effectiveness</td>
</tr>
<tr>
<td></td>
<td>conditions</td>
<td>Waste/by-products</td>
<td>Global</td>
</tr>
<tr>
<td></td>
<td>Quality</td>
<td>Air &amp; odour</td>
<td>Global</td>
</tr>
<tr>
<td></td>
<td>Global</td>
<td>Soil &amp; ground water</td>
<td>Global</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Noise &amp; vibrations</td>
<td>Global</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Raw/auxiliary materials</td>
<td></td>
</tr>
</tbody>
</table>

#### 2.C.7

**Bacterial cellulose production from cotton-based waste textiles: Enzymatic saccharification enhanced by ionic liquid pre-treatment**

- **Proven:** 28
- **Applicability:** +
- **Safety and working conditions:** 0
- **Quality:** 0
- **Global:** -
- **Water use:** 0
- **Wastewater:** 0
- **Energy:** 0
- **Waste/by-products:** +
- **Air & odour:** 0
- **Soil & ground water:** 0
- **Noise & vibrations:** +
- **Raw/auxiliary materials:** +
- **Global:** +

**Economic viability:** No

---

28 The technique has not yet been proven on an industrial scale (only on pilot scale).
### Dyeing

**Efficient measures in dyeing process**

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</thead>
<tbody>
<tr>
<td></td>
<td>Proven</td>
<td>Applicability</td>
<td>Safety and working conditions</td>
</tr>
<tr>
<td>2.A.5</td>
<td>29.5</td>
<td>+/-29.5</td>
<td>+</td>
</tr>
<tr>
<td>2.B.1</td>
<td>0</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>2.B.2</td>
<td>0</td>
<td>+/-32.5</td>
<td>0</td>
</tr>
</tbody>
</table>

---

29 According to the TWG members, in Morocco, this technique is only applicable for new plants.

30 Restriction: The technique is BAT only for new plants.

31 The techniques are economically viable in large companies.

32 For blends with elastane fibres the applicability is limited.

33 Restriction: This technique is BAT with technical limitations.
<table>
<thead>
<tr>
<th>Technique</th>
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<th>Environmental benefit</th>
<th>Economic viability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proven</td>
<td>Applicability</td>
<td>Safety and working conditions</td>
</tr>
<tr>
<td>2.B.3 Airflow jet dyeing machines with the use of air, either in addition to or instead of water and Soft-flow dyeing machines with no contact between the bath and the fabric</td>
<td>++/-34</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>2.C.6 Direct re-use of dye baths and auto-control of the process online</td>
<td>++/-36</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>2.D.4 Equipment optimisation in batch dyeing.</td>
<td>++</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

34 The technique cannot be used for dyeing linen fabric because the linen lint causes scaling of the machine.
35 This technique implies new investment in machinery. According to the TWG members, in Morocco, the technique is only economically viable for large companies (i.e. companies with more than 250 employees).
36 This technique is only applicable for certain types of dyestuffs, like acid dyestuff and disperse dyestuff. While for other types of dyestuffs, like active dyestuffs, the technique is not applicable.
37 The RAMAN spectroscopy unit used and other similar ones available on the market are quite expensive. The technique is therefore not considered economically viable.
Dyeing

Less pollutant dyes

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<tbody>
<tr>
<td></td>
<td>Proven</td>
<td>Applicability</td>
<td>Safety and working conditions</td>
</tr>
<tr>
<td>3.C.1 Dispersing agents with higher bio eliminability in dye formulations</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>3.C.2 Dyeing with sulphur dyes</td>
<td>+</td>
<td>-/+39</td>
<td>+</td>
</tr>
<tr>
<td>3.C.4 Silicate-free fixation method for cold pad batch dyeing</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>3.C.5 Exhaust dyeing of cellulosic fibres with high-fixation polyfunctional reactive dyestuffs</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

38 Dispersing agents with higher bio eliminability in dye formulations are more expensive than conventional ones.
39 In Morocco textile companies usually test the sulphur dyes before to use them in dyeing processes in order to check the quality of the final products. This technique is applicable for dyeing dark colours only.
40 Sulphur dyes are more expensive than conventional ones.
41 Restriction: BAT for dyeing dark colours only.
42 This technique increase the cost: polyfunctional reactive dyestuffs are more expensive per kilogram than conventional dyes.
<table>
<thead>
<tr>
<th>Technique</th>
<th>Technical viability</th>
<th>Environmental benefit</th>
<th>Economic viability</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.C.6</td>
<td></td>
<td></td>
<td>BAT?</td>
</tr>
<tr>
<td>Exhaust dyeing with low-salt reactive dyes</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>3.C.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dyeing without water and chemicals</td>
<td>+</td>
<td>-/+ 44</td>
<td>+</td>
</tr>
</tbody>
</table>

43 Costs of water treatment are reduced.
44 This technique is applicable for synthetic fibres only.
45 Costs are very low.
46 Restriction: BAT for synthetic fibres only.
Dyeing

Other measures

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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proven</td>
<td>Applicability</td>
<td>Safety and working conditions</td>
</tr>
<tr>
<td>1.B.2 PH-controlled dyeing techniques</td>
<td>+ + 0 0 +</td>
<td>0 0 + + 0 0 0 0 + +</td>
<td>Yes</td>
</tr>
<tr>
<td>3.B.1 Adoption of an enzymatic treatment to remove the non-fixed dyestuff not only from the fibre, but also from the exhausted dye bath</td>
<td>+ -/+ 47 + + -/+</td>
<td>+ 0 + 0 0 + 0 + + +</td>
<td>Yes 48</td>
</tr>
<tr>
<td>3.D.7 Exhaust dyeing of polyester and polyester blends with carrier-free dyeing techniques or with use of environmentally optimised carriers</td>
<td>+ + 49 + 0 + + + - 0 + 0 0 + + +</td>
<td>Yes 50</td>
<td></td>
</tr>
<tr>
<td>3.D.8 Use of non-carrier dyeable PES (PTT) fibres</td>
<td>+ + + 0 0 0 0 0 + 0 0 0 0 + + +</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

47 The technique is only applicable to exhaust dyeing with reactive dyestuffs.
48 Restriction: This technique is a BAT with technical limitations.
49 This technique can be applied to all PES qualities.
50 According to the TWG Members, in Morocco costs can arise from the intensive use of energy.
End of pipe techniques

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<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td></td>
<td>Proven</td>
<td>Applicability</td>
<td>Safety and working conditions</td>
</tr>
<tr>
<td>4.A.1 Treatment of mixed waste water with about 60% water recycling.</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>4.A.2 Recycling of textile waste water by treatment of selected streams with membrane techniques.</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>4.A.3 Application of physical-chemical processes and cross-flow filtration</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>4.A.4 Water purification tertiary treatment using photo-oxidation</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
</tbody>
</table>

51 In the opinion of TWG Members, in Morocco this technique is expensive in term of investment and maintenance and for this reason only viable for medium and large companies (large companies have more than 250 employees).
52 According to the TWG Members, in Morocco the economic viability of this technique is higher in large capacity plants than in small capacity plants.
53 This technique has only been proven on a semi-industrial scale.
54 According to the TWG Members, in Morocco the economic viability of this technique is higher in large capacity plants than in small capacity plants.
## Chapter 5

### 4.A.5 Purification of Industrial And Mixed Wastewater By Combined Membrane Filtration And Sonochemical Technologies

- Proven: 55
- Applicability: -
- Safety and working conditions: +
- Quality: 0
- Global: -
- Water use: 0
- Wastewater: +
- Energy: 0
- Waste/by-products: 0
- Air & odour: 0
- Soil & ground water: 0
- Noise & vibrations: 0
- Raw/auxiliary materials: +
- Global: +

<table>
<thead>
<tr>
<th>Environmental benefit</th>
<th>Technical viability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost feasibility and cost effectiveness</td>
<td>+56</td>
</tr>
</tbody>
</table>

**Economic viability:** No

55 The technique has not yet been proven on a full industrial scale (only on a pilot scale).
56 The technique implies a reduction in chemicals consumption and laboratory costs.
57 In Morocco, it is currently difficult to apply this technique as there is not enough space at the production sites. Homogenisation tanks are however frequently used to mix wastewater before treatment.
58 The effect on water use is positive when the treated water is reused as process water.
59 Some of the water treatment techniques require additional energy.
60 Some of the water treatment techniques create a residue (sludge) during the treatment process.
61 When the water treatment system doesn’t function optimally, odour might become a problem.
62 Some of the water treatment techniques require the use of chemicals, e.g. physicochemical removal of phosphorous.
63 The costs for wastewater purification depend on the individual situation.
64 Restrictions: BAT with technical and economic limitations.

### 4.A.6 Appropriately treat industrial wastewater by implementing a combination of suitable waste purification techniques

- Proven: +
- Applicability: -/+57
- Safety and working conditions: 0
- Quality: 0
- Global: -/+58
- Water use: 0/+58
- Wastewater: +
- Energy: -/059
- Waste/by-products: -/060
- Air & odour: -/061
- Soil & ground water: 0
- Noise & vibrations: -/062
- Raw/auxiliary materials: +

<table>
<thead>
<tr>
<th>Environmental benefit</th>
<th>Technical viability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost feasibility and cost effectiveness</td>
<td>0/-/--63</td>
</tr>
</tbody>
</table>

**Economic viability:** Yes64

147
<table>
<thead>
<tr>
<th>Technique</th>
<th>Technical viability</th>
<th>Environmental benefit</th>
<th>Economic viability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4.A.7</strong> Removal of disperse dyes from textile wastewater using bio-sludge</td>
<td>-65</td>
<td>0 0 0 -</td>
<td>0 + 0 0 0 0 0 + + -</td>
</tr>
<tr>
<td><strong>4.A.8</strong> Anaerobic degradation of textile dye bath effluent using Halomonas sp</td>
<td>-66 -/+67</td>
<td>0 0 -</td>
<td>0 + 0 0 0 0 0 0 + 0</td>
</tr>
<tr>
<td><strong>4.A.9</strong> Colour removal of dyes from synthetic and real textile wastewater in one- and two-stage anaerobic systems.</td>
<td>-68 -/+69</td>
<td>0 0 -</td>
<td>0 + 0 0 0 0 0 0 + 0</td>
</tr>
<tr>
<td><strong>4.A.10</strong> Integrating photobiological hydrogen production with dye-metal bio removal from simulated textile wastewater</td>
<td>-70</td>
<td>+ 0 -</td>
<td>0 + 0 0 0 0 0 0 + -</td>
</tr>
</tbody>
</table>

65 The technique has not yet been proven on an industrial scale (only on research scale).
66 The technique has not yet been proven on a large industrial scale.
67 The technique can be applied to wastewater produced by azo-reactive dye used by a nearby textile industry.
68 The technique has not yet been proven on an industrial scale.
69 The technique can be applied in synthetic textile wastewater and in real textile wastewater.
70 The technique has not yet been proven on an industrial scale (only on research scale).
<table>
<thead>
<tr>
<th>Technique</th>
<th>Technical viability</th>
<th>Environmental benefit</th>
<th>Economic viability</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.A.11 Textiles wastewater treatment using anoxic filter bed and biological wriggle bed-ozone biological aerated filter</td>
<td>Proven 71</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4.A.12 Evaluation of the efficacy of a bacterial consortium for the removal of colour, reduction of heavy metals, and toxicity from textile dye effluent</td>
<td>- 73</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>4.A.13 Biosorption of reactive dye from textile wastewater by non-viable biomass of Aspergillus niger and Spirogyra sp</td>
<td>-75</td>
<td>+76</td>
<td>+</td>
</tr>
</tbody>
</table>

71 The technique has not yet been proven on an industrial scale (only on pilot scale).
72 According to the TWG Members, in Morocco, the technique is not economically viable due to high investment and operational (maintenance) costs.
73 Technique has not yet been proven on an industrial scale (only on research scale).
74 In Morocco government funding is requested.
75 The technique has not yet been proven on an industrial scale (only on pilot scale).
76 The technique can be applied to new and existing installations.
## Chapter 5

<table>
<thead>
<tr>
<th>Technique</th>
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<th>Economic viability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proven</td>
<td>Applicability</td>
<td>Safety and working conditions</td>
</tr>
<tr>
<td>4.A.14 Use of Chlorella vulgaris for bioremediation of textile wastewater</td>
<td>+</td>
<td>+</td>
<td>77</td>
</tr>
<tr>
<td>4.A.15 Chemical coagulation/flocculation technologies for removal of colour from textile wastewaters</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>4.A.16 Up flow anaerobic sludge blanket reactor in removal of colour and reduction of COD in real textile wastewater</td>
<td>-</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>4.A.17 Potential of combined fungal and bacterial treatment for colour removal in textile wastewater</td>
<td>-</td>
<td>78</td>
<td>-</td>
</tr>
<tr>
<td>4.A.18 Electrochemical oxidation for the treatment of textile industry wastewater</td>
<td>-</td>
<td>80</td>
<td>0</td>
</tr>
</tbody>
</table>

77 The technique can be applied to new and existing installations.
78 The technique has not yet been proven on an industrial scale (only on a pilot scale).
79 This technique is difficult to apply.
80 The technique has not yet been proven on an industrial scale (only on research scale).
81 According to the TWG Members, in Morocco, the technique is not economically viable, due to high operational (electricity) costs.
### Table 5.1: Technical, Environmental, and Economic Viability of Selected Techniques

<table>
<thead>
<tr>
<th>Technique</th>
<th>Technical viability</th>
<th>Environmental benefit</th>
<th>Economic viability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Proven</strong></td>
<td><strong>Applicability</strong></td>
<td><strong>Safety and working conditions</strong></td>
<td><strong>Quality</strong></td>
</tr>
<tr>
<td><strong>4.A.19</strong></td>
<td>Removal of reactive dyes from wastewater by adsorption on coir pith activated carbon</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>4.A.20</strong></td>
<td>Utilization of modified silk cotton hull waste as an adsorbent for the removal of textile dye (reactive blue MR) from aqueous solution</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><strong>4.A.21</strong></td>
<td>Biological and oxidative treatment of cotton textile dye-bath effluents by fixed and fluidized bed reactors</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td><strong>4.A.22</strong></td>
<td>Biosorption of anionic textile dyes by nonviable biomass of fungi and yeast</td>
<td>-85</td>
<td>+</td>
</tr>
</tbody>
</table>

82 This technique can be applied when waste materials from coir industries are available.
83 Additional skills for personnel are requested. This implies operational and training and personnel costs.
84 The technique has not yet been proven on an industrial scale (only on research scale).
85 The technique has not yet been proven on an industrial scale (only on pilot scale).
Chapter 5

<table>
<thead>
<tr>
<th>Technique</th>
</tr>
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<tbody>
<tr>
<td>Oxidation techniques (thermal incineration, catalytic incineration), Condensation techniques (e.g. heat exchangers), Absorption techniques (e.g. wet scrubbers), Particulates separation techniques (e.g. electrostatic precipitators, cyclones, fabric filters), Adsorption techniques (e.g. activated carbon adsorption).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technical viability</th>
<th>Environmental benefit</th>
<th>Economic viability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proven</td>
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<tr>
<td>Applicability</td>
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<td>Safety and working conditions</td>
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<tr>
<td>Quality</td>
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<td></td>
</tr>
<tr>
<td>Global</td>
<td>Water use</td>
<td>Wastewater</td>
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<tr>
<td></td>
<td>Energy</td>
<td>Waste/by-products</td>
</tr>
<tr>
<td></td>
<td>Air &amp; odour</td>
<td>Soil &amp; ground water</td>
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<tr>
<td></td>
<td>Noise &amp; vibrations</td>
<td>Raw/auxiliary materials</td>
</tr>
<tr>
<td></td>
<td>Global</td>
<td>Cost feasibility and cost effectiveness</td>
</tr>
</tbody>
</table>

| 4.B.1. | +/ -86 | 0 | 0 | -/+ | 0 | 0 | - | 0 | + | 0 | 0 | 0 | + | -/--87 | Yes88 |

As can be observed in the table some techniques have been as proven on at laboratory scale. According to the BAT classification included in the BREF these techniques can be considered “emerging techniques”.

---

86 The applicability depends on the kind of technique used.
87 Costs depend on the kind of technique used, but are, in general, high. According to the TWG Members, in Morocco, this technique is economically viable for large capacity plants only.
88 Restrictions: Some of the oxidation techniques have technical and economic limitations.
5.2 BAT conclusions

Based on Table 15, the following conclusions can be formulated for the textile sector.

Remarks:
Unless otherwise stated, the BAT conclusions presented in this section are generally applicable to the textile sector.

The techniques listed and described in these BAT conclusions are neither prescriptive nor exhaustive. Other techniques that ensure (at least) an equivalent level of environmental protection can be used.

Usually, in a BAT study, emission levels associated with the best available techniques (BAT AELs) are determined. These are the range of emission levels obtained under normal operating conditions using a BAT or a combination of BAT, expressed as an average over a given period of time, under specified reference conditions.

These BAT AELs are considered as the ultimate goal, whether it is by applying one or a combination of technique: as long as the environmental performance of an installation is in line with BAT AELs. In the present study however, the determination of BAT AELs was impossible due to lack of performance data. BAT are simply listed according to the textile process to which they apply. Depending on the environmental performance level one envisages, one or a combination of techniques might have to be applied. Combinations of techniques were not evaluated in this study.

5.2.1 General BAT for all textile companies

BAT for general measures is to implement one or a combination of the following techniques:

- Management and good housekeeping (G1)
- Input/output streams evaluation/inventory (G2)
- Automated preparation and dispensing of chemicals (G3)
- Optimising water consumption in textile operations (G4)
- Insulation of High Temperature (HT) machines (G5)

5.2.2 BAT for pre-treatment processes

5.2.2.1 BAT for the sizing process

There is one BAT for the sizing process:

- Use of techniques that allow reduced load of sizing agents on the fibre (compact spinning) (2.A.2)
Chapter 6

One technique is identified as BAT, but only under certain conditions:
- *Selection of sizing agents with improved environmental performance (3.D.1)*
  This technique is only a BAT if it is economically viable for the company/installation concerned. Moreover this technique is only a BAT for non-integrated mills.

### 5.2.2.2 BAT for the desizing process

BAT for the desizing process is to implement one or a combination of the following techniques:
- *Minimizing sizing agent add-on by pre-wetting the warp yarns (2.A.1)*
- *Application of the oxidative route for efficient, universal size removal (2.D.3)*

### 5.2.2.3 BAT for the scouring (washing) process

There is one BAT for the scouring process:
- *Omitting the use of detergents in after washing of cotton dyed with reactive dyes (2.A.4)*

### 5.2.2.4 BAT for the mercerising (and caustification) process

One technique was identified as BAT for mercerising process:
- *Recovery of alkali from mercerizing (2.C.2)*

### 5.2.2.5 BAT for the bleaching process

BAT for the bleaching process is to implement one or a combination of the following techniques:
- *Minimizing consumption of complexing agents in hydrogen peroxide bleaching (2.A.3)*
- *Dry bleaching using ozone instead of wet washing using chlorine or hydrogen peroxide (2.B.8)*
- *Substitution for sodium hypochlorite and chlorine-containing compounds in bleaching operations (3.D.3)*

### 5.2.2.6 BAT for integrated measures in pretreatment

One technique was identified as BAT for integrated measures in pretreatment:
- *Optimization of cotton warp yarn pre-treatment (2.D.2)*

The following technique is only BAT for companies with new machinery used in this process:
- *One-step desizing, scouring and bleaching of cotton fabric (2.D.1)*
5.2.2.7 Other BAT measures in pretreatment

This technique referred to other BAT measures in pretreatment is considered BAT:

- Selection of biodegradable/ bio eliminable complexing agents in pre-treatment and dyeing processes (3.D.4)

The following technique is only BAT when it is used for certain kind of fibres:

- Man-made fibre preparation agents with improved environmental performance (3.A.2)

5.2.3 BAT dyeing processes

5.2.3.1 Efficient measures in dyeing

BAT for efficient measures in dyeing is to implement one or a combination of the following techniques:

- Equipment optimisation in batch dyeing (2.D.4)
- Minimization of dye liquor losses in pad dyeing techniques (2.B.1)

The following techniques are only BAT under certain conditions.

- Alternative process for continuous (and semi continuous) dyeing of cellulosic fabric with functional reactive dyes (2.A.5)
  This technique is only a BAT for new installations.
- After treatment in PES dyeing (2.B.2)
  For blends with elastane fibres, the applicability is limited.

5.2.3.2 Less pollutant dyes BAT

BAT for less pollutant dyes is to implement one or a combination of the following techniques:

- Dispersing agents with higher bio eliminability in dye formulations (3.C.1)
- Silicate-free fixation method for cold pad batch dyeing (3.C.4)
- Exhaust dyeing of cellulosic fibres with high-fixation polyfunctional reactive dyestuffs (3.C.5)
- Exhaust dyeing with low-salt reactive dyes (3.C.6)

The following technique is only BAT under certain conditions:

- Dyeing with sulphur dyes (3.C.2)
  This technique is only a BAT for dyeing dark colours.
- Dyeing without water and chemicals (3.C.7)
  This technique is applicable for synthetic fibres only.
5.2.3.3 Other BAT

It is BAT to apply one or a combination of the following techniques:

- **PH-controlled dyeing techniques (1.B.2)**
- **Exhaust dyeing of polyester and polyester blends with carrier-free dyeing techniques or with use of environmentally optimised carriers (3.D.7)**
- **Use of non-carrier dyeable PES (PTT) fibres (3.D.8)**

The following technique is only BAT under certain conditions:

- *Adoption of an enzymatic treatment to remove the non-fixed dyestuff not only from the fibre, but also from the exhausted dye bath (3.B.1)*
  This technique is a BAT for exhaust dyeing with reactive dyestuffs.

5.2.3.4 End of pipe BAT techniques

It is BAT to apply one or a combination of the following techniques:

- **Treatment of mixed wastewater with about 60% water recycling (4.A.1)**
- **Application of physico-chemical processes and cross-flow filtration (4.A.3)**
- **Water purification tertiary treatment using photo-oxidation (4.A.4)**
- **Use of Chlorella vulgaris for bioremediation of textile wastewater (4.A.14)**
- **Chemical coagulation/flocculation technologies for removal of colour from textile wastewaters (4.A.15)**
- **Utilization of modiWed silk cotton hull waste as an adsorbent for the removal of textile dye (reactive blue MR) from aqueous solution (4.A.20)**

The following technique is considered BAT under certain conditions:

- ** Appropriately treat industrial wastewater by implementing a combination of suitable waste purification techniques (4.A.6)**
  This technique is only a BAT when companies have certain characteristics: enough surface on production sites and when homogenisation tanks are frequently used to mix wastewater before treatment.
- **Oxidation techniques (thermal incineration, catalytic incineration); Condensation techniques (e.g. heat exchangers); Absorption techniques (e.g. wet scrubbers); Particulate separation techniques (e.g. electrostatic precipitators, cyclones, fabric filters); Adsorption techniques (e.g. activated carbon adsorption (4.B.1)**
  This technique is only a BAT if it is economically viable for the company/installation concerned.
CHAPTER 6 RECOMMENDATIONS

In this chapter a number of general conclusions related to the BAT conclusions are formulated. Also, a number of experience and limitations encountered during the process of writing this study are highlighted. Based on these elements, this chapter serves as a valuation of the report and its results.

The chapter contains a reflection on the quality of data, evaluation and general contents of the report by the author as well as the TWG members. Also, since the regulatory framework of the MPC currently does not include the use of BAT, members of the TWG reflected on the priorities in the outcome of the study, the BAT.
6.1 Priorities in BAT conclusions

In this chapter the main priorities related to this BAT Report of Textile industry are highlighted. The conclusions aim to point out how this report can be used by both industrial companies and policymakers.

A general priority, when it comes to BAT, is the need for implementation of monitoring systems. In order to determine BAT and BAT associated emission levels, and to translate those into emission limit values, monitoring data are needed. When implementing these emission limit values, it is only possible to have control on implementation and compliance of legislation when adequate monitoring systems are used. Since monitoring is a basis in order to implement the BAT-principle, it is important to mention that good monitoring systems often require significant investments as well.

With this report we not only want to provide a list of environmentally friendly techniques, but also to provide an effective tool to improve the environmental impact of the textiles industry in Morocco. With this report we want to support textile companies in the identification of the (best) available techniques to improve their environmental performance. As explained in the previous chapters, the authors of this report have classified the BAT in the following categories:

- Energy efficiency measures
- Resources efficiency measures
- Selection/substitution of chemicals with others more environmental friendly
- End of pipe techniques

This choice has been made to allow companies to easily identify the technique could implement to improve their environmental performance. In addition, in Morocco there is an urgent need to upgrade, develop and modernize the textile sector in order to:

- help SMEs keep up with the high pace of innovation and technological changes in the rapidly changing field;
- promote business, technological and research collaborations;
- create new jobs;
- expand textile exports;
- invest in new products and processes for its future survival and prosperity;
- ensure industrial growth while keeping the environmental and social impacts at a sustainable level;
- focus on higher market segments;
- recover market share in local market.

Another priority of the report is to provide a useful tool for Moroccan policy institutions to further develop their environmental legislation. In many countries of the south coast of Mediterranean basin, we can observe an evolution of the
environmental legislation that follows the main important European Directives. Despite this we can’t identify in any of the Arab Countries legislation inspired to the principles of IPPC Directive. In the future evolution of environmental legislation we can expect that some of these Countries will implement the principles of the mentioned Directive enhancing the capacity of the legislative framework to prevent and control the pollution with an integrated approach. If this were to happen, this BAT sector report could aim to cover the role played by the BREF in European Legislation.

6.2 Lack of driving forces for environmentally friendly techniques and measures

Analysing the traditional drivers for eco-innovation, we can point out the Moroccan situation and describe how these drivers could favour or not the adoption of environmentally friendly techniques in the future. In this paragraph the following driving forces are included: environmental legislation, market requests, cost of the environmental resources, economic incentives.

Legislation is an important driving force for environmentally friendly techniques and measures. Current legislation is sufficient, but its complete implementation is still hampered, pending the creation of control and follow-up tools, such as water quality inspection, etc.

Industrial pollution has received particular interest in the national environmental policy which resulted in 1) the establishment of an adequate regulatory framework through the enactment of Law 10/95 on Water and Law 11/03 on environmental protection and enhancement and 2) the adoption of an incentive called the ‘Industrial Pollution Fund’ (FODEP), which promotes environmental upgrading through the technical and financial support of industrial companies. This fund, which comes to an end by 2013, is replaced by another one: **Voluntary Mechanism for Industrial Water Pollution Control** funded by the state and decentralized to Hydraulic Basins Agencies for implementation during the period 2011-2013.

The pressure of the market on textile companies can represent a driver to improve the environmental performance of textile processes. Indeed, the majority of textile companies work for the European market where there are environmental requirements in regard to exports and for these reasons Moroccan textile companies are obliged to apply European standards to products and processes. On the other hand, the pressure of the market on textile companies does not yet represent a driver to improve the environmental performance of textile processes for companies that work for the local market. These companies produce low quality products sold at low prices. Local consumer behaviour is still not oriented to select the products with the highest environmental performance. In any case on this issue future positive developments could be expected. For example the competition of emerging countries like India, Pakistan and China could convince Moroccan producers to differentiate their products by increasing quality, including environmental quality.

The cost of the environmental resources represents another driving force to promote eco-innovation. In Morocco the costs of some resources are still too low to represent a
driver to implement more environmentally friendly techniques. An example is the cost of water. The textile industry uses a huge amount of water. As described in chapter 4 there are many techniques aiming at the reduction of water use. Despite this the low cost of water in Morocco could represent an obstacle to adopting these techniques.

Finally, in Morocco there are still no concrete public incentives and there is no access to finances to promote the adoption of environmental techniques. Policymakers could improve this aspect by granting, for example, tax reductions or subsidies to companies adopting cleaner production measures.

6.3 Limitations to the BAT evaluation and report

There are two main limitations to the current report. These limitations can be taken into account for a possible future update of the report or future similar reports.

Both limitations are linked to the availability of quantitative data, data needed to assess the environmentally friendly techniques in Chapter 5 (for example in some cases there are no data on the additional energy required by some of the water treatment techniques) and to determine BAT associated emission values (BAT-AEL).

A lack of quantitative data prevented us from performing a quantitative analysis of the environmental performance and economic viability (affordability and cost-effectiveness). We have, however, tried to identify the BAT in an objective way, using the qualitative approach as described in the methodology report for BAT selection. An approach which is mainly based on expert judgement by the TWG members.

The lack of environmental performance data also prevented us from determining BAT-AEL, basis for emission limit values (ELV) for the Moroccan textile industry.

6.4 Value of the report to TWG members

According to the Moroccan TWG members, the information included in this report is sufficient to be used by the administrative and industrial parties involved. Moreover, the Moroccan TWG members find that the report provides a broad overview of the Moroccan textiles industry and the BAT.

The report is considered a reference document to be taken into account when developing future environmental projects within the Moroccan textiles industry. Company representatives, but also other parties (such as permit writers and legislators) can use this report as a reference document on the textile industry and its BAT.
MAIN REFERENCES


Main references and sources


Main references and sources


Main websites consulted

http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.createPage&s_ref=LIFE03%20ENV/E/000166

http://purifast.tecnotex.it/project.asp

http://www.dyecco.com/

http://www.tecnotex.it/prowater/


www.resolive.com
### LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFB</td>
<td>Anaerobic Filter Bed</td>
</tr>
<tr>
<td>AOX</td>
<td>Absorbable organo-halogen</td>
</tr>
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<td>AV</td>
<td>Added Value</td>
</tr>
<tr>
<td>BAT</td>
<td>Best Available Technique</td>
</tr>
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<td>BAT4MED</td>
<td>Boosting Best Available Techniques in the Mediterranean Partner Countries</td>
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<td>BOD</td>
<td>Biochemical oxygen demand</td>
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<td>BAT reference documents</td>
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<td>BWB</td>
<td>Biological Wriggle Bed</td>
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<td>CAS</td>
<td>Compressed Air Systems</td>
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<td>Computational Fluid Dynamics</td>
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<td>Chlorinated Hydrocarbon Solvents</td>
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<td>Methane</td>
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<td>CMPP</td>
<td>Moroccan Cleaner Production Center</td>
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<td>CO₂</td>
<td>Carbon dioxide</td>
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<td>COD</td>
<td>Chemical Oxygen Demand</td>
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<td>Emission Control Measures</td>
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<td>Amino Carboxylic Acids</td>
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<td>Energy Efficient Design</td>
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<td>High rate algae ponds</td>
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<td>Sodium hydroxide</td>
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<tr>
<td>And O*</td>
<td>Oxygen species</td>
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<td>Scuola Superiore di Studi Universitari e di Perfezionamento Sant’Anna</td>
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<td>Total Volatile Suspended Solids</td>
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<td>Technical Working Group</td>
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<td>Upflow Anaerobic Sludge Blanket Reactor</td>
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<tr>
<td>UF</td>
<td>Ultrafiltration</td>
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<td>US</td>
<td>Ultrafiltration (UF) combined with sonication (US)</td>
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<tr>
<td>VOC</td>
<td>Volatile Organic Compounds</td>
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</tbody>
</table>
ANNEXES
LIST OF THE ANNEXES

Annex 1: Participants to the BAT study
Annex 2: Technical Data Sheets
ANNEX 1: PARTICIPANTS TO THE BAT STUDY

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Plants visited during the course of this study

<table>
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<th>Company</th>
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<th>Contact Person</th>
<th>E-mail</th>
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<tbody>
<tr>
<td>CIB</td>
<td>Casablanca</td>
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<td></td>
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</tr>
<tr>
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<td>Casablanca</td>
<td>M. Ali Belamine</td>
<td><a href="mailto:a.belamine@gidatex.net">a.belamine@gidatex.net</a></td>
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<tr>
<td>ITEX</td>
<td>Casablanca</td>
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<td>2K TEINT</td>
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<td>BLANCATEX</td>
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ANNEX 2: TECHNICAL DATA SHEETS

For additional information on the different techniques described in chapter 4, different technical data sheets were made. These can be found through the BAT4MED website: http://databases.bat4med.org/