BAT4MED

BOOSTING BEST AVAILABLE TECHNIQUES IN THE MEDITERRANEAN PARTNER COUNTRIES
Best Available Techniques (BAT) for the Textile Industry in Tunisia

Study carried out by

Istituto di Management - Scuola Superiore di Studi Universitari e di Perfezionamento Sant’Anna (SSSUP, Italy), International Centre for Environmental Technologies of Tunisia (CITET, Tunisia)

December 2012
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 feasibility 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.

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 Tunisian textile sector composed by many companies belonging to these types of processes.

When needed, technique descriptions are further elaborated 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 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.
CHAPTER 1  INTRODUCTION ................................................................................................................... 13
  1.1  Background of this study: the BAT4MED project ................................................................. 13
      1.1.1  Context ............................................................................................................................. 13
      1.1.2  Industrial emissions and best available techniques ..................................................... 14
      1.1.3  Main aims of the BAT4MED project ............................................................................. 15
      1.1.4  Sector-based BAT studies .............................................................................................. 15
  1.2  The BAT study for the Tunisian textile industry ............................................................... 16
      1.2.1  Main aims of the study .................................................................................................. 16
      1.2.2  Content of the study .................................................................................................. 16
      1.2.3  Procedure and guidance ............................................................................................ 17

CHAPTER 2  SOCIO-ECONOMIC AND ENVIRONMENTAL-LEGISLATIVE FRAMEWORK OF THE SECTOR .................................................................................................................. 19
  2.1  Description and delimitation of the sector ........................................................................ 19
      2.1.1  Delimitation and sub-classification of the sector ......................................................... 19
      2.1.2  The distribution chain ................................................................................................. 20
  2.2  Socio-economic characteristics of the sector ................................................................ 21
      2.2.1  Number and sizes of the companies ......................................................................... 21
      2.2.2  Employment ................................................................................................................. 22
      2.2.3  Evolution of turnover, added value, export, import and profit ................................. 23
          2.2.3.1  Turnover ............................................................................................................... 23
          2.2.3.2  Added value .......................................................................................................... 23
          2.2.3.3  Export .................................................................................................................. 23
          2.2.3.4  Import .................................................................................................................. 23
          2.2.3.5  Profit .................................................................................................................... 24
      2.2.4  Evolution of investments .......................................................................................... 24
      2.2.5  Production and price setting .................................................................................... 24
      2.2.6  Conclusion ................................................................................................................. 24
  2.3  Sector viability ...................................................................................................................... 25
      2.3.1  Procedure .................................................................................................................... 25
      2.3.2  Competitive position .................................................................................................. 25
          2.3.2.1  Aim and approach ............................................................................................... 25
          2.3.2.2  Potential entry of new competitors ...................................................................... 25
          2.3.2.3  Threat of substitutes .......................................................................................... 26
          2.3.2.4  Bargaining power of suppliers ............................................................................. 26
          2.3.2.5  Bargaining power of buyers ................................................................................. 27
          2.3.2.6  Rivalry among existing competitors .................................................................... 27
          2.3.2.7  General conclusion of the competition analysis .................................................. 27
      2.3.3  Conclusive estimation of the viability of the sector ................................................... 28
  2.4  Environmental-regulatory aspects .................................................................................... 28
      2.4.1  Tunisian environmental legislation ............................................................................ 28
      2.4.2  Egyptian environmental legislation ........................................................................... 35
      2.4.3  European legislation .................................................................................................. 36
          2.4.3.1  Industrial Emissions Directive ............................................................................... 36
          2.4.3.2  Urban Wastewater Directive .............................................................................. 38
          2.4.3.3  Emission Trading Scheme (ETS) Directive ......................................................... 39
          2.4.3.4  The Waste Framework Directive ......................................................................... 40
          2.4.3.5  Water protection and management: the Water Framework Directive ............... 40
          2.4.3.6  REACH Regulation: Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals .......................................................... 41
CHAPTER 3  PROCESS DESCRIPTION IN TEXTILES dyeing and FINISHING SUB-SECTOR ...... 45

3.1  General information on the textile dyeing and finishing sub-sector ................. 46

3.1.1  Introduction ....................................................................................................... 46

3.1.1.1  Types of fibre .................................................................................................... 47
3.1.1.2  Textiles products ............................................................................................. 47

3.1.2  Dyeing and finishing processes ......................................................................... 47

3.1.2.1  Preparation ...................................................................................................... 47
3.1.2.2  Description of the dyeing process .................................................................... 48
3.1.2.3  Machinery used in dyeing is .......................................................................... 49
3.1.2.4  Dyes used in the dyeing process: ..................................................................... 50
3.1.2.5  Description of the finishing process ................................................................. 54
3.1.2.6  Types of finishing sub-processes: ................................................................. 54

3.2  Overview of main applied process steps and their environmental impacts in the Tunisian textiles dyeing and finishing sub-sector .............................................. 56

3.2.1  Woven fabric dyeing and finishing process for cotton and its blends .............. 56

3.2.1.1  Process description ......................................................................................... 56
3.2.1.2  Main waste flows generated by the process .................................................... 62
3.2.1.3  Wastewater quality ....................................................................................... 66
3.2.1.4  Resources consumption ................................................................................ 66

3.2.2  Woven fabric dyeing and finishing process for wool and its blends .................. 66

3.2.2.1  Process description ......................................................................................... 66
3.2.2.2  Main waste flows generated by the process .................................................... 71
3.2.2.3  Wastewater quality ....................................................................................... 74

3.2.3  Knitted fabric dyeing and finishing process for cotton and its blends .............. 74

3.2.3.1  Process description ......................................................................................... 74
3.2.3.2  Main waste flows generated by the process .................................................... 74
3.2.3.3  Wastewater quality ....................................................................................... 75
3.2.3.4  Resources consumption ................................................................................ 75

3.2.4  Knitted fabric dyeing and finishing process for cellulose and its blends .......... 75

3.2.4.1  Process description ......................................................................................... 75
3.2.4.2  Main waste flows generated by the process .................................................... 78
3.2.4.3  Wastewater quality ....................................................................................... 81
3.2.4.4  Resources consumption ................................................................................ 81

3.2.5  Jeans washing process ..................................................................................... 81

3.2.5.1  Process description ......................................................................................... 81
3.2.5.2  Wastewater quality ....................................................................................... 83
3.2.5.3  Resources consumption ................................................................................ 83

3.2.6  Jeans dyeing process ....................................................................................... 83

3.2.6.1  Description of jeans dyeing process using direct dyes ..................................... 83
3.2.6.2  Description of jeans dyeing process using reactive dyes ................................ 85
3.2.6.3  Wastewater quality ....................................................................................... 87

CHAPTER 4  Available environmentally friendly techniques ........................................ 89

4.1  Introduction .......................................................................................................... 90

4.2  Techniques for the textile sector ................................................................. 91

4.3  Resource efficiency measures ..................................................................... 94

4.3.1  Efficient use of chemicals and raw materials ........................................ 95

4.3.1.1  Ref. Datasheet 2.A.6: Avoiding batch softening: application of softeners by pad mangles or by spraying and foaming application systems ........................................ 95

4.3.1.2  Ref. Datasheet 2.A.4: Omitting the use of detergents in afterwashing of cotton dyed with reactive dyes ......................................................................................... 96
4.3.1.3 Ref. Datasheet 2.A.3: Minimizing consumption of complexing agents in hydrogen peroxide bleaching ................................................................. 96
4.3.1.4 Ref. Datasheet 2.A.5: Alternative process for continuous (and semicontinuous) dyeing of cellulosic fabric with reactive dyes ....................................................... 97
4.3.2 Efficient use of water .................................................................................... 98
4.3.2.1 Ref. Datasheet 2.B.1: Minimization of dye liquor losses in pad dyeing techniques .98
4.3.2.2 Ref. Datasheet 2.B.2: Aftertreatment in PES dyeing ...................................... 99
4.3.2.3 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 ............................................................. 100
4.3.2.4 Ref. Datasheet 2.B.6: Increasing washing efficiency and water flow control ...... 100
4.3.2.5 Ref. Datasheet 2.B.7: Re-use rinse water from process baths in the production process .............................................................................................................. 101
4.3.2.6 Ref. Datasheet 2.B.8: Dry bleaching using ozone instead of wet washing using chlorine or hydrogen peroxide ................................................................. 102
4.3.3 Resources recovery measures ....................................................................... 102
4.3.3.1 Ref. Datasheet 2.C.1: Recovery of sizing agents by ultra-filtration .................. 102
4.3.3.2 Ref. Datasheet 2.C.2: Recovery of alkali from mercerizing ............................... 104
4.3.3.3 Ref. Datasheet 2.C.3: Recovery of printing paste from supply system in rotary screen printing machines and Recycling of residual printing pastes .................. 104
4.3.3.4 Ref. Datasheet 2.C.4: Equipment optimisation in batch dyeing ...................... 107
4.3.3.5 Ref. Datasheet 2.C.5: Recovery of printing paste from supply system in rotary screen printing machines and Recycling of residual printing pastes .................. 104
4.3.3.6 Ref. Datasheet 2.C.6: Direct re-use of dye baths and auto-control of the process online .............................................................................................................. 105
4.3.4 Integrated process measures ......................................................................... 106
4.3.4.1 Ref. Datasheet 2.D.4: Equipment optimisation in batch dyeing ...................... 107
4.4 Use of enzymatic treatment/enzymes in processes .............................................. 108
4.4.1 Selection/substitution of chemicals with others more environmentally friendly .... 108
4.4.1.1 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 .... 108
4.4.2 Less pollutant dyes ....................................................................................... 109
4.4.2.1 Ref. Datasheet 3.C.1: Dispersing agents with higher bioeliminability in dye formulations ........................................................................................................... 109
4.4.2.2 Ref. Datasheet 3.C.2: Dyeing with sulphur dyes ............................................. 110
4.4.2.3 Ref. Datasheet 3.C.3: Emission reduction in dyeing wool with metal-complex dyestuffs ........................................................................................................ 111
4.4.2.4 Ref. Datasheet 3.C.4: Silicate-free fixation method for cold pad batch reactive dyeing ................................................................................................................. 111
4.4.2.5 Ref. Datasheet 3.C.5: Exhaust dyeing of cellulosic fibres with high-fixation polyfunctional reactive dyestuffs ................................................................. 113
4.4.2.6 Ref. Datasheet 3.C.6: Exhaust dyeing with low-salt reactive dyes ................. 113
4.4.2.7 Ref. Datasheet 3.C.7: Dyeing without water and chemicals ............................ 114
4.4.3 Other measures ............................................................................................ 115
4.4.3.1 Ref. Datasheet 3.D.2: Substitution for alkylphenol ethoxylates (and other hazardous surfactants) .......................................................................................... 115
4.4.3.2 Ref. Datasheet 3.D.3: Substitution for sodium hypochlorite and chlorine-containing compounds in bleaching operations ....................................................... 116
4.4.3.3 Ref. Datasheet 3.D.4: Selection of biodegradable/bioeliminable complexing agents in pretreatment and dyeing processes .................................................. 117
4.4.3.4 Ref. Datasheet 3.D.5: Selection of antifoaming agents with improved environmental performance ........................................................................................................ 118
4.4.3.5 Ref. Datasheet 3.D.6: Exhaust dying of polyester and polyester blends with carrier-free dying techniques or with use of environmentally optimised carriers .... 119
4.4.3.6 Ref. Datasheet 3.D.11: Formaldehyde-free or formaldehyde-poor easy-care finishing agents ...................................................................................................... 120
4.4.3.7 Ref. Datasheet 3.D.12: Use environment-friendly alternative chemicals for finishing activities ........................................................................................................ 121
4.4.3.8 Ref. Datasheet 3.D.13: Dry mechanical softening using only solid balls (polyorganosiloxane) instead of wet chemical softening using water and chemical agents ................................................................. 122

4.4.4 End of pipe techniques .................................................................................................................. 122

4.4.5 Wastewater abatement techniques ............................................................................................... 123

4.4.5.1 Ref. Datasheet 4.A.1: Treatment of mixed wastewater with about 60% water recycling ........................................................................................................................................... 123

4.4.5.2 Ref. Datasheet 4.A.2: Recycling of textile wastewater by treatment of selected streams with membrane techniques .......................................................................................... 124

4.4.5.3 Ref. Datasheet 4.A.3: Application of physical-chemical processes and cross-flow filtration ............................................................................................................................................ 125

4.4.5.4 Ref. Datasheet 4.A.4: Water purification tertiary treatment using photo-oxidation .................................................................................................................................................. 126

4.4.5.5 Ref. Datasheet 4.A.5: Purification of industrial and mixed wastewater by combined membrane filtration and sonochemical technologies ........................................................................ 127

4.4.5.6 Ref. Datasheet 4.A.6: Appropriately treat industrial wastewater by implementing a combination of suitable waste purification techniques ........................................................................ 128

4.4.5.7 Ref. Datasheet 4.A.7: Removal of disperse dyes from textile wastewater using bio-sludge .............................................................................................................................................. 129

4.4.6 Ref. Datasheet 4.A.11: Textiles wastewater treatment using anoxic filter bed and biological wriggle bed-ozone biological aerated filter .............................................. 129

4.4.6.1 Ref. Datasheet 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 ................................................................................................. 130


4.4.6.3 Ref. Datasheet 4.A.15: Chemical coagulation/flocculation technologies for removal of colour from textile wastewaters .................................................................................................................. 132

4.4.6.4 Ref. Datasheet 4.A.16: Upflow anaerobic sludge blanket reactor in removal of colour and reduction of COD in real textile wastewater ................................................................. 133


4.4.7.1 Ref. Datasheet 4.A.21: Biological and oxidative treatment of cotton textile dye-bath effluents by fixed and fluidized bed reactors .................................................................................. 135

4.5 General good management practices for textile sector ..................................................................... 137

4.5.1.1 Ref. Datasheet G.1: Management and good housekeeping ......................................................... 137

4.5.1.2 Ref. Datasheet G.2: Input/output streams evaluation/inventory ................................................. 138

4.5.1.3 Ref. Datasheet G.3: Automated preparation and dispensing of chemicals ............................... 139

4.5.1.4 Ref. Datasheet G.4: Optimising water consumption in textile operations ............................... 139

4.5.1.5 Ref. Datasheet G.5: Insulation of High Temperature (HT) machines ......................................... 140

4.6 Horizontal techniques .................................................................................................................... 141

4.6.1 Best Available Techniques to Industrial Cooling Systems ............................................................ 141

4.6.1.1 Integrated heat management techniques .................................................................................. 141

4.6.1.2 Techniques for the reduction of water requirements ................................................................ 142

4.6.1.3 Techniques for the reduction of entrainment of organisms .................................................... 142

4.6.1.4 Techniques for the reduction of emissions to water .................................................................. 142

4.6.1.5 Reduction of air emissions ....................................................................................................... 142

4.6.1.6 Reduction of noise emissions .................................................................................................. 143

4.6.1.7 Reduction of risk of leakage .................................................................................................... 143

4.6.2 Best Available Techniques on Energy Efficiency .......................................................................... 143

4.6.2.1 Cogeneration .......................................................................................................................... 143

4.6.2.2 Techniques to optimise the energy efficiency of combustion by relevant techniques .......... 144

4.6.2.3 Techniques to optimise the energy efficiency of Compressed air systems (CAS) ................ 145
CHAPTER 5

5.1 Evaluation of the available environmentally friendly techniques .......... 166
5.2 BAT conclusions ................................................................. 188
  5.2.1 General BAT for all textile companies .................................. 188
  5.2.2 Resource efficiency measures ............................................. 188
    5.2.2.1 Efficient use of chemicals and raw materials .................. 188
    5.2.2.2 Efficient use of water .................................................. 189
    5.2.2.3 Resources recovery measures ....................................... 189
    5.2.2.4 Integrated process measures ......................................... 190
  5.2.3 Selection/substitution of chemicals with others more environmentally friendly ... 190
    5.2.3.1 Use of enzymatic treatment/enzymes in processes ........... 190
    5.2.3.2 Less pollutant dyes ..................................................... 190
    5.2.3.3 Other measures .......................................................... 190
  5.2.4 End of pipe techniques ...................................................... 191
    5.2.4.1 Wastewater abatement techniques ................................. 191

CHAPTER 6

6.1 Priorities based on BAT conclusions ........................................... 194
  6.1.1 Lack of driving forces for environmentally friendly techniques and measures 195
6.2 Limitations to the BAT evaluation and report .................................. 196
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 International Centre for Environmental Technologies of Tunisia (CITET) and the TWG members met together three times during the duration of the project.

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.¹ 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, the Euro-Mediterranean leaders decided in 2005 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)
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 preventive 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
efficiency’ or ‘Monitoring’\(^2\). 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 **textile industry** and the **dairy 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 close collaboration with European institutes with specific knowledge of 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

---

\(^2\) 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 the art, 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 Tunisian 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 Tunisia 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 Tunisian 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, five 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 on Food, Drink and Milk Industries and the Flemish BAT study of the textile sector, some initial basic differences between the EU and the Tunisian 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 met three times to discuss content related matters (8 November 2011, 29 March 2012 and 6 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 main activities of the textile and clothing sector in Tunisia are spread over the following sub-sectors:

- Spinning,
- Weaving,
- Knitting,
- Dyeing and Finishing,
- Clothing,
- Other textile industries.

Taking into account the environmental relevance of the dyeing and finishing processes and the importance of these processes in Tunisia this report will be focused mainly on these two production processes.

The dyeing and finishing processes can take place at different stages of the production process (yarn, fabric, and garment). The sequence of treatments is very variable and dependent on the requirements of final users.

As the scope of the BAT Study is on the activities with the highest environmental impact we focus on the activities that involve dyeing and finishing processes. The impact of these processes is high, both in regard to the consumption of resources,
especially water, and due to the generation of pollution, especially wastewater. The dyeing and finishing processes contain mainly the following activities:
- Pre-treatment,
- Dyeing,
- Printing,
- Finishing,
- Coating,
- Washing,
- Drying.

About 90% of dyeing and finishing companies’ activities involve the following processes:
- Dyeing and finishing of woven fabric,
- Dyeing and finishing of knitted fabric,
- Jeans washing,
- Jeans dyeing.

As explained above we will restrict our analysis to the four processes that have the highest potential for the environmental improvement of the sector in Tunisia.

2.1.2 The distribution chain

The positioning of the textile companies in the distribution chain is shown in Figure 1.
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 data given in this paragraph are related to both textile and clothing sectors because we do not have specific statistics available only for dyeing and finishing companies and on other hand many companies are integrated and cover several steps from the whole chain from fibre treatment to the final product.

2.2.1 Number and sizes of the companies

According to the latest statistics published by the Agency for Promotion of Industry and Innovation (APII) in January 2012, the textile and clothing sector in Tunisia consists of about 2000 companies (employing 10 or more). The majority of these companies are SMEs (employing fewer than 200 employees) of which more than 60% employ
fewer than 100 employees. 1752 companies active in textile and clothing sector are producing only for export.

The geographic distribution of textile and clothing companies is given in the table below:

<table>
<thead>
<tr>
<th>Region</th>
<th>Number of companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tunis</td>
<td>21%</td>
</tr>
<tr>
<td>Monastir</td>
<td>27%</td>
</tr>
<tr>
<td>Sousse</td>
<td>12%</td>
</tr>
<tr>
<td>Nabeul</td>
<td>11%</td>
</tr>
<tr>
<td>Sfax</td>
<td>9%</td>
</tr>
<tr>
<td>Bizerte</td>
<td>6%</td>
</tr>
<tr>
<td>Other regions</td>
<td>14%</td>
</tr>
</tbody>
</table>

The 10 largest textile companies in Tunisia are presented in the table below:

<table>
<thead>
<tr>
<th>Company</th>
<th>Turnover</th>
</tr>
</thead>
<tbody>
<tr>
<td>BENETTON</td>
<td>23% of the whole sector turnover</td>
</tr>
<tr>
<td>MIC</td>
<td></td>
</tr>
<tr>
<td>SARTEX</td>
<td></td>
</tr>
<tr>
<td>DEMCO</td>
<td></td>
</tr>
<tr>
<td>GARTEX</td>
<td></td>
</tr>
<tr>
<td>VDV</td>
<td></td>
</tr>
<tr>
<td>ALBATEX</td>
<td></td>
</tr>
<tr>
<td>LEECOOPER</td>
<td></td>
</tr>
<tr>
<td>SITEX</td>
<td></td>
</tr>
<tr>
<td>TUNICOTEX GROUPE</td>
<td></td>
</tr>
</tbody>
</table>

Source: CETTEX

About 300 companies include dyeing and finishing amongst their activities.

### 2.2.2 Employment

The textile and clothing sector employs about 200,000 people contributing to 39% of total employment in manufacturing industry.
2.2.3 Evolution of turnover, added value, export, import and profit

2.2.3.1 Turnover

The evolution of turnover during the period 2004–2008 is shown in the table below:

<table>
<thead>
<tr>
<th>Year</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turnover (Million TND)</td>
<td>5,190.5</td>
<td>5,120.3</td>
<td>4,876</td>
<td>5,341</td>
<td>5,364</td>
</tr>
</tbody>
</table>

*Source: National Institute of Statistics*

2.2.3.2 Added value

The added value in the Textile and Clothing sector represents 32% of production (turnover).

The evolution of the added value 2004–2008 is shown in the table below:

<table>
<thead>
<tr>
<th>Year</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Added value (Million TND)</td>
<td>1,661</td>
<td>1,638.4</td>
<td>1,560.3</td>
<td>1,709.1</td>
<td>1,716.4</td>
</tr>
</tbody>
</table>

*Source: Agency for Promotion of Industry and Innovation (APII)*

2.2.3.3 Export

The evolution of export during the period 2004–2008 is shown in the table below:

<table>
<thead>
<tr>
<th>Year</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Export value (Million TND)</td>
<td>4,481.2</td>
<td>4,452.4</td>
<td>4,422.0</td>
<td>5,184.9</td>
<td>5,183.1</td>
</tr>
</tbody>
</table>

*Source: National Institute of Statistics*

2.2.3.4 Import

The evolution of import during the period 2004–2008 is shown in the table below:

<table>
<thead>
<tr>
<th>Year</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Import value (Million TND)</td>
<td>2,995.8</td>
<td>2,962.3</td>
<td>2,979.5</td>
<td>3,531.9</td>
<td>3,494.4</td>
</tr>
</tbody>
</table>

*Source: National Institute of Statistics*
### 2.2.3.5 Profit

The evolution of profit 2004–2008 is shown in the table below:

<table>
<thead>
<tr>
<th>Year</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profit (Million TND)</td>
<td>1,485.4</td>
<td>1,490.6</td>
<td>1,442.5</td>
<td>1,653.0</td>
<td>1,688.7</td>
</tr>
</tbody>
</table>

Source: Agency for Promotion of Industry and Innovation (APII)

### 2.2.4 Evolution of investments

The share of Textile and Clothing Industries in investment in manufacturing industry is around 15%.

Foreign direct investments have a strong presence in the sector with 966 companies with foreign participation, among them 640 companies with 100% foreign capital.

French companies are the leading foreign investors in the textile and clothing sector in Tunisia (40%), followed by Italian companies (26%).

The evolution of investments during the period 2004-2008 is shown in the table below:

<table>
<thead>
<tr>
<th>Year</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investments (Million TND)</td>
<td>155</td>
<td>150</td>
<td>139</td>
<td>173</td>
<td>193</td>
</tr>
</tbody>
</table>

Source: Agency for Promotion of Industry and Innovation (APII)

### 2.2.5 Production and price setting

The operating costs of Textile and Clothing sector in Tunisia are shown in the table below:

<table>
<thead>
<tr>
<th>Labour costs (TND/h)</th>
<th>Electricity (TND/kWh)</th>
<th>Natural gas (TND/Nm³)</th>
<th>Water (TND/m³)</th>
<th>Building costs (TND/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.6</td>
<td>0.125</td>
<td>0.260</td>
<td>0.8</td>
<td>800</td>
</tr>
</tbody>
</table>

### 2.2.6 Conclusion

The Textile and Clothing sector is considered to be strategic for the Tunisian Economy. It is the largest sector within the manufacturing industry in terms of exports, employment and added value.
Chapter 2

The added value of the sector represents 32% of the production value and 19% of the added value of manufacturing industry.

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

Tunisia will face stronger competition from new EU member countries, especially from Eastern Europe. These countries have a similar profile to Tunisia and therefore the threat that European investors will turn away from Tunisia is real.

The European Union is the world’s largest market for trade in textiles and clothing. To maintain its market share in the EU, and more than 95% of export is directed at the EU (especially France, Germany and Italy) given the evolution of European consumption, Tunisia, should increase its clothing exports at the rate of 6% per year. Note that the pace of change seems more affected by Tunisian exports since 2002.

On another level, new members becoming full members of the enlarged European Union (like Romania) will suffer competition from Asia and elsewhere (Asian countries and eastern countries will be new competitors).

The EU enlargement threatens Tunisia in terms of FDI to the extent that new members will have a strong attraction for European investors in the prospect of relocation. Also new members, who have increased the number of people working in the sector within the EU from 2 to 2.7 million, will try to consolidate their research strategy of co-contracting.
In this respect, the new EU member countries are positioned similarly to Tunisia and the threat that European investors will turn away from Tunisia is real.

The push to secure FDI is becoming more and more aggressive. Competing countries on the southern rim of the Mediterranean and Eastern Europe count on foreign direct investment, especially for high added value activities. Eastern European countries are currently enjoying considerable FDI flows from Europe. The issue of attractiveness remains a major issue for the development of Tunisian industry.

2.3.2.3 Threat of substitutes

Faced with competition from Asia, Tunisia has succeeded in boosting added value and is now addressing a second vector for growth and innovation based on the following key concepts: design, technical textiles, finishing, restocking, small and medium series, and logistic services.

The Tunisian textile sector is already focusing on promising activities like manufacture of upmarket ready-to-wear garments, technical textiles, hosiery, finishing, improving the quality of fabric, and model making.

The idea is to cover the entire value chain, above and beyond mere manufacturing. Upstream, this means weaving and finishing of textiles, notably those that are increasingly technical. There are many examples of target activities in technical fabrics: non-flammable, antiseptic, antibacterial, biodegradable, climate control, composite, water-resistant/breathable (membrane) fabrics, to name just a few. The development objective for finishing activities is to increase from 40 million metres of fabric (covering 10% of needs in 2007) to 140 million metres in 2016 (covering 40% of needs). Downstream, efforts will focus on logistic services with shorter turn-around time, which will help secure markets for small and medium-sized series and made-to-order. This will boost Tunisia’s effort to position itself more securely on markets for fast fashion and restocking, recent trends for which the keynotes are flexibility and reactivity. Strategic orientation is thus to continue to succeed in moving from subcontracting to finished product. The goal is to increase from 70 companies in 2007 to 300 companies in 2016 in the whole textile chain, representing 20% of companies in the sector.

(Source: Ministry of Industry, Energy and SMEs, national industrial strategy for the years leading up to 2016, 2008.)

2.3.2.4 Bargaining power of suppliers

There is no major difficulty to import all kind of raw materials and textile accessories used by Tunisian garment manufacturers. But, the majority of Tunisian garment manufacturers do not have total freedom to choose their own fabric suppliers.
The decisions in this area are controlled directly by the ‘order givers’ who impose through a set of technical specifications the choice by giving the name of the fabric suppliers. Then the manufacturers have to negotiate the best price with the preselected supplier.

This is mostly called ‘forced supplying’.

2.3.2.5 Bargaining power of buyers

The global financial crisis and particularly the European financial crisis has a direct influence on the demand for textile and clothing products. Therefore, it will impact the selling price of textile and clothing products.

Moreover, the competition from Asian countries, especially China, is not in favour of a position as price negotiator.

2.3.2.6 Rivalry among existing competitors

Tunisia’s textile and clothing industry has enjoyed remarkable development. This is due mainly to implementation of a national upgrading programme, first in the region, and to an ongoing progress in strategic partnerships with Europe since the 1970s.

The upgrading programme, launched in 1995, helps Tunisian companies in their efforts to modernise equipment, resources, and management style. This has led to substantial improvement in the level of competitiveness of Tunisian companies.

The European Union is Tunisia’s prime market as well as its leading industrial partner. Its top European economic partners are France, Italy and Germany. More than 90% of textile and clothing exports are shipped to the EU market and there are about 1,000 textile and clothing companies with European holdings working in Tunisia, the largest number on the southern rim of the Mediterranean. Exports to the countries of the European Union enjoyed an average annual growth of 4% between 2004 and 2008.

On the other hand the companies are technically supervised by the Textile Technical Centre (CETTEX) and supported by the National Textile Federation which defends the interests of the sector and traces its strategic.

2.3.2.7 General conclusion of the competition analysis

The textile and clothing sector remains a sector of socio-economic importance in Tunisia. It has been privileged by the Tunisian government through the implementation of a wide range of incentive mechanisms in order to attract foreign investors to settle in Tunisia. Furthermore, the Tunisian upgrading programme has consolidated the competitiveness of the textile and clothing sector in terms of
Chapter 2

enhancing productivity and quality. However, the majority of companies are currently working in subcontracting to other European firms with a low added value for the end products. The national strategy aims to move from straightforward subcontracting to co-contracting and then entirely finished goods. To reach this goal, the training system will have to be strengthened if it is to provide better qualified human resources for high added-value activities, notably style, design, and highly technical fabrics.

It will also be necessary to enhance promotion and marketing by the sector with European principals, a vital market for Tunisia, while also securing promising new markets in the Middle East, the Americas, Asia and new European countries.

In conclusion, the Tunisian textile and clothing sector remains competitive despite the European financial crisis and the problems of instability at national level after the revolution of January 2011. However, a lot of efforts must be managed at national level in order to maintain and enhance its market share.

2.3.3 Conclusive estimation of the viability of the sector

In conclusion, the Tunisian textile and clothing sector remains viable. In fact, the sector remains competitive despite the great competition from Asian and Eastern European countries. The added value was low but the financial state wasn’t bad. Actually, several efforts were managed by the Tunisian State in order to maintain and enhance its market share.

2.4 Environmental-regulatory aspects

The following paragraph outlines the environmental-regulatory framework of this BAT study, focussing primarily on Tunisian legislation. Foreign legislation is also addressed.

2.4.1 Tunisian environmental legislation

The textile and clothing industry has a number of impacts on the environment, such as: water consumption, wastewater emissions, energy consumption, air emissions and solid waste.

- Environmental Impact Assessment (EIA):
  According to Decree 2005-1991 of 11 July concerning environmental impact assessment and defining the categories of units subject to environmental impact assessment and the categories of units subject to specifications, textile plants whose processes include one of these activities must carry out an Environmental Impact Assessment (EIA):
  - Dyeing,
  - Washing,
  - Coating,
  - Printing,
Chapter 2

- Knitting and weaving,
- Finishing.

An EIA is an assessment of the possible positive or negative impact that a proposed project may have on the environment, together consisting of the environmental, social and economic aspects. For the activities listed above, the EIA is mandatory before the implementation or the expansion of the project

- **Classified establishments, unhealthy or inconvenient:**
  According to the Order of the Minister for Industry and Technology of February 23, 2010, amending and supplementing the Order of the Minister for Industry, Energy and Small and Medium Enterprises of November 15, 2005, textile plants whose processes include one of these activities and producing a quantity of textiles of more than 500 kg/day must carry out a Hazards Study (HS):
  - Dyeing,
  - Bleaching,
  - Washing,
  - Printing,
  - Finishing.

An HS is an essential element in managing the process safety impact of new projects and the ongoing operation of existing plants.

- **Water consumption:**
  According to Decree 2002-335 of 14 February, all industrial plants that use more than 5,000 m³/year of water must undertake a diagnosis of water consumption every five years. This diagnosis covers equipment and production methods related to water use. This technical diagnosis must be made by a specialized expert approved by the State.

- **Energy consumption:**
  According to Decree 2009-2269 of 31 July amending Decree 2004-2144 of 2 September on the mandatory energy audit for companies, all industrial plants that use more than 800 toe (tonne of oil equivalent)/year of energy must undergo an energy consumption audit every five years. This audit covers equipment and production methods related to energy use. This technical audit must be carried out by a specialized expert approved by the State.

- **Wastewater emissions:**
  The Tunisian environmental legal requirements for industrial wastewater emissions are presented by Tunisian Standard (NT 106.02). The emission limit values of some pollutants are presented in the table below:
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Surface water (land and river)</th>
<th>Coastal and maritime system</th>
<th>Sewer system</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>-</td>
<td>6.5 &lt; pH &lt; 8.5</td>
<td>6.5 &lt; pH &lt; 8.5</td>
<td>6.5 &lt; pH &lt; 9</td>
</tr>
<tr>
<td>Temperature</td>
<td>°C</td>
<td>35</td>
<td>25</td>
<td>35</td>
</tr>
<tr>
<td>Colour</td>
<td>Scale(Pt-Co)</td>
<td>100</td>
<td>70</td>
<td>Fixed as appropriate</td>
</tr>
<tr>
<td>COD</td>
<td>mg O₂/l</td>
<td>90</td>
<td>90</td>
<td>1,000</td>
</tr>
<tr>
<td>BOD₅</td>
<td>mg O₂/l</td>
<td>30</td>
<td>30</td>
<td>400</td>
</tr>
<tr>
<td>TKN</td>
<td>mg/l</td>
<td>30</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Oil and grease</td>
<td>mg/l</td>
<td>20</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>TSS</td>
<td>mg/l</td>
<td>30</td>
<td>30</td>
<td>400</td>
</tr>
<tr>
<td>Settleable solids</td>
<td>mg/l</td>
<td>0.3</td>
<td>0.3</td>
<td>-</td>
</tr>
<tr>
<td>Anionic detergent (ABS)</td>
<td>mg/l</td>
<td>2</td>
<td>0.5</td>
<td>5</td>
</tr>
<tr>
<td>Chlorine</td>
<td>mg/l</td>
<td>Without requirements</td>
<td>600</td>
<td>700</td>
</tr>
<tr>
<td>Sulphate (SO₄)</td>
<td>mg/l</td>
<td>1,000</td>
<td>600</td>
<td>400</td>
</tr>
<tr>
<td>Na</td>
<td>mg/l</td>
<td>Without requirements</td>
<td>300</td>
<td>1,000</td>
</tr>
<tr>
<td>P</td>
<td>mg/l</td>
<td>0.1</td>
<td>0.05</td>
<td>10</td>
</tr>
<tr>
<td>K</td>
<td>mg/l</td>
<td>1,000</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Fe</td>
<td>mg/l</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Al</td>
<td>mg/l</td>
<td>5</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Ag</td>
<td>mg/l</td>
<td>0.1</td>
<td>0.05</td>
<td>0.1</td>
</tr>
<tr>
<td>Hg</td>
<td>mg/l</td>
<td>0.001</td>
<td>0.001</td>
<td>0.01</td>
</tr>
<tr>
<td>Cr (VI)</td>
<td>mg/l</td>
<td>0.5</td>
<td>0.01</td>
<td>0.5</td>
</tr>
<tr>
<td>Cr (III)</td>
<td>mg/l</td>
<td>2</td>
<td>0.5</td>
<td>2</td>
</tr>
<tr>
<td>As</td>
<td>mg/l</td>
<td>0.1</td>
<td>0.05</td>
<td>0.1</td>
</tr>
<tr>
<td>Sb</td>
<td>mg/l</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Cd</td>
<td>mg/l</td>
<td>0.005</td>
<td>0.005</td>
<td>0.1</td>
</tr>
<tr>
<td>Sn</td>
<td>mg/l</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>CN</td>
<td>mg/l</td>
<td>0.05</td>
<td>0.05</td>
<td>0.5</td>
</tr>
<tr>
<td>Cu</td>
<td>mg/l</td>
<td>1.5</td>
<td>0.5</td>
<td>1</td>
</tr>
<tr>
<td>Faecal Coliform</td>
<td>MPN/100 ml</td>
<td>2,000</td>
<td>2,000</td>
<td>Without requirements</td>
</tr>
<tr>
<td>Salmonella</td>
<td>MPN/5,000 ml</td>
<td>Absence</td>
<td>Absence</td>
<td>Without requirements</td>
</tr>
<tr>
<td>Faecal streptococci</td>
<td>MPN/100 ml</td>
<td>1,000</td>
<td>1,000</td>
<td>Without requirements</td>
</tr>
<tr>
<td>Cholera vibrios</td>
<td>MPN/5,000 ml</td>
<td>Absence</td>
<td>Absence</td>
<td>Without requirements</td>
</tr>
</tbody>
</table>
• **Air emissions:**

In accordance with Decree 2010-2519 of 28 September, air emission limit values relevant to the textile industry are presented in the table below:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Limit value of air pollutant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total dust</td>
<td>• 100 mg/m³, if the hourly flow is less than or equal to 1 kg/h</td>
</tr>
<tr>
<td></td>
<td>• 40 mg/m³, if the hourly flow is more than 1 kg/h</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>10 mg/m³</td>
</tr>
<tr>
<td>SO₂</td>
<td>300 mg/m³, if the hourly flow is more than 25 kg/h</td>
</tr>
<tr>
<td>NO₂</td>
<td>500 mg/m³, if the hourly flow is more than 25 kg/h</td>
</tr>
<tr>
<td>HCl</td>
<td>50 mg/m³, if the hourly flow is more than 1 kg/h</td>
</tr>
<tr>
<td>HF</td>
<td>5 mg/m³</td>
</tr>
<tr>
<td>VOC</td>
<td>110 mg/m³, if the hourly flow is more than 2 kg/h</td>
</tr>
<tr>
<td>Cd, Hg, Tl</td>
<td>If the total hourly flow of cadmium, mercury and thallium and their compounds exceeds 1 g/h, the limit value is 0.05 mg/m³ per metal and 0.1 mg/m³ for total metals (expressed as Cd + Hg + Tl)</td>
</tr>
<tr>
<td>As, Se, Te</td>
<td>If the total hourly flow of arsenic, selenium and tellurium, and their compounds, exceeds 5 g/h, the limit value is 1 mg/m³ (expressed as As + Se + Te)</td>
</tr>
<tr>
<td>Pb</td>
<td>If the total hourly flow of lead and its compounds exceeds 10 g/h, the limit value is 1 mg/m³</td>
</tr>
<tr>
<td>Cr, Sb, Cu, Co, Mn, Ni, Sn, V, Zn</td>
<td>If the total hourly flow of antimony, chromium, cobalt, copper, tin, manganese, nickel, vanadium, zinc and their compounds exceeds 25 g/h, the limit value is 5 mg/m³ (expressed in Cr + Sb + Cu + Co + Mn + Ni + Sn + V + Zn)</td>
</tr>
<tr>
<td>Phosphine, phosgene</td>
<td>If the hourly flow of phosphine or phosgene exceeds 10 g/h, the limit value is 1 mg/m³ for each product</td>
</tr>
<tr>
<td>HCN, HBr, HCl, hydrogen sulphide</td>
<td>If the hourly flow of hydrogen cyanide or bromine and inorganic gaseous bromine compounds or chlorine or hydrogen sulphide exceeds 50 g/h, the limit value is 5 mg/m³ for each product</td>
</tr>
<tr>
<td>Ammonia (NH₃)</td>
<td>If the hourly flow of ammonia exceeds 100 g/h, the limit value is 50 mg/m³</td>
</tr>
<tr>
<td>Asbestos</td>
<td>The limit value of asbestos is 0.1 mg/m³ and 0.5 mg/m³ for total dust, whatever the amount of raw asbestos</td>
</tr>
<tr>
<td>Other fibres</td>
<td>The limit value is 1 mg/m³ per fibre and 50 mg/m³ for total dust, if the amount of fibres, other than asbestos, exceeds 100 kg/year</td>
</tr>
</tbody>
</table>

According to Annex 3 of Decree 2010-2519 of 28 September, the air emission limit values for boiler and combustion plants are:
Emission limit value for SO$_2$, NO$_x$, dust and CO:

Table 12. Limit values of SO$_2$, NO$_x$, dust and CO for boilers having thermal power from 20 to 50 MWth

<table>
<thead>
<tr>
<th>Combustible</th>
<th>SO$_2$ (mg/Nm$^3$)</th>
<th>NO$_x$ (mg/Nm$^3$)</th>
<th>Dust (mg/Nm$^3$)</th>
<th>CO (mg/Nm$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water column</td>
<td>Smoke column</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Gas</td>
<td>35</td>
<td>180</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>LPG</td>
<td>5</td>
<td>200</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>Gas of coke</td>
<td>400</td>
<td>200</td>
<td>10</td>
<td>250</td>
</tr>
<tr>
<td>HF gas</td>
<td>200</td>
<td>200</td>
<td>10</td>
<td>250</td>
</tr>
<tr>
<td>Domestic fuel</td>
<td>350</td>
<td>150</td>
<td>200</td>
<td>50</td>
</tr>
<tr>
<td>Liquid combustible</td>
<td>1,700</td>
<td>450</td>
<td>550</td>
<td>100</td>
</tr>
<tr>
<td>Solid combustible</td>
<td>1,700</td>
<td>450</td>
<td>550</td>
<td>75</td>
</tr>
<tr>
<td>Biomass</td>
<td>200</td>
<td>400</td>
<td>50</td>
<td>200</td>
</tr>
</tbody>
</table>

Table 13. Limit values of SO$_2$, NO$_x$, dust and CO for boilers having thermal power from 50 to 100 MWth

<table>
<thead>
<tr>
<th>Combustibles</th>
<th>SO$_2$ (mg/Nm$^3$)</th>
<th>NO$_x$ (mg/Nm$^3$)</th>
<th>Dust (mg/Nm$^3$)</th>
<th>CO (mg/Nm$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural gas</td>
<td>35</td>
<td>120</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>LPG</td>
<td>5</td>
<td>200</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>Gas of coke</td>
<td>400</td>
<td>200</td>
<td>10</td>
<td>250</td>
</tr>
<tr>
<td>HF gas</td>
<td>200</td>
<td>200</td>
<td>10</td>
<td>250</td>
</tr>
<tr>
<td>Liquid combustible</td>
<td>850</td>
<td>400</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Solid combustible</td>
<td>850</td>
<td>400</td>
<td>50</td>
<td>200</td>
</tr>
<tr>
<td>Biomass</td>
<td>200</td>
<td>400</td>
<td>50</td>
<td>200</td>
</tr>
</tbody>
</table>

Table 14. Limit values of SO$_2$, NO$_x$, dust and CO for boilers having thermal power from 100 to 300 MWth

<table>
<thead>
<tr>
<th>Combustibles</th>
<th>SO$_2$ (mg/Nm$^3$)</th>
<th>NO$_x$ (mg/Nm$^3$)</th>
<th>Dust (mg/Nm$^3$)</th>
<th>CO (mg/Nm$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural gas</td>
<td>35</td>
<td>120</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>LPG</td>
<td>5</td>
<td>200</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>Gas of coke</td>
<td>400</td>
<td>200</td>
<td>10</td>
<td>250</td>
</tr>
<tr>
<td>HF gas</td>
<td>200</td>
<td>200</td>
<td>10</td>
<td>250</td>
</tr>
<tr>
<td>Liquid combustible</td>
<td>400 to 200</td>
<td>200</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>Solid combustible</td>
<td>200</td>
<td>200</td>
<td>30</td>
<td>150</td>
</tr>
<tr>
<td>Biomass</td>
<td>200</td>
<td>300</td>
<td>30</td>
<td>150</td>
</tr>
</tbody>
</table>
Table 15. Limit values of SO₂, NOₓ, dust and CO for boilers having thermal power greater than 300 MWth

<table>
<thead>
<tr>
<th>Combustibles</th>
<th>SO₂ (mg/Nm³)</th>
<th>NOₓ (mg/Nm³)</th>
<th>Dust (mg/Nm³)</th>
<th>CO (mg/Nm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural gas</td>
<td>35</td>
<td>100</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>LPG</td>
<td>5</td>
<td>200</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>Gas of coke</td>
<td>400</td>
<td>200</td>
<td>10</td>
<td>250</td>
</tr>
<tr>
<td>HF gas</td>
<td>200</td>
<td>200</td>
<td>10</td>
<td>250</td>
</tr>
<tr>
<td>Liquid combustible</td>
<td>200</td>
<td>200</td>
<td>30</td>
<td>150</td>
</tr>
<tr>
<td>Solid combustible</td>
<td>200</td>
<td>200</td>
<td>30</td>
<td>150</td>
</tr>
<tr>
<td>Biomass</td>
<td>200</td>
<td>200</td>
<td>30</td>
<td>150</td>
</tr>
</tbody>
</table>

- Emission limit values for polycyclic aromatic hydrocarbons (PAH) and VOCs

Table 16. Limit values for polycyclic aromatic hydrocarbons (PAH) and VOCs

<table>
<thead>
<tr>
<th>Pollutants</th>
<th>Emission limit Value (mg/Nm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAH</td>
<td>0.1</td>
</tr>
<tr>
<td>VOC</td>
<td>110 expressed as total carbon</td>
</tr>
</tbody>
</table>

- Emission limit value for toxic metals and their compounds for boilers using solid and liquid combustible

Table 17. Limit values of toxic metals and their compounds for boilers using solid and liquid combustibles

<table>
<thead>
<tr>
<th>Compounds</th>
<th>Emission limit value (*) (mg/Nm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadmium (Cd), mercury (Hg) and thallium (Tl) and its compounds</td>
<td>0.05 by metal and 0.1 for the sum expressed in (Cd + Hg + Tl)</td>
</tr>
<tr>
<td>Arsenic (As), selenium (Se), tellurium (Te) and its compounds</td>
<td>1 expressed in (As + Se + Te)</td>
</tr>
<tr>
<td>Lead (Pb and its compounds)</td>
<td>1 (expressed in Pb)</td>
</tr>
</tbody>
</table>

(*) Average over the sampling period of at least 30 minutes and up to eight hours.

<table>
<thead>
<tr>
<th>Compounds</th>
<th>Emission limit value (*) (mg/Nm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antimony (Sb), chromium (Cr), cobalt (Co), Tin (Sn), manganese (Mn), nickel (Ni), vanadium (V), zinc (Zn) and their compounds.</td>
<td>10 expressed in (Sb + Cr + Co + Cu + Sn + Mn + Ni + V + Zn) (**)</td>
</tr>
<tr>
<td></td>
<td>5 expressed in (Sb + Cr + Co + Cu + Sn + Mn + Ni + V + Zn) (**)</td>
</tr>
</tbody>
</table>

(*) Average over the sampling period of at least 30 minutes and up to eight hours.

(**) Facility outside agglomerations over 250,000 and whose power is between 20 MWth and 50 MWth, set emission limit is 20 mg/Nm³.
Ammonia emission limit value

When a boiler is equipped with a device for treatment of the oxides of nitrogen to ammonia or urea, ammonia emissions shall not exceed the value of 20 mg/Nm³.

Solid waste:
Tunisia has numerous laws and regulations dealing with the management of solid waste. Among these law and regulations we find:

- Law 41 of 10 June 1996 constitutes the most detailed regulation of the management, disposal and control of solid waste at national and local levels. Its key elements are:
  - classifies waste according to its origin and characteristics;
  - defines government and municipal responsibilities;
  - encourages private sector participation;
  - establishes priority of waste minimization, recycling and composting;
  - establishes that producers, importers and distributors of packaging are responsible for their products when they are discarded as waste;
  - provides basis for national waste management facility and siting programme;
  - establishes procedures for managing waste, monitoring facilities, and enforcing standards.
On the basis of this law, the basic regulatory framework for the management of dangerous waste was developed with the following components:
  - a decree with a list of hazardous wastes;
  - a modal register prepared specially for hazardous waste producers;
  - a modal annual declaration specifically for hazardous waste producers, and
  - a monitoring form specially for the transport of hazardous waste.
- Decree 2000-2339 of 10 October establishing the list of hazardous waste.
- Decree 2002-693 of 1 April establishing the conditions and modalities for recovery of used lubricating oils and used oil filters and their management.
- Decree 2005-3395 of 26 December establishing conditions and modalities for the collection of used batteries and accumulators in order to ensure their sound management and to prevent their release into the environment.

Noise:
Concerning noise we have Decree 84-1556 of 29 December 1984 the level of noise emitted by an industrial plant during the daytime shall not exceed 50 decibels,
measured in front of the nearest homes in the area of activity. At night, additional precautions should be taken in order to not cause inconvenience to local residents.

2.4.2 Egyptian environmental legislation

The following paragraph lists the environmental legislation relevant to the textiles industry:

- **Wastewater emissions:**
  The Egyptian environmental legal requirements for industrial wastewater emissions are presented in the table below:

<table>
<thead>
<tr>
<th>Parameter (mg/l unless otherwise stated)</th>
<th>Law 4/94: Discharge coastal environment</th>
<th>Law 93/62: Discharge to sewer system (as Decree 44/2000)</th>
<th>Law 48/82: Discharge into:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Underground reservoir and Nile branches/canal</td>
<td>Nile (main stream)</td>
<td>Drain</td>
</tr>
<tr>
<td>BOD₅</td>
<td>60</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>COD</td>
<td>&lt;600</td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td>pH (without unit)</td>
<td>6-9</td>
<td>6-9</td>
<td>6-9</td>
</tr>
<tr>
<td>Oil and Grease</td>
<td>15</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>10°C&lt;T&gt;avg. temp. of receiving body</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>Settleable solids</td>
<td>60</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>TSS</td>
<td>-</td>
<td>20</td>
<td>-</td>
</tr>
<tr>
<td>TDS</td>
<td>2,000</td>
<td>800</td>
<td>2,000</td>
</tr>
<tr>
<td>Chlorine</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
</tbody>
</table>

  *Source: EEAA*

- **Air emissions:**
  The limits values of air pollutants relevant to the textile industry according to Egyptian requirements (Law 4/1994) are presented in the table below:
Table 19. Egyptian standard for air emissions

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Relevant processes</th>
<th>Threshold limit values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PPM</td>
</tr>
<tr>
<td>Cotton dust and fluff</td>
<td>Spinning, weaving, knitting, etc.</td>
<td>0.2</td>
</tr>
<tr>
<td>Sulphuric acid</td>
<td>Desizing, viscose, spinning, dyeing, carbonizing</td>
<td></td>
</tr>
<tr>
<td>Sodium hydroxide</td>
<td>Scouring, mercerizing, wastewater treatment</td>
<td>2</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Blending</td>
<td>1</td>
</tr>
<tr>
<td>Aniline</td>
<td>Dyeing</td>
<td>2</td>
</tr>
<tr>
<td>Ammonia</td>
<td>Dyeing</td>
<td>2.5</td>
</tr>
<tr>
<td>Ethylene</td>
<td>Dyeing</td>
<td>10</td>
</tr>
<tr>
<td>Urea</td>
<td>Printing</td>
<td>2</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>Printing, finishing</td>
<td>2</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>Printing</td>
<td>10</td>
</tr>
<tr>
<td>Xylene</td>
<td>Printing</td>
<td>100</td>
</tr>
<tr>
<td>Acryonitrile</td>
<td>Finishing</td>
<td>2</td>
</tr>
<tr>
<td>Silicon</td>
<td>Finishing</td>
<td></td>
</tr>
<tr>
<td>Yellow phosphorus</td>
<td>Finishing</td>
<td></td>
</tr>
<tr>
<td>Toluene</td>
<td>Finishing</td>
<td>100</td>
</tr>
<tr>
<td>Paraffin wax</td>
<td>Finishing</td>
<td></td>
</tr>
<tr>
<td>Manganese fumes</td>
<td>workshop</td>
<td></td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>Boilers</td>
<td>50</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>Boilers</td>
<td></td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>Boilers</td>
<td></td>
</tr>
<tr>
<td>Nitrogen dioxide</td>
<td>Boilers, sizing</td>
<td>3</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>Boilers</td>
<td>2</td>
</tr>
<tr>
<td>Soldering fumes</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Ozone</td>
<td>Toluene solvent coating</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Source: EEAA

2.4.3 European legislation

2.4.3.1 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).

Source: European Commission – DG Environment:
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 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.

2.4.3.2 Urban Wastewater Directive

Directive 91/271/EEC concerns the collection, treatment and discharge of urban wastewater and the treatment and discharge of wastewater from certain industrial sectors. Its aim is to protect the environment from any adverse effects caused by the discharge of such waters.

Industrial wastewater entering collecting systems and the disposal of wastewater and sludge from urban wastewater 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 wastewater 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 wastewater not entering urban wastewater 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.

2.4.3.3 Emission Trading Scheme (ETS) Directive\textsuperscript{6}

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.

\textsuperscript{6}http://ec.europa.eu/clima/policies/ets/index_en.htm
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.

2.4.3.4 The Waste Framework Directive\(^7\)

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:

- 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.

2.4.3.5 Water protection and management: the Water Framework Directive\(^8\)

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.

2.4.3.6 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 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.

9 http://ec.europa.eu/environment/chemicals/reach/reach_intro.htm
2.4.4 Standards of textile wastewater discharge in different countries

The table below shows the limit values of textile wastewater in different countries in case of discharge into land or rivers.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>France</th>
<th>Germany</th>
<th>Italia</th>
<th>Indonesia</th>
<th>Japan</th>
<th>Venezuela</th>
<th>India</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td></td>
<td>6.5-8.5</td>
<td>6-9</td>
<td>5.5-9.5</td>
<td>6-9</td>
<td>5.8-8.6</td>
<td>6-9</td>
<td>5.5-9</td>
</tr>
<tr>
<td>TSS mg/l</td>
<td>30</td>
<td>40</td>
<td>80</td>
<td>60</td>
<td>200</td>
<td>60</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>COD mg/l</td>
<td>120</td>
<td>160</td>
<td>160</td>
<td>250</td>
<td>30/120</td>
<td>350</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>BODS mg/l</td>
<td>40</td>
<td>25</td>
<td>40</td>
<td>85</td>
<td>160</td>
<td>100</td>
<td>100-150</td>
<td></td>
</tr>
<tr>
<td>Oil and Grease mg/l</td>
<td>-</td>
<td>-</td>
<td>20</td>
<td>5</td>
<td>5/35</td>
<td>20</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Colour Scale (Pt-Co)</td>
<td>100</td>
<td>-</td>
<td>Imperceptible with dilution 1:20</td>
<td>-</td>
<td>-</td>
<td>500</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Phenol mg/l</td>
<td>-</td>
<td>1</td>
<td>0.5</td>
<td>5</td>
<td>0.5</td>
<td>5</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Cr mg/l</td>
<td>0.5</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

2.4.5 Cameroonian legislation

The Cameroonian environmental legal requirements for wastewater emissions of textile industry are presented in the table below.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Surface water (land and river)</th>
<th>Specially protected system</th>
<th>Sewer system</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td></td>
<td>6 &lt; pH &lt; 9</td>
<td>6 &lt; pH &lt; 9</td>
<td>6 &lt; pH &lt; 9</td>
</tr>
<tr>
<td>Temperature °C</td>
<td></td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Colour Scale (Pt-Co)</td>
<td></td>
<td>Colourless</td>
<td>Colourless</td>
<td></td>
</tr>
<tr>
<td>Odour</td>
<td></td>
<td>Odourless</td>
<td>Odourless</td>
<td></td>
</tr>
<tr>
<td>COD mg O₂/l</td>
<td>200</td>
<td>90</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td>BOD₅ mg O₂/l</td>
<td>50</td>
<td>20</td>
<td>800</td>
<td></td>
</tr>
<tr>
<td>TN mg/l</td>
<td>20</td>
<td>10</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>Oil and grease mg/l</td>
<td>15</td>
<td>15</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>TSS mg/l</td>
<td>30</td>
<td>30</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td>P mg/l</td>
<td>10</td>
<td>5</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>TH mg/l</td>
<td>50</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phenols mg/l</td>
<td>0.01</td>
<td>0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F mg/l</td>
<td>100</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parameter</td>
<td>Unit</td>
<td>Surface water (land and river)</td>
<td>Specially protected system</td>
<td>Sewer system</td>
</tr>
<tr>
<td>--------------------</td>
<td>---------------</td>
<td>--------------------------------</td>
<td>---------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>pH</td>
<td>-</td>
<td>6 &lt; pH &lt; 9</td>
<td>6 &lt; pH &lt; 9</td>
<td>6 &lt; pH &lt; 9</td>
</tr>
<tr>
<td>Temperature</td>
<td>°C</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Colour</td>
<td>Scale(Pt-Co)</td>
<td>Colourless</td>
<td>Colourless</td>
<td></td>
</tr>
<tr>
<td>Odour</td>
<td></td>
<td>Odourless</td>
<td>Odourless</td>
<td></td>
</tr>
<tr>
<td>COD</td>
<td>mg O₂/l</td>
<td>200</td>
<td>90</td>
<td>2,000</td>
</tr>
<tr>
<td>BOD₅</td>
<td>mg O₂/l</td>
<td>50</td>
<td>20</td>
<td>800</td>
</tr>
<tr>
<td>TN</td>
<td>mg/l</td>
<td>20</td>
<td>10</td>
<td>150</td>
</tr>
<tr>
<td>Oil and grease</td>
<td>mg/l</td>
<td>15</td>
<td>15</td>
<td>-</td>
</tr>
<tr>
<td>TSS</td>
<td>mg/l</td>
<td>30</td>
<td>30</td>
<td>600</td>
</tr>
<tr>
<td>P</td>
<td>mg/l</td>
<td>10</td>
<td>5</td>
<td>50</td>
</tr>
<tr>
<td>Cr (VI)</td>
<td>mg/l</td>
<td>0.1</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Cr (III)</td>
<td>mg/l</td>
<td>1</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>As</td>
<td>mg/l</td>
<td>1</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>CN</td>
<td>mg/l</td>
<td>1</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Cu</td>
<td>mg/l</td>
<td>1</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Zn</td>
<td>mg/l</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Faecal Coliform</td>
<td>MPN/100 ml</td>
<td>400</td>
<td>400</td>
<td>Without requirements</td>
</tr>
<tr>
<td>Salmonella</td>
<td>MPN/5,000 ml</td>
<td>Absence</td>
<td>Absence</td>
<td>Without requirements</td>
</tr>
<tr>
<td>Faecal streptococci</td>
<td>MPN/100 ml</td>
<td>1,000</td>
<td>1,000</td>
<td>Without requirements</td>
</tr>
<tr>
<td>Cholera vibrios</td>
<td>MPN/5,000 ml</td>
<td>Absence</td>
<td>Absence</td>
<td>Without requirements</td>
</tr>
</tbody>
</table>

The Cameroonian environmental legal requirements for air emissions of textile industry are presented in the table below:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Limit value of air pollutant</th>
</tr>
</thead>
</table>
| Total dust      | • 100 mg/m³, if the hourly flow is less than or equal to 1 kg/h  
|                 | • 50 mg/m³, if the hourly flow is more than 1 kg/h                                           |
| SO₂             | 500 mg/m³, if the hourly flow is more than 25 kg/h                                            |
| NO₂             | 500 mg/m³, if the hourly flow is more than 25 kg/h                                            |
| HCl             | 50 mg/m³, if the hourly flow is more than 1 kg/h                                              |
| HF              | 10 mg/m³, if the hourly flow is more than 500 g/h                                             |
| VOC             | 150 mg/m³, if the hourly flow is more than 2 kg/h                                              |
| PAH             | 20 mg/m³, if the hourly flow is more than 2 kg/h                                               |
| Cd, Hg, Tl      | If the total hourly flow of cadmium, mercury and thallium and their compounds exceeds 1g/h,  
<p>|                 | the limit value is 0.2 mg/m³ for total metals (expressed as Cd + Hg + Tl)                     |</p>
<table>
<thead>
<tr>
<th>Substance</th>
<th>Limit Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>As, Se, Te</td>
<td>If the total hourly flow of arsenic, selenium and tellurium, and their compounds, exceeds 5 g/h, the limit value is 1 mg/m³ (expressed as As + Se + Te)</td>
</tr>
<tr>
<td>Cr, Sb, Cu, Co, Mn, Ni, Sn, V, Zn, Pb</td>
<td>If the total hourly flow of antimony, chromium, cobalt, copper, tin, manganese, nickel, lead, vanadium, zinc and their compounds exceeds 25 g/h, the limit value is 5 mg/m³ (expressed in Cr + Sb + Cu + Co + Mn + Ni + Pb + Sn + V + Zn)</td>
</tr>
<tr>
<td>Phosphine, phosgene</td>
<td>If the hourly flow of phosphine or phosgene exceeds 10 g/h, the limit value is 1 mg/m³ for each product</td>
</tr>
<tr>
<td>Ammonia (NH₃)</td>
<td>If the hourly flow of ammonia exceeds 100 g/h, the limit value is 20 mg/m³</td>
</tr>
<tr>
<td>Asbestos</td>
<td>The limit value of asbestos is 0.1 mg/m³ and 0.5 mg/m³ for total dust, if the annual flow is more than 100 kg/year</td>
</tr>
</tbody>
</table>
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 General information on the textile dyeing and finishing sub-sector

3.1.1 Introduction

The textiles dyeing and finishing sub-sector includes all those industries whose main activity is to provide textile materials with the suitable characteristics for their use as an intermediate or end product.

These characteristics are:
- Colour and technical specifications of the colour (fastness),
- Lustre,
- Texture,
- Dimensional stability,
- Tailority.

Generally this sequence of process steps is followed: the material is prepared for dyeing or printing, the material is dyed or printed and, then, the sizing and finishing processes are applied.

These processes are determined by a series of fundamental factors, such as:
- The fibres,
- The textile products (types of yarn and types of weave to make the fabrics),
- The dyes,
- The auxiliary and chemical products,
- The temperature,
- The dyeing time,
- The machinery used,
- The water (quality and quantity).

The relationship between these factors depends on the following conditions:
- Each type of fibre requires a certain family of dyes,
- Each fabric requires certain, more suitable handling conditions (in rope form or open-width),
- A cycle of temperature variation with time and specific physical-chemical conditions of the aqueous dye solution (pH, redox potential, conductivity, etc.), which together must be optimised, in each case, corresponds to the system which consists of the fibre, the dye and the type of machine,
- The textile machinery conditions the type of textile product and the dye cycle temperatures that are usable,
- The water affects the rest of factors.
The dyeing process may be optimised by varying the parameters to obtain a top quality dye at the lowest possible cost.

There are numerous dyeing systems and they include everything from consignment processes (batches by a defined weight and length) to semi-continuous processes (open-width or in rope form) to continuous processes (open-width or in rope form). Depending on the fibres and dyes used, dyeing is carried out at between 20° and 135°C in high temperature systems.

### 3.1.1.1 Types of fibre

Depending on their origin, fibres can be classified into:

- **Natural fibres**: these fibres are of vegetable or animal origin such as cotton, linen, wool and silk.
- **Chemical fibres of natural polymers**: they are so called because they are fibres that are artificially obtained from a natural polymer such as cellulose. Rayon, cellulose acetate, etc. are artificial fibres. Later in this document, they shall be referred to as cellulosic fibres.
- **Chemical fibres of synthetic polymers**: these are obtained by the organic synthesis of petrochemical derivatives. They have a polymeric structure and include polyester, polyamide, acrylic fibres, polyolefin and spandex fibres.

### 3.1.1.2 Textiles products

The dyeing of textiles fibres can be done on intermediate products or end products. Below the most significant products are described:

- **Cable**: the parallel union of a high number of filaments, generally to be converted into cut fibre,
- **Rovings and slivers**: the union of fibres which come from napping, combing or from the roving frames,
- **Yarn**: generally from the stretching with twist of an appropriate sliver. It is presented in hank or bobbin form,
- **Woven fabric**: laminar textile structure generally formed by the orthogonal interweaving of warp thread, with weft threads,
- **Knitwear (knitted fabric)**: laminar textile structure formed by the interweaving of one or more threads on the base mesh structure.

### 3.1.2 Dyeing and finishing processes

Here we present the basics of the most common dyeing and finishing processes.

#### 3.1.2.1 Preparation

Preparation includes all operations prior to dyeing, whose aim is to ensure that the physical and chemical properties of both the finished textiles, and, in some cases, of
the intermediate products, favouring the later reactions that take place in dyeing. For this reason, some of these operations may be considered similar to the finishing operations and, in fact, they are not very different at all.

The aim, therefore, of preparation operations is to clean the textile materials of the impurities that are present in them or to provide them with special qualities and characteristics.

Among preparation operations, the following are noteworthy:

- Mercerising,
- Scouring,
- Degreasing,
- Carbonisation,
- Fulling,
- Singeing,
- Desizing,
- Heat setting,
- Chemical washing,
- Solvent washing,
- Chemical bleaching,
- Optical bleaching.

### 3.1.2.2 Description of the dyeing process

Dyeing is the process of modifying the colour of a textile element, in any form, through the application of a dye material. Both continuous procedures and batch dyeing processes exist. In either of the two cases, the aim is to achieve the bath exhaustion and fixation of as much dye as possible to the fabric or textile element, to limit dye losses in the later washing stages, and during use.

The application of any dye can be described according to the following stages:

- First stage: transfer of the dye from the dye bath to the fibre surface.
- Second stage: diffusion or migration of the dye molecules from the surface of the fibre to the interior of the material to be dyed.
- Third stage: fixing of the dye on the reactive points of the fibre’s molecular structure.

#### i. Batch or discontinuous dyeing:

In the case of discontinuous dyeing, which is also called exhaustion, the procedure consists of immersing a weight of fabric or yarn, normally between 100 and 1,000 kg, into the dye bath, which contains the dye solution. Given the affinity of the dyes for fibres, the molecules present in the solution are incorporated by the fibres, in a transfer that may take anything from a few minutes to hours.

The use of chemical auxiliary additives, as well as the control of the bath environment (physical variables, basically the temperature) can accelerate this operation and optimise it. Once the dye is fixed in the fibre, the fibre goes through a washing process in which both the dye which has not become fixed and the auxiliary products used to help the fixation process are eliminated.
That is to say, in order to reduce the dye content in wastewater, high-affinity dyes should be selected or the bath ratio must be reduced if the affinity is low.

The same dye can present different affinities for different fibres and, consequently, it is difficult to generalise the exhaustion associated with each dye, and requires systematic testing in the laboratories of each industry.

Machinery used in batch dyeing is:

**Cabinets:** the textile material (yarn in hank form) is static on a support, the bath in motion is driven by a pump and the cabinet is at atmospheric pressure.

**Autoclave:** as in the previous case, the textile material remains static and the dye bath is in motion. It consists of a horizontal or vertical cylindrical recipient with supports onto which the different textile material, spun thread, flock or fabric is placed. The bath passes through the material driven by a circulation pump. The receptacle is closed and work is done under pressure.

**ii. Continuous dyeing:**

In the case of continuous dyeing, the textile materials are fed continuously into a dyeing apparatus, at a speed of between 50 and 250 m/min. The apparatus consists of a first stage of incorporating the dye, followed by the addition of the chemical auxiliaries, the application of heat to aid fixation and, later, the washing of the surplus, as in the case of discontinuous dyeing, though in this case, in continuous washing facilities.

Fixation in continuous processes is far faster than in batch dyeing, but it requires processing at least 10,000 metres. Nevertheless, today, machines may be found on the market that are capable of dyeing, in continuous form, lengths of material of only 2,000 metres.

**3.1.2.3 Machinery used in dyeing is**

**Winch:** this is used for fabric dyeing in rope form. The denomination of rope form refers to the passage of the fabric through a ring, joining the ends. The fabric is in motion whereas the bath is static. It is composed of a cylinder of trapezoidal section, a driving element which performs the shifting of the fabric, and some bars to separate the rope in order to avoid malformations and jams.

Currently this machine is substituted by Jets and Overflows.

**Jigger:** this machine which is used for the open-width dyeing of fabric by means of rollers that roll it up and unroll it, passing it through the bath, while the latter is static. They may be atmospheric in order to work at 100°C, while those that work under pressurised conditions may reach 145°C.

**Jet:** is a rope form dyeing machine. The fabric is set in motion by the action of a nozzle (hence the denomination jet), through which the bath passes, where both the bath and the fabric are in simultaneous movement. The high speed produced by the injection in the bath causes turbulence, which facilitates the penetration of the dye solution towards the interior of the fabric and good equalisation of the dye, in a shorter space of time, and with lower water consumption than in the old winches.
Airflow: is similar to a jet but with the impulse of a mixture of air and dye solution, which allows a more delicate treatment of the fabric. Water consumption is greatly reduced since only the necessary amount of dye is added, eliminating the concept of bath accumulation.

Overflow: the fabric and the bath are in motion. As in the case of the jet, the bath acts on the fabric but in this case, the fabric is dragged by a winder and not just by the action of the nozzle.

It is usually used for the dyeing of many types of fabric in rope form, from the most resistant to delicate fabrics.

Foulard: this universal machine is used to impregnate the textile material with any liquid. It is described in this chapter in order to present the pad-steam process.

Pad-steam: this machine applies a steaming to a dye impregnation in a foulard machine. In this way, the dye is fixed on the fibre in a short period of time. It is often used in the dyeing of cellulosic fibres.

The dyeing process may be applied at any stage and to any type of material.

3.1.2.4 Dyes used in the dyeing process:

The families of dyes used for the dyeing of yarn, fabric and knitwear are the following:

→ Direct dyes:

The dyeing operation with a direct dye consists of bringing the fibre into contact with the dye dissolved in water and heating to boiling point. In order to aid the operation, a neutral electrolyte is often added, such as sodium chloride or sulphate, and surfactant-type products (wetting agents, levelling agents, etc.). Direct dyes belong to several families of chemical compounds, and are characterised by being aromatic organic compounds containing sulphonic groups that act as solubilisers.

Chemically, direct dyes belong to the following types:

→ Azo dyes of diphenyl amines, such as benzidine, stilbene, aryl diamines, ureics, amides.
→ Thiazolic dyes.

→ Insoluble azo dyes:

This dye is not used any more in Tunisia, it is forbidden by all standards and directives such as Oeko Tex and REACH.

The basis of dyeing with insoluble azo dyes lies in the formation of coloured pigment on the fibre, which is achieved when treating the textile, generally in two baths, with the two components that, when combined, form the dye. The first component, the so-called developer, is a naphthenic derivative that contains amino and hydroxyl groups. Nowadays, mainly hydroxylated derivatives are used as developers, and so this dyeing is also known as naphthol dyeing.

The textile material impregnated with the developer is put into a second bath in a diaze solution, which, when it reacts with the developer produces the insoluble azo dye on the fibre. This dyeing procedure gives extraordinary wash fastness, far higher than that offered by direct dyes themselves, though with far higher production costs.
Sulphur dyes:
The chemical make-up of these dyes is not easy to define. They are given this name because they contain sulphur, generally forming a chain (Ar-S-S-Ar or Ar-S-S-S-Ar). The sulphur may be easily oxidised to become sulphuric acid. The traditional dyes, which are generally low in cost, contain a high concentration of impurities such as salts, sulphides and polysulphides. In an alkaline medium and in the presence of reductive agents, they are transformed into soluble leuco derivatives which are easily absorbed by the fibres.
The dyeing operation using these dyes consists of the following stages:
- Dissolving the dye using a reductive agent: sodium sulphide, sodium bisulphide, ammonium sulphide, sodium hydrosulphite or glucose.
- Dyeing with the addition of a neutral electrolyte, such as sodium chloride and wetting agents.
- Oxidation of the dye absorbed in the fibre with oxidising systems based on bromates, iodates, chlorites, potassium dichromate (practically out of use), peroxides or oxygen.
- Later treatment with metallic salts, detergent, sodium acetate or with sodium dichromate and acetic acid to increase the fastness of the colours against light, washing, rubbing, etc.

Soluble sulphur dyes:
This type of dye is a variant of the previous ones, synthesised with thiosulphate groups. The formation of insoluble pigment is done by a reaction with sodium polysulphide in a second bath.
These dyes are suitable for application in continuous mode following the sequence:
- Padding of the dye,
- Drying of fabric,
- Padding with sodium polysulphide,
- Washing,
- Soaping.

Vat dyes:
Of different chemical constitution (that may derive from indigo or from anthraquinone), they are insoluble in water, and are transformed by reduction in an alkaline medium into hydrosoluble leuco derivatives with substantiveness for textile fibres, on which they develop the prime colour by ulterior oxidation.
The dyeing operation with these dyes consists of the following stages:
- Reduction of the dye with sodium hydrosulphite, formaldehyde or acetaldehyde sulphonylate, using caustic soda as an alkali.
- Dyeing with the addition of electrolyte (common salt or sodium sulphate), wetting agents and levelling agents.
- Oxidation by washing with cold water or treatment with oxygenated water or potassium dichromate and sulphuric acid.
- Later washing and soaping treatments.

Reactive dyes:
Reactive dyes are one of the most used families of dyes for the dyeing of cotton, rayon and linen fabrics. Due to their inherent chemical characteristics, only a part of the dye
which is added to the dye bath reacts chemically with the fibre by means of a covalent bond. The rest of the dye reacts with the water and is known as hydrolysed dye. Part of the latter remains in the dye wastewater and the rest remains inside the fibre but does not have good fastness properties and so must be eliminated in successive soaping and hot rinsing operations.

Reactive dyes include the families of dichlorotriazines, monochlorotriazines, trichloropyridines, difluorochloropyrimidines, vinylsulphonics, etc.

The dye operation using these dyes consists of the following stages:
- Absorption, analogous to the dyeing with direct dyes.
- Reaction, in which the dye chemically combines with the fibre by means of a covalent bond.
- Later treatment to eliminate the hydrolysed dye.
- The application of these dyes can be done either in continuous mode or in batches, which, in the case of yarn is usually done by packing in an autoclave.

The use of any of these systems with reactive dyes implies the consumption of certain chemicals, such as salt. In some cases, in continuous mode processes, urea is used due to its hygroscopic nature.

Specifically for wool, the operations are:
- Exhaustion dyeing, which may be used for flock, combing, hank and fabric spinning.
- Dyeing through padding-cold rest, only applicable for knitwear.

**Acid dyes:**
These dyes colour the wool and protein fibres in an acid or basic solution. They may be classified into five large groups:
- Azo dyes,
- Anthraquinonic dyes,
- Derivatives of triphenylmethane,
- Azinic type,
- Xanthene type.

The last two are frequently used in obtaining certain shades.

In the dyeing process with these dyes, several auxiliary agents are used such as:
- Levelling agents, which may be anionic compounds which are similar to the fibre or cationic or pseudocationic compounds, which are similar to the dyes, such as, for example, sulphated castor oils, oleic and sulphated polycastor acids or alkylaryl sulphonates.
- Acetic or formic acid to exhaust the dye onto the fibre,
- Sodium sulphate,
- Ammonium sulphate.

**Premetallised dyes:**
These dyes are composed of a metal atom to which one or two molecules, generally of acid dye, are added, forming a co-ordination complex with affinity for the protein and polyamidic fibres.

The metal is usually chrome, although others may be used such as copper, nickel, cobalt, etc.

The types of premetallised dyes developed are:
— Premetallised dyes 1:1, which dye in a strongly acid bath, formed of chrome and azoic-type dyes.
— Premetallised dyes 1:2, which are in turn divided into:
  - Premetallised dyes 1:2, which dye in a neutral bath and do not contain ionic solubiliser groups, and for whose application ammonic salts are used to maintain the pH.
  - Premetallised dyes 1:2, which contain ionic solubiliser groups and, in addition to the acetate or ammonium sulphate buffer, require an equaliser and pH adjustment with acetic acid.

**Chrome dyes:**
The dyes pertaining to this type, which are also called chromable acid dyes, need the aid of a chrome salt to be able to fix perfectly onto the fibre, and they may be classified into the following chemical groups:
— Azo dyes,
— Anthraquinonic dyes,
— Triphenylmethanes,
— Others, such as derivatives of thiazone, of the oxazines and of xanthenes.
The most commonly used chromium salts are: anhydrous potassium dichromate, sodium dichromate and potassium chromate.
The procedure depends on the dyes used and the type of material dyed. The dichromate may be applied to the wool before dyeing (pre-chroming procedure), with the dye in the same bath (simultaneous chroming procedure) or after dyeing (afterchroming procedure). These procedures have fallen into disuse and are only used in some very specific cases in place of the ‘low chrome’ procedure.

**Disperse dyes:**
These are non-ionic organic compounds, almost insoluble in water, which are applied in aqueous dispersion, responding to the following structures:
— Dyes with azo groups, principally mono- and some di- azoderivatives, which encompass a broad range of shades.
— Nitrodiphenylamine dyes for yellows and oranges.
— Anthraquinonic dyes for oranges, greens and blues.
— The dispersing agents (surfactants) used in the preparation and application of disperse dyes are:
  — Esters of sulphuric acid, such as alkylsulphates in chains of 12-13 carbon atoms, sulphated oils, sulphated esters and amides.
  — Sulphonic derivatives, in which the radical chain may be alkyl, alkylaryl, amides, esters or lignins.
  — Among the most commonly used are the derivatives of β-naphthylene sulphonic acid and its products of condensation with formaldehyde.
  — Oxyethylene derivatives, for example, alkylaryl oxyethylenes and alkylamine oxyethylenes.
The application methods depend on the way that the textile materials are found. Dyeing can be done by exhaustion at high temperature or with a carrier at temperatures of 100°C. (The latter is falling into disuse).
Traditionally, in the case of polyester, following dyeing at 130°C, a reductive bath is necessary, which is performed at a lower temperature.

Cationic dyes:
Cationic dyes are highly numerous organic based salts with a wide variety of chemical structures, among which the following are included:

- Derivatives of di- and triphenyl methane.
- Derivatives of diphenyl-amine which includes a series of dyes of a simple structure which belong to the family of azines, oxazines, tiazines, indamines, rhodamines, galloycyanines, etc.
- Azoic or anthraquinonic-type dyes.
- Dyes with a heterocyclic structure containing quaternary nitrogen.

3.1.2.5 Description of the finishing process

Following dyeing, later treatments may be performed on the fabric in order to achieve special characteristics for the end textile product. The fabric’s characteristics may be changed by performing physical or mechanical treatments (dry finishing processes) or by applying chemicals (wet sizing processes). In some cases, the results could be achieved in any of both ways, as is the case of lustre. In others, only one possible way exists, as is the case of impermeability or fire-retardant qualities.

All wet treatments are principally based on the coating or impregnation of the fabric with different substances, which may be applied indistinctly to bleached or dyed fabrics. Normally, the wet finishing subprocesses follow the operations below:

- Application of the finishing products, by immersion in a bath containing the chemicals, and later squeezing in the foulard; application of finishes using minimal impregnation techniques; foam systems; scraper devices, etc.
- Fixation by the effect of temperature.

3.1.2.6 Types of finishing sub-processes:

i. Mechanical finishing:
The most common mechanical finishing processes are described below:

Heat setting:
This is a ‘dry’ subprocess aimed at stabilising and contributing suitable properties to synthetic fabrics, or to those that have a high proportion of synthetic material. When the thermoplastic fibres are thermostabilised, they keep their shape and width throughout the following finishing stages, in addition, acquiring physical properties of resistance and elasticity making the garment more suitable for its end use.

Brushing and raising:
These are used to reduce the fabric’s shine due to rubbing against a surface, changing the appearance of the fabric, breaking some individual fibres by means of small hooks.
Softening or calendering:
Calendering through the effect of the temperature and pressure gives rise to the softening of the surface of the fabric and lustre increases. In calendering, the fabric passes between two or more cylinders, one of which is made of steel, while the others are made of very soft material (normally the contact surface is cotton). The steel cylinder may also be heated using gas or steam.

Embossing:
This is an effect that may be achieved in a calender that has a cylinder with motifs in relief, which are transferred to the fabric.

Chintz effect:
This is one of the effects that may be achieved by means of a calender with a microgrooved cylinder, which gives the characteristic lustre to the treated fabrics. Luminosity may be given to the fabric by compressing both surfaces of the fabric, which may be achieved by passing the fabric between the two calender cylinders. The lustre may be improved if the cylinders have grooves.

Shearing:
Shearing levels the height of pile or fibre by passing the fabric through a shearer. When the aim is to eliminate all fibres that protrude, the operation is known as levelling.

Sanforizing:
Using the principle of compressive shrinkage, the tendency of the fabric to shrink during its end use is reduced, following a series of successive washes.

ii. Chemical finishing:
The most common chemical sizing processes have specific functions: softening, hydrophobing, waterproofing, flame-retardant treatment, bactericide, etc. The main finishing subprocesses are as follows:

Chemical softening:
Different types of softeners may be used:
- Cationic softeners such as: quaternary ammonium salts, amino esters and amino amides,
- Non-ionic glycolic polyester or polyether glycol-type softeners,
- Reactive softeners such as fatty acid amides and triazine derivatives.

Anti-static treatment:
The aim of this process is to reduce the static charge of synthetic fibres by means of treatment with an aqueous solution of anti-static agents (magnesium chloride, polyethylene glycol and polyalkylene oxide).

Flame-retardant treatment:
The aim of this process is to increase the fire resistance of textiles materials with the application of flame-retardant products (normally organophosphates and halogenated compounds).

Shrink-resistant treatment:
The aim is to avoid diminishing dimensions due to external causes, especially by washing with water.
The operation consists of relaxing the fabric in an aqueous medium, or by applying chemicals, normally resins.

**Waterproofing:**
This consists of the treatment of the fibres with hydrophobic agents, that is to say, water repellents (silicones, fluorocarbons, paraffin emulsions with aluminium salts and zirconium, resins).

**Crease resistant treatment:**
The aim of this process is to prevent fabrics from creasing easily with wear. This is achieved through cross-linking treatment – reactive products that are exempt of free formaldehyde, which may be applied by drying and heat condensation or by polymerisation after the garment has been made, among others.

**Coating:**
This consists in the application to the fibres, on one or both sides, of a plastic layer (PVC, PVA, PUR, copolymers of vinyl acetate/chloride). The coating is applied thermally, in a layer, in such a way that the coat fixes to the fabric through cooling.

Other textile coating operations are:
- Powder coating (thermoadhesive resins for interfacing),
- Application of paste coating,
- Transfer coating.

### 3.2 Overview of main applied process steps and their environmental impacts in the Tunisian textiles dyeing and finishing sub-sector

In this paragraph we will focus our analysis on the following processes:
- Woven fabric dyeing and finishing process,
- Knitted fabric (knitwear) dyeing and finishing process,
- Jeans washing process,
- Jeans dyeing process.

### 3.2.1 Woven fabric dyeing and finishing process for cotton and its blends

#### 3.2.1.1 Process description

The process of dyeing and finishing for woven cotton fabrics and its blends (see Flow chart below) basically consists of the following operations:
- Singing,
- Desizing,
- Scouring,
- Mercerising and rinsing,
- Optical and chemical bleaching,
- Drying,
- Heat setting,
- Dyeing and rinsing,
— Final drying,
— Finishing.

The flow chart process is as follows:
Figure 2. Flow chart of dyeing and finishing process for cotton woven fabrics and blends
1. **Singeing**

The singeing operation is also known as gassing or burning depending on the procedure used. Its aim is to eliminate the fibres and fuzz that protrude from the yarn and also from the fabric.

2. **Desizing**

Desizing or quenching aims to eliminate the pastes which are added to the warp for weaving. Desizing procedures are selected according to the type of sizing in the fabric:

- Desizing of starch pastes: this treatment consists of using amylase-type enzymes to degrade the starch, at an appropriate pH and established temperature. Sodium persulphate is also used as a desizing product.

- Desizing with polyvinyl alcohol (PVA), carboxymethyl cellulose (CMC), (CMA), etc. Since they are hydrosoluble pastes, they are directly eliminated by washing with a detergent at a suitable pH, depending on the case in question.

- Desizing of special pastes, which always require direct instructions from the manufacturer. Special pastes are used to achieve high efficiency in weaving, for example on looms that insert the weft by means of a jet of water.

3. **Scouring**

The scouring operation on cotton aims to eliminate the natural impurities contained in the fibre itself, which consist of waxes, pectins and hemicellulose. Treatment is carried out in discontinuous or continuous systems by means of the action of an alkali, such as caustic soda alone or with detergent products, to solubilise and/or emulsify the impurities of the cotton, sequestrants and small quantities of reductive products, such as sodium hydrosulphite. The process is also known as cotton boiling, and may be done in an autoclave at a temperature of 100°C to 130-140°C, for 2 to 8 hours in discontinuous processes. A final rinse with water is needed in order to extract all the impurities separated from the cotton.

4. **Mercerising and rinsing**

The mercerising operation consists of subjecting the cotton to the action of the concentrated caustic soda (28-30°Be), so as to provide it with some characteristics that it does not possess or that it possesses in insufficient amounts, such as lustre, dye affinity, better dimensional stability, and an 15-20% increase in the mechanical resistance of the yarn. This is done by subjecting the threads to tension, during or after impregnation in a 30°-Be caustic soda solution at temperatures lower than 20°C and, later, successive washes are performed until the concentration of soda has fallen to values that no longer modify the cotton. In order to facilitate the impregnation of the cotton, anionic wetting agents are also added which can be phenolic or non-phenolic derivatives, the latter currently being the most commonly used, which are based on sulphur esters of average molecular weight (4 to 12 carbon atoms).
The final stage is the neutralisation of the alkaline remains, which are still contained in the thread, if the following operation is not to be performed at alkaline pH, generally with chlorhydric acid or sulphuric acid.

A commonly employed variant in the mercerising operation in the so-called causticizing process, which is done with a lower concentration of soda, 18°Be, the main objective of which is to increase the cotton’s affinity for the dyes.

Causticizing need not be done in the mercerising machines themselves.

5. **Optical and chemical bleaching**

The chemical bleaching operation aims to eliminate the yellowish, reddish or brownish colour that is still present in the cotton after the previous treatments, by means of the oxidising action of compounds derived from chlorine or peroxides.

It consists of bringing the fabric into contact with correctly defined oxidising solution, at a variable temperature and time, according to the process carried out (exhaustion, pad-steaming, etc.) until the materials that colour the cotton are destroyed, causing minimal degradation to the fabric.

The oxidisers that usually used are sodium hypochlorite, sodium chlorite and hydrogen peroxide, which must be used in the presence of other products in order to regulate the pH and stabilise their decomposition.

These products are alkalis such as sodium silicate, sodium carbonate, trisodium phosphate, caustic soda, etc. when using sodium hypochlorite or hydrogen peroxide. Or acid-types, such as monosodium phosphate, formic, acetic or oxalic acid, in the case of sodium chlorite.

Usually used in the bleaching operation, in addition to the previously mentioned products, are optical bleachers, whose application means that higher degrees of whiteness and fastness may be obtained. Their action is based on the principle of fluorescence and must have chemical structures with an affinity for each of the fibres to which they are to be applied.

Most optical bleaching agents used can be placed into the following families:

- Coumarins,
- Stilbenes,
- Benizimidazoles,
- With heterocyclic nucleus,
- Naphthalenesulphonic acid derivatives,
- Other.

After the bleaching operation, a series of rinses is carried out in order to eliminate all substances used from the fabric and to totally develop the fibre’s whiteness.

6. **Drying**

If the fabric has a component of synthetic fibres, drying must be carried out in order to apply the heat setting process, unless the heat setting is done as the first operation.
7. **Heat setting**

Heat setting must be applied to all fabrics that contain synthetic fibres either on their own or in blends with natural or artificial fibres, as a treatment before dyeing or printing and as a final treatment. Its aim is to free the synthetic fibres of the tensions to which they have been subjected in the course of drawing during spinning and taking them through the process of thermal relaxation of the internal tensions to a state of balance that protects them from later deformation. In order that no deformations are suffered during later hot processes, the fabric must not be subjected to treatment at a temperature higher than that of the heat setting process. It is performed in a stenter, with the fabric open-width in order to allow its relaxation and dimensional fixing.

8. **Dyeing**

The families of dyes used for the dyeing of cotton and blend fabrics are:

- Direct dyes,
- Sulphur dyes,
- Soluble-type sulphur dyes,
- Vat dyes,
- Reactive dyes,
- Disperse dyes,
- Acid dyes,
- Cationic dyes,
- Premetallised dyes.

The auxiliary products used depending on the type of dye are to be found in the table of Flow chart shown in ¡Error! No se encuentra el origen de la referencia.

9. **Final drying**

Following dyeing, the last operation is drying which is generally performed in two stages:

- The mechanical elimination of water by means of hydro-extraction,
- Drying by applying thermal energy.

This operation is generally done in the stenter with direct gas heating. It allows also the dimensional stability to the fabric.

10. **Finishing**

Cotton fibre fabric and blends thereof allow any of the following finishing processes:

- **Mechanical:**
  - Calendering,
  - Shearing,
  - Brushing,
  - Wetting,
  - Raising,
  - Palmer machine.
Chemical:
- Crease resistant treatment,
- Waterproofing,
- Softening,
- Hydrophobic,
- Wash and wear,
- Stain resistant treatment,
- Flame-retardant treatment.

3.2.1.2 Main waste flows generated by the process

The main waste flows generated by the process are presented by the table below:
Table 23. Main waste flows generated by woven fabric dyeing and finishing process for cotton and blends

<table>
<thead>
<tr>
<th>Process steps</th>
<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water</td>
<td>Energy</td>
</tr>
<tr>
<td>Singeing</td>
<td></td>
<td>Electrical energy</td>
</tr>
<tr>
<td>Desizing</td>
<td>Water</td>
<td>Electrical energy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scouring</td>
<td>Water</td>
<td>Electrical energy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mercerising</td>
<td>Water</td>
<td>Electrical energy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optical and chemical bleaching</td>
<td>Water</td>
<td>Electrical energy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drying</td>
<td></td>
<td>Electrical energy</td>
</tr>
<tr>
<td>Heat setting</td>
<td></td>
<td>Electrical energy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dyeing</td>
<td>Soft water</td>
<td>Electrical energy</td>
</tr>
<tr>
<td>--------</td>
<td>------------</td>
<td>------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heat (steam)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Disperse dyes</td>
<td>Acid dyes</td>
</tr>
<tr>
<td>--------------------------</td>
<td>---------------</td>
<td>-----------</td>
</tr>
<tr>
<td><strong>Rinsing</strong></td>
<td>Soft water</td>
<td>Electrical energy</td>
</tr>
<tr>
<td><strong>Drying</strong></td>
<td>Electrical energy</td>
<td>Heat (steam)</td>
</tr>
<tr>
<td><strong>Mechanical finishing</strong></td>
<td>Electrical energy</td>
<td></td>
</tr>
<tr>
<td><strong>Chemical finishing</strong></td>
<td>Electrical energy</td>
<td>Chemical agents</td>
</tr>
</tbody>
</table>

Chapter 3
3.2.1.3 Wastewater quality

The characteristics of wastewater generated by woven fabric dyeing and finishing process are given in the table below:

Table 24. Characteristics of wastewater generated by woven fabric dyeing and finishing process for cotton and blends

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Range of concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>-</td>
<td>10-12</td>
</tr>
<tr>
<td>COD</td>
<td>mg O₂/l</td>
<td>1,500-2,800</td>
</tr>
<tr>
<td>BOD₅</td>
<td>mg O₂/l</td>
<td>400-900</td>
</tr>
<tr>
<td>TSS</td>
<td>mg/l</td>
<td>100-150</td>
</tr>
<tr>
<td>Colour</td>
<td>mg (Co – Pt)/l</td>
<td>1,000-3,000</td>
</tr>
<tr>
<td>Conductivity</td>
<td>µS/cm</td>
<td>4000-9,600</td>
</tr>
</tbody>
</table>

3.2.1.4 Resources consumption

The average consumption of water and energy by Tunisian companies active in this field are presented in the table below:

Table 25. Consumption of water and energy by woven fabric dyeing and finishing process in Tunisian companies

<table>
<thead>
<tr>
<th>Water Consumption</th>
<th>Electricity consumption</th>
<th>Natural gas consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Consumption (l/kg)</td>
<td>BAT (l/kg)</td>
<td>Actual Consumption (kWh/kg)</td>
</tr>
<tr>
<td>70.5</td>
<td>&lt; 55-65</td>
<td>1.06</td>
</tr>
</tbody>
</table>

3.2.2 Woven fabric dyeing and finishing process for wool and its blends

3.2.2.1 Process description

The process of dyeing and finishing for wool woven fabrics and blends thereof (see Flow chart below) basically consists of the following operations:

- Carbonisation,
- Chemical or solvent washing,
- Fixing,
- Fulling,
- Bleaching,
- Heat setting,
- Dyeing,
— Drying,
— Finishing.

The flow chart process is as follows:
Figure 3. Flow chart of dyeing and finishing process for wool woven fabric and blends

**AUXILIARY MATERIALS BY TYPE OF DYE**

<table>
<thead>
<tr>
<th>Type</th>
<th>Acid</th>
<th>Premetallised</th>
<th>Chrome</th>
<th>Cationic</th>
<th>Reactive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Equalisers</td>
<td>Detergents</td>
<td>Chrome salts</td>
<td>Acetic/formic acid</td>
<td>Neutral electrolyte</td>
</tr>
<tr>
<td></td>
<td>Acetic/formic acid</td>
<td>Acetic acid</td>
<td></td>
<td>Cationic or ionic retarders</td>
<td>Wetting agents</td>
</tr>
<tr>
<td></td>
<td>Ammonium sulph.</td>
<td>Equalisers</td>
<td></td>
<td>Equalisers</td>
<td>Alkali (NaOH, NaHCO₃ or Na₂CO₃)</td>
</tr>
<tr>
<td></td>
<td>Sodium sulphate</td>
<td>Ammonium salts</td>
<td></td>
<td>Equalisers</td>
<td></td>
</tr>
</tbody>
</table>

**CHEMICAL WASH**
- Detergent
- Electrolytes
- Heat
- Water

**CARBONISATION**
- Wetting agents
- Inorganic acids
- HCl
- H₂SO₄
- Heat
- Water

**CHEMICAL & OPTICAL BLEACHING**
- Reductive
- Water
- Heat
- SO₂ liquid or gas/
- Sulphur acid
- Optical bleaching agents

**THERMOFIXATION**
- Water
- HCl/
- H₂SO₄
- Detergent

**FULLING**
- Heat
- Water
- Steam

**WASHING**
- Water

**CHEMICAL & OPTICAL BLEACHING**
- Oxidants
- Water
- Hydrogen peroxide
- Sodium perborate
- Optical bleaching agents

**RISING**
- Heat
- Water

**DYEING & RINSING**
- Heat
- Water

**DRYING**
- Heat

**FINISHING**
- Heat

**PREPARATION OF DYE**
- Water

**FINISHED FABRIC**
1. Carbonisation
Carbonisation aims to chemically eliminate the remains of cellulosic matter, which accompany wool as impurities. It is done by impregnating the wool with strong mineral acids or with salts that generate these acids, followed by drying and later treatment at a temperature of 105-115°C.
The carbonisation process of wool in continuous mode consists of the following stages:

- Impregnation with an aqueous solution of sulphuric acid and with the addition of a stable wetting agent in acid medium.
- Drying in two chambers, the first at 60°C and the second at 80 to 90°C.
- Carbonisation in an oven at 105-110°C.
- Beating in a beating machine in order to eliminate the carbonised vegetable particles adhered to the wool.
- Neutralisation of the acid contained in the fibre, followed by a thorough wash in order to eliminate any excess of alkalinity on the fibre.

2. Chemical or solvent washing
The washing of wool fabric is an operation that can be performed and repeated at several moments throughout the process. Thus, for example, they are done on the material leaving the loom, on the material leaving the fulling machine, or on the material leaving the dyeing stage. It is used whenever necessary in order to eliminate traces of foreign substances, which have still not been removed from the fibre or that have deposited on the fabric by accident; or to neutralise the bad smell that the fabric sometimes has.

The first case is especially interesting in dyeing, that is, washing the material leaving the loom. This operation consists of eliminating the additional substances to the wool fibre during the spinning process and those that are temporarily added in the sizing of the warp yarn for weaving. The process is generally performed discontinuously with the fabric in rope form.

The solutions used in chemical washing depend on the type of residue or foreign substance that the fabric contains and, in general, may be grouped into two types:

- Neutral, consisting of water at 80-90°C in order to eliminate pastes and dextrins and active anion detergents. They are used in the washing of articles dyed with acid dyes, which cannot be washed using common processes since the dye would run.
- Alkaline, formed, in general, by sodium carbonate and soap.

Solvent washing may also be performed in order to eliminate the fats that are in the fibre, both residual and oils and lubricants used to facilitate the weaving process.

The degreasers employed in solvent washing are mixtures of emulsions of organohalogenated compound solvents (trichloroethylene and perchloroethylene). These exhausted solvents can be regenerated by a distillation process.
3. Fixing

The fixing operation includes a series of procedures that aim to achieve a certain degree of dimensional stability of the wool fibre and its manufactured derivatives, yarns and fabrics when these are subjected to later wet treatments. Different ‘degrees of fixation’ exist, depending on the intensity of the treatment, which shall depend on the ‘degree of stability’ desired for the later wet treatment and thus, the following degrees and types may be considered:

- Cohesive fixation, which is the fixing that disappears when the fabric is left to relax in cold water.
- Temporary fixation, which is when the stable fixing to relaxation in cold water, but not in hot water as an operation prior to dyeing.
- Permanent fixation, which is the stable fixing to the relaxation in hot water, as a finishing operation.

There are two most commonly used industrial processes for fixing wool articles, as required as an operation prior to washing and dyeing treatments: fixing in a crabbing machine and fixing performed in a ‘decatising’ machine:

- Fixing in a crabbing machine is done by making the fabric pass completely open-width through boiling water, beaming it under pressure in a steel cylinder which is previously submerged in water at the desired temperature (70-100°C). Once beamed, it continues to turn in the boiling water for the necessary length of time in order to achieve the degree of fixation required. Finally, the fabric is submerged in cold water to cool it, keeping it beamed in the same way. The solutions used may vary from water to soap or alkaline, but generally, the treatment is done with just water.
- Fixing in the decatising machine consists of beaming the woollen fabric accompanied by a cotton or polyester fabric, in a copper cylinder with holes in it, to later subject it to the action of steam. The intensity of fixation depends on the length of time that the steam acts, the temperature of the steam and the degree of cooling carried out on the fabric before unrolling.

4. Fulling

The fulling operation, also called milling or felting, consists of a progressive tangling process of the wool fibres caused by its flaky surface, giving rise to a dimensional change of the piece of fabric which translates into an increase in thickness and a reduction in length and width. This is applied to worsteds and woollens.

It is done in the so-called fulling machine, in which the fabric, in endless rope form, is compressed in order to facilitate felting, which is produced in the presence of humidity and an acid or alkaline medium. The ideal values for felting in an alkaline medium are pH 10 and 44°C, and for acid pH 0.5 and 44°C. In alkaline felting, it is preferable to use soap rather than sodium hydroxide or carbonate, given that it acts as a lubricant facilitating considerably the movement of the fibres.
5. **Optical and chemical bleaching**
The chemical bleaching operation, whose aim is to eliminate the natural colour of the wool fibre, may be done by means of:
- Reductive agents such as gas sulphurous anhydride, liquid sulphurous anhydride, sulphurous acid, sulphite, bisulphite and hydrosulphite.
- Oxidising agents such as oxygenated water and persalts.

6. **Heat setting**
Heat setting of blended wool fabric with chemical fibres aims to achieve their dimensional stability at the same time as the fixation of the width and weight per square metre of fabric, by means of heating to the temperature of heat setting and later cooling inside the stenter.

7. **Dyeing**
The families of dyes used for the dyeing of wool fabrics are:
- Cationic dyes,
- Acid dyes,
- Premetallised dyes,
- Chrome dyes,
- Reactive dyes for wool.

The auxiliary products used according to the type of dye are found in the table of Flow chart shown in ¡Error! No se encuentra el origen de la referencia.

8. **Drying**
As in the case of other processes, the drying operation is done after the wet treatments, generally in two stages:
- Mechanical elimination of water,
- Drying using thermal energy.

9. **Finishing**
Finishing is the last operation. In wool fabrics, mechanical finishing is most commonly applied:
- Permanent fixing,
- Raising,
- Shearing,
- Brushing,
- Wetting,
- Pressing,
- Decatising,
- Calendering.

### 3.2.2.2 Main waste flows generated by the process

The main waste flows generated by the process are presented by the table below:
## Table 26. Main waste flows generated by woven fabric dyeing and finishing process for wool and blends

<table>
<thead>
<tr>
<th>Process steps</th>
<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water</td>
<td>Energy</td>
</tr>
<tr>
<td>Carbonisation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical washing</td>
<td>Water</td>
<td>Electrical energy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solvent washing</td>
<td>Water</td>
<td>Electrical energy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixing</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Electrical energy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fulling</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optical and chemical bleaching</td>
<td>Water</td>
<td>Electrical energy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Chapter 3

<table>
<thead>
<tr>
<th>Process</th>
<th>Electrical energy</th>
<th>Water</th>
<th>Vapours</th>
<th>Specific pollutants according to the dyes used (metals, for example)</th>
<th>Fibres and dust</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heat setting</strong></td>
<td>Electrical energy</td>
<td>Heat</td>
<td>Water vapour</td>
<td>- VocS</td>
<td>Fibres and dust</td>
</tr>
<tr>
<td><strong>Dyeing</strong></td>
<td>Water</td>
<td>Heat (steam)</td>
<td>- Acids dyes</td>
<td>- Levelling agents&lt;br&gt;- Acetic/formic acid&lt;br&gt;- Ammonium sulphate&lt;br&gt;- Sodium sulphate&lt;br&gt;- Premetallised dyes&lt;br&gt;- Detergents&lt;br&gt;- Acetic acid&lt;br&gt;- Levelling agents&lt;br&gt;- Chromium acids dyes&lt;br&gt;- Chromium salts&lt;br&gt;- Reactive dyes&lt;br&gt;- Neutral electrolyte&lt;br&gt;- Wetting agents&lt;br&gt;- Alkali (NaOH, NaHCO₃ or Na₂CO₃)</td>
<td>- VocS</td>
</tr>
<tr>
<td><strong>Drying</strong></td>
<td>Electrical energy</td>
<td>Heat (steam)</td>
<td>- COD</td>
<td>- Colour&lt;br&gt;- Specific pollutants&lt;br&gt;- Vapours</td>
<td></td>
</tr>
<tr>
<td><strong>Finishing</strong></td>
<td>Water</td>
<td>Electrical energy</td>
<td>It depends on the type of finish</td>
<td>- COD&lt;br&gt;- BOD&lt;br&gt;- Specific pollutants according to finishes used (AOX, surfactants, fats, etc.)</td>
<td>- VocS</td>
</tr>
</tbody>
</table>
3.2.2.3 Wastewater quality

The characteristics of wastewater generated by the process of dyeing and finishing for wool fabrics and blends are given in the table below:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Range of concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td></td>
<td>6-7</td>
</tr>
<tr>
<td>COD</td>
<td>mg O₂/l</td>
<td>300-1,500</td>
</tr>
<tr>
<td>BOD₅</td>
<td>mg O₂/l</td>
<td>250-500</td>
</tr>
<tr>
<td>TSS</td>
<td>mg/l</td>
<td>100-150</td>
</tr>
<tr>
<td>Colour</td>
<td>mg (Co – Pt)/l</td>
<td>500-1,500</td>
</tr>
<tr>
<td>Conductivity</td>
<td>µS/cm</td>
<td>2,200-3,000</td>
</tr>
</tbody>
</table>

3.2.3 Knitted fabric dyeing and finishing process for cotton and its blends

3.2.3.1 Process description

The dyeing processes that may be done on the garment or tricot item follow the same operations (except the desizing) as in the case of dyeing cotton woven fabrics (see ¡Error! No se encuentra el origen de la referencia.).

On the other hand, singeing, which is quite common in woven fabrics, is not so common for knitted fabrics.

So, the dyeing processes of cotton knitted fabrics and blends can contains the following steps:

- Scouring,
- Mercerising and rinsing,
- Optical and chemical bleaching,
- Drying,
- Heat setting,
- Dyeing and rinsing,
- Final drying,
- Finishing.

3.2.3.2 Main waste flows generated by the process

(See table presented in the paragraph 3.2.1 / b)
3.2.3.3 Wastewater quality

The characteristics of wastewater generated by the process of dyeing and finishing for cotton knitted fabrics and blends are given in the table below:

Table 28. Characteristics of wastewater generated by knitted fabric dyeing and finishing process for cotton and blends

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Range of concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>-</td>
<td>6-11</td>
</tr>
<tr>
<td>COD</td>
<td>mg O₂/l</td>
<td>600-800</td>
</tr>
<tr>
<td>BOD₅</td>
<td>mg O₂/l</td>
<td>200-300</td>
</tr>
<tr>
<td>TSS</td>
<td>mg/l</td>
<td>50-120</td>
</tr>
<tr>
<td>Colour</td>
<td>mg (Co – Pt)/l</td>
<td>500-1,500</td>
</tr>
<tr>
<td>Conductivity</td>
<td>µS/cm</td>
<td>500-9,200</td>
</tr>
</tbody>
</table>

3.2.3.4 Resources consumption

The average consumption of water and energy by Tunisian companies active in this field are presented in the table below:

Table 29. Consumption of water and energy by knitted fabric dyeing and finishing process in Tunisian companies

<table>
<thead>
<tr>
<th>Water Consumption</th>
<th>Electricity consumption</th>
<th>Natural gas consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual consumption (l/kg)</td>
<td>BAT (l/kg)</td>
<td>Actual consumption (kWh/kg)</td>
</tr>
<tr>
<td>76</td>
<td>&lt; 70-80</td>
<td>1.1</td>
</tr>
</tbody>
</table>

3.2.4 Knitted fabric dyeing and finishing process for cellulose and its blends

3.2.4.1 Process description

The dyeing process for cellulosic knitted fabric and blends (see Flow chart below) includes the following operations:

- Scouring,
- Optical and chemical bleaching,
- Dyeing,
Chapter 3

— Drying,
— Heat setting,
— Finishing.

The flow chart process is as follows:
Figure 4. Flow chart of dyeing and finishing process for cellulosic knitted fabric and blends

<table>
<thead>
<tr>
<th>AUXILIARY MATERIALS BY TYPE OF DYE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Direct</strong></td>
</tr>
<tr>
<td>Neutral electrolyte</td>
</tr>
<tr>
<td>Wetting agents</td>
</tr>
<tr>
<td>Equalisers</td>
</tr>
<tr>
<td><strong>Reactive</strong></td>
</tr>
<tr>
<td>Neutral electrolyte</td>
</tr>
<tr>
<td>Wetting agents</td>
</tr>
<tr>
<td>Alkali (NaOH, NaHCO₃ or Na₂CO₃)</td>
</tr>
<tr>
<td><strong>Sulphur</strong></td>
</tr>
<tr>
<td>Reductive agent</td>
</tr>
<tr>
<td>Neutral electrolyte</td>
</tr>
<tr>
<td>Wetting agents</td>
</tr>
<tr>
<td>Oxidant</td>
</tr>
<tr>
<td>Sodium acetate</td>
</tr>
<tr>
<td><strong>Vat</strong></td>
</tr>
<tr>
<td>NaOH</td>
</tr>
<tr>
<td>Reductive</td>
</tr>
<tr>
<td>Electrolyte</td>
</tr>
<tr>
<td>Wetting agents</td>
</tr>
<tr>
<td>Equalisers</td>
</tr>
<tr>
<td>Oxidants</td>
</tr>
<tr>
<td><strong>Soluble sulphur</strong></td>
</tr>
<tr>
<td>Equalisers</td>
</tr>
<tr>
<td>Neutral electrolyte</td>
</tr>
<tr>
<td>Wetting agents</td>
</tr>
<tr>
<td>Oxidant</td>
</tr>
<tr>
<td>Detergent</td>
</tr>
<tr>
<td>Sodium acetate</td>
</tr>
</tbody>
</table>

The flow chart illustrates the process of dyeing and finishing for cellulosic knitted fabric and blends. The process begins with raw knitwear fabric, which goes through scouring and washing. Subsequently, it undergoes chemical and optical bleaching before moving to dyeing. After dyeing, the fabric is washed and then heat set. Finally, it undergoes finishes to achieve the finished knitwear.
3.2.4.2 Main waste flows generated by the process

The main waste flows generated by the process are presented by the table below:

<table>
<thead>
<tr>
<th>Process steps</th>
<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water</td>
<td>Energy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scouring</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optical and chemical bleaching</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dyeing</td>
<td>Soft water</td>
<td>Electrical energy</td>
</tr>
</tbody>
</table>

**Table 30. Main waste flows generated by knitted fabric dyeing and finishing process for cellulose and blends**

- **Water**
  - Scouring: NaOH, Detergents
  - Optical and chemical bleaching: NaClO₂/H₂O₂, pH buffer, Optical bleaching agents
  - Dyeing: Direct dyes, Neutral electrolyte, Wetting agents, Levelling agents

- **Energy**
  - Scouring: Electrical energy
  - Optical and chemical bleaching: Heat (steam)
  - Dyeing: Heat (steam)

- **Wastewater**
  - Scouring: COD, Alkalinity
  - Optical and chemical bleaching: Oxidising agents, AOX (if hypo-chlorite is used), COD
  - Dyeing: COD, Colour, Specific pollutants according to the dyes used (metals, for example)

- **Air emissions**
  - Scouring: Alkaline vapours
  - Optical and chemical bleaching: Vapours, Aerosols
  - Dyeing: Vapours
<table>
<thead>
<tr>
<th>Chapter 3</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>— Sulphur dyes</td>
<td></td>
</tr>
<tr>
<td>— Reductive agent</td>
<td></td>
</tr>
<tr>
<td>— Neutral electrolyte</td>
<td></td>
</tr>
<tr>
<td>— Wetting agents</td>
<td></td>
</tr>
<tr>
<td>— Oxidising agent</td>
<td></td>
</tr>
<tr>
<td>— Surfactants</td>
<td></td>
</tr>
<tr>
<td>— Sodium acetate</td>
<td></td>
</tr>
<tr>
<td>— Vat dyes</td>
<td></td>
</tr>
<tr>
<td>— NaOH</td>
<td></td>
</tr>
<tr>
<td>— Reductive agent</td>
<td></td>
</tr>
<tr>
<td>— Neutral electrolyte</td>
<td></td>
</tr>
<tr>
<td>— Wetting agents</td>
<td></td>
</tr>
<tr>
<td>— Levelling agents</td>
<td></td>
</tr>
<tr>
<td>— Oxidising agents</td>
<td></td>
</tr>
<tr>
<td>— Detergent</td>
<td></td>
</tr>
<tr>
<td>— Soluble-type sulphur dyes</td>
<td></td>
</tr>
<tr>
<td>— Reductive agent</td>
<td></td>
</tr>
<tr>
<td>— Neutral electrolyte</td>
<td></td>
</tr>
<tr>
<td>— Wetting agents</td>
<td></td>
</tr>
<tr>
<td>— Oxidising agent</td>
<td></td>
</tr>
<tr>
<td>— Cationising agent</td>
<td></td>
</tr>
<tr>
<td>— Sodium acetate</td>
<td></td>
</tr>
<tr>
<td>Process</td>
<td>Energy Sources</td>
</tr>
<tr>
<td>------------------</td>
<td>-----------------------------------------------------</td>
</tr>
<tr>
<td><strong>Drying</strong></td>
<td>- Electrical energy</td>
</tr>
<tr>
<td></td>
<td>- Heat (steam)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Heat setting</strong></td>
<td>- Electrical energy</td>
</tr>
<tr>
<td></td>
<td>- Heat</td>
</tr>
<tr>
<td><strong>Finishing</strong></td>
<td>- Water</td>
</tr>
<tr>
<td></td>
<td>- Electrical energy</td>
</tr>
<tr>
<td></td>
<td>- It depends on the type of finish</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.2.4.3 Wastewater quality

The characteristics of the wastewater generated by the dyeing and finishing process for cellulosic knitted fabrics and blends are the same as those generated by the dyeing and finishing process for cotton knitted fabrics and blends.

3.2.4.4 Resources consumption

The average consumption of water and energy by Tunisian companies active in this field are presented in the table below:

3.2.5 Jeans washing process

3.2.5.1 Process description

The jeans washing process can contain the following steps:

- Desizing,
- Rinsing,
- Stone washing,
- Rinsing,
- Bleaching,
- Rinsing,
- Neutralization,
- Rinsing,
- Softening,
- Squeezing,
- Drying,
- Control,
- Packaging.

The main input and output flows of auxiliary materials, water and energy in the jeans washing process are illustrated in the figure below:
Figure 5. Main input and output flows of auxiliary materials, water and energy in the jeans washing process

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Processing steps</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Electrical energy</td>
<td>1. Desizing</td>
<td>• Wastewater</td>
</tr>
<tr>
<td>• Water (1000 l)</td>
<td></td>
<td>• Heat</td>
</tr>
<tr>
<td>• Dispersing agent (1 g/l)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Sequestering agent (1 g/l)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Enzyme (Amylase) : 2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Heat (T= 50°C – 15 mn)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Electrical energy</td>
<td>2. Rinsing</td>
<td>• Wastewater</td>
</tr>
<tr>
<td>• Water (1000 l) :5 mn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Electrical energy</td>
<td>3. Rinsing</td>
<td>• Wastewater</td>
</tr>
<tr>
<td>• Water (1000 l) :5 mn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Electrical energy</td>
<td>4. Stone washing</td>
<td>• Wastewater</td>
</tr>
<tr>
<td>• Water (1000 l)</td>
<td></td>
<td>• Stone</td>
</tr>
<tr>
<td>• Stone 100 kg</td>
<td></td>
<td>• Heat</td>
</tr>
<tr>
<td>• Dispersing agent (1 g/l)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Lubricant (1 g/l)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Neutral Enzyme (1.5%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Heat (T = 50°C - 30 mn)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Electrical energy</td>
<td>5. Rinsing</td>
<td>• Wastewater</td>
</tr>
<tr>
<td>• Water (1000 l) :5 mn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Electrical energy</td>
<td>6. Rinsing</td>
<td>• Wastewater</td>
</tr>
<tr>
<td>• Water (1000 l) :5 mn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Electrical energy</td>
<td>7. Bleaching</td>
<td>• Wastewater</td>
</tr>
<tr>
<td>• Water (1000 l)</td>
<td></td>
<td>• Heat</td>
</tr>
<tr>
<td>• Sodium hypochlorite (2g/l)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Dispersing agent (1 g/l)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Lubricant (1 g/l)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Antioxidant (0.5 g/l)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Heat (T= 50°C - 10 mn)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Electrical energy</td>
<td>8. Rinsing</td>
<td>• Wastewater</td>
</tr>
<tr>
<td>• Water (1000 l) :5 mn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Electrical energy</td>
<td>9. Neutralization</td>
<td>• Wastewater</td>
</tr>
<tr>
<td>• Water (1000 l)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.2.5.2 Wastewater quality

The characteristics of wastewater generated by the jeans washing process are given in the table below:

Table 31. Characteristics of wastewater generated by the jeans washing process

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Range of concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>-</td>
<td>8-10</td>
</tr>
<tr>
<td>COD</td>
<td>mg O₂/l</td>
<td>800-2,460</td>
</tr>
<tr>
<td>BOD₅</td>
<td>mg O₂/l</td>
<td>260-1500</td>
</tr>
<tr>
<td>TSS</td>
<td>mg/l</td>
<td>400-900</td>
</tr>
<tr>
<td>Detergent</td>
<td>mg/l</td>
<td>5-20</td>
</tr>
</tbody>
</table>

3.2.5.3 Resources consumption

The average consumption of water and energy by Tunisian companies active in this field are presented in the table below:

Table 32. Consumption of water and energy by the jeans washing process

<table>
<thead>
<tr>
<th>Water Consumption</th>
<th>Electricity consumption</th>
<th>Natural gas consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual consumption (l/kg)</td>
<td>BAT (l/kg)</td>
<td>Actual consumption (kWh/kg)</td>
</tr>
<tr>
<td>62</td>
<td>&lt; 55-65</td>
<td>0.58</td>
</tr>
</tbody>
</table>

3.2.6 Jeans dyeing process

3.2.6.1 Description of jeans dyeing process using direct dyes

The jeans dyeing process with direct dyes can contain the following steps:

− Desizing,
− Rinsing,
− Enzyme washing,
− Rinsing,
− Dyeing,
− Rinsing,
− Fixing,
Chapter 3

- Rinsing,
- Softening,
- Squeezing,
- Drying,
- Control,
- Packaging.

The main input and output flows of auxiliary materials, water and energy in the jeans dyeing process with direct dyes are illustrated in the figure below:

**Figure 6. Main input and output flows of auxiliary materials, water and energy in the jeans dyeing process with direct dyes**

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Processing steps</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Electrical energy</td>
<td>1. Desizing</td>
<td>• Wastewater • Heat</td>
</tr>
<tr>
<td>• Water (1000 l)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Dispersing agent (1 g/l)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Sequestering agent (1 g/l)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• enzyme (Amylase) : 2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Heat (T= 50°C – 15 mn)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Electrical energy</td>
<td>2. Rinsing</td>
<td>• Wastewater</td>
</tr>
<tr>
<td>• Water (1000 l)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Enzyme washing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Acid Enzyme (1%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Heat (T= 50°C – 15 mn)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Electrical energy</td>
<td>3. Enzyme washing</td>
<td>• Wastewater</td>
</tr>
<tr>
<td>• Water (800 l)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Acid Enzyme (1%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Heat (T= 50°C – 15 mn)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Electrical energy</td>
<td>4. Rinsing</td>
<td>• Wastewater</td>
</tr>
<tr>
<td>• Water (1000 l)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Enzyme washing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Acid Enzyme (1%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Heat (T= 50°C – 15 mn)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Electrical energy</td>
<td>5. Dyeing</td>
<td>• Wastewater • Heat</td>
</tr>
<tr>
<td>• Water (800 l)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Direct dyes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Heating up to 90°C (2°C/ mn)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Salt (10 – 30 g/l)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T=90°C (30-60 mn)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Cooling up to 65°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Dyeing</td>
<td>6. Rinsing</td>
<td>• Wastewater</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Electrical energy</td>
<td>7. Rinsing</td>
<td>• Wastewater</td>
</tr>
<tr>
<td>• Water (800 l)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Dyeing</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Electrical energy</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.2.6.2 Description of jeans dyeing process using reactive dyes

The jeans dyeing process with reactive dyes can contain the following steps:

- Desizing,
- Rinsing,
- Enzyme washing,
- Rinsing,
- Dyeing,
- Rinsing,
- Fixing,
- Soaping,
- Rinsing,
- Softening,
- Squeezing,
- Drying,
- Control,
- Packaging.

The main input and output flows of auxiliary materials, water and energy in the jeans dyeing process with reactive dyes are illustrated in the figure below:
Figure 7. Main input and output flows of auxiliary materials, water and energy in the jeans dyeing process with reactive dyes

Inputs

- Electrical energy
- Water (1000 l)
- Dispersing agent (1 g/l)
- Sequestering agent (1 g/l)
- Enzyme (Amylase) : 2%
- Heat (T= 50°C – 15 mn)

Processing steps

1. Desizing

- Wastewater
- Heat

2. Rinsing

- Wastewater

3. Enzyme washing

- Wastewater

4. Rinsing

5. Dyeing

- Wastewater
- Heat

6. Rinsing

- Wastewater

7. Rinsing

- Wastewater

8. Fixing

- Wastewater

Outputs

- Electrical energy
- Water (1000 l)
- Fixing agent (2%) (10 – 40mn)
3.2.6.3 Wastewater quality

The characteristics of wastewater generated by jeans dyeing process are given in the table below:

Table 33. Characteristics of wastewater generated by jeans dyeing process

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Range of concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>-</td>
<td>9-11</td>
</tr>
<tr>
<td>COD</td>
<td>mg O₂/l</td>
<td>600-5,150</td>
</tr>
<tr>
<td>BOD₅</td>
<td>mg O₂/l</td>
<td>130-3,640</td>
</tr>
<tr>
<td>TSS</td>
<td>mg/l</td>
<td>200-1,100</td>
</tr>
<tr>
<td>Detergent</td>
<td>mg/l</td>
<td>5-20</td>
</tr>
</tbody>
</table>
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 finishing and dyeing processes. This selection could be justified by two main reasons: the environmental relevance of these phases, the characteristics of the Tunisian textile sector composed by many companies belonging to these types of processes. The candidate 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.
Chapter 4

4.1 Introduction

This Chapter provides a description of the environmentally friendly techniques that can be implemented in the textile sector.

Some issues should be clarified beforehand.

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 (like textile BREF, scientific articles, and international projects, EU technical reports) by the partners of 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) (Tunisian textile sector experts) decided to focus on dyeing and finishing processes. This is justified by two main reasons: the high environmental relevance of these processes and large companies belonging to these types of processes.

![Diagram showing processes in green selected by the Tunisian Technical Working Group](image)

Figure 8. Areas in green show the processes selected by the members of the Tunisian Technical Working Group
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.

In the table below the names of the techniques that will be described in this chapter and their classification are summarized.

### 4.2 Techniques for the textile sector.

**Table 34. Classification of techniques analysed in Chapter 4**

<table>
<thead>
<tr>
<th>Class</th>
<th>Sub-class</th>
<th>Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Resources efficiency measures</td>
<td>Efficient use of chemicals and raw materials</td>
<td>Avoiding batch softening. Application of softeners by pad mangles or by spraying and foaming application systems</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Omitting the use of detergents in afterwashing of cotton dyed with reactive dyes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minimizing consumption of complexing agents in hydrogen peroxide bleaching</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alternative process for continuous (and semi-continuous) dyeing of cellulosic fabric with reactive dyes</td>
</tr>
<tr>
<td></td>
<td>Efficient use of water</td>
<td>Minimization of dye liquor losses in pad dyeing techniques</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aftertreatment in PES dyeing.</td>
</tr>
<tr>
<td></td>
<td></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></td>
<td>Increasing washing efficiency and water flow control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Re-use rinse water from process baths in the production process</td>
</tr>
<tr>
<td>Resources recovery measures</td>
<td>Dry bleaching using ozone instead of wet washing using chlorine or hydrogen peroxide</td>
<td></td>
</tr>
<tr>
<td>-----------------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Recovery of sizing agents by ultrafiltration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Recovery of alkali from mercerizing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Recovery of printing paste from supply system in rotary screen printing machines and Recycling of residual printing pastes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Direct re-use of dye baths and auto-control of the process online</td>
<td></td>
</tr>
<tr>
<td>Integrated process measures</td>
<td>Equipment optimisation in batch dyeing</td>
<td></td>
</tr>
<tr>
<td>Use of enzymatic treatment/enzymes in processes</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>
<td></td>
</tr>
<tr>
<td>Use of less pollutant dyes</td>
<td>Dispersing agents with higher bioeliminability in dye formulations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dyeing with sulphur dyes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Emission reduction in dyeing wool with metal-complex dyestuffs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Silicate-free fixation method for cold pad batch dyeing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exhaust dyeing of cellulosic fibres with high-fixation polyfunctional reactive dyestuffs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exhaust dyeing with low-salt reactive dyes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dyeing without water and chemicals</td>
<td></td>
</tr>
<tr>
<td>Other measures</td>
<td>Substitution for alkylphenol ethoxylates (and other hazardous surfactants)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Substitution for sodium hypochlorite and chlorine-containing compounds in bleaching operations</td>
<td></td>
</tr>
</tbody>
</table>
### 3. End of pipe techniques

<table>
<thead>
<tr>
<th>Wastewater abatement techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection of biodegradable/bioeliminable complexing agents in pretreatment and dyeing processes</td>
</tr>
<tr>
<td>Selection of antifoaming agents with improved environmental performance</td>
</tr>
<tr>
<td>Dry mechanical softening using only solid balls (polyorganosiloxane) instead of wet chemical softening using water and chemical agents</td>
</tr>
<tr>
<td>Exhaust dyeing of polyester and polyester blends with carrier-free dyeing techniques or with use of environmentally optimised carriers</td>
</tr>
<tr>
<td>Use environment-friendly alternative chemicals for finishing activities</td>
</tr>
<tr>
<td>Formaldehyde-free or formaldehyde-poor easy-care finishing agents</td>
</tr>
<tr>
<td>Use environment-friendly alternative chemicals for finishing activities</td>
</tr>
<tr>
<td>Treatment of mixed wastewater with about 60% water recycling.</td>
</tr>
<tr>
<td>Recycling of textile wastewater by treatment of selected streams with membrane techniques.</td>
</tr>
<tr>
<td>Application of physical-chemical processes and cross-flow filtration</td>
</tr>
<tr>
<td>Water purification tertiary treatment using photo-oxidation</td>
</tr>
<tr>
<td>Purification Of Industrial And Mixed Wastewater By Combined Membrane Filtration And Sonochemical Technologies</td>
</tr>
<tr>
<td>Appropriately treat industrial wastewater by implementing a combination of suitable waste purification techniques</td>
</tr>
<tr>
<td>Removal of disperse dyes from textile wastewater using bio-sludge</td>
</tr>
</tbody>
</table>
Textiles wastewater treatment using anoxic filter bed and biological wriggle bed-ozone biological aerated filter

Evaluation of the efficacy of a bacterial consortium for the removal of colour, reduction of heavy metals, and toxicity from textile dye effluent

Biosorption of reactive dye from textile wastewater by non-viable biomass of Aspergillus niger and Spirogyra sp.

Chemical coagulation/flocculation technologies for removal of colour from textile wastewaters

Upflow anaerobic sludge blanket reactor in removal of colour and reduction of COD in real textile wastewater

Electrochemical oxidation for the treatment of textile industry wastewater

Removal of reactive dyes from wastewater by adsorption on coir pith activated carbon

Biological and oxidative treatment of cotton textile dye-bath effluents by fixed and fluidized bed reactors

In the next sections for each technique, when possible, the following aspects are addressed:

- description of the technique
- applicability and operational data
- environmental benefit
- economic aspects
- driving force for implementation
- literature references

You will find in this report a short description of each technique. For further details please use the indicated literature references.

### 4.3 Resource efficiency measures

This paragraph discusses techniques to achieve a higher efficiency in the use of resources. In this case the resources are seen from the quantitative point of view
and the techniques summarised will enable an increase in the efficiency of processes that use them.

The paragraph is composed by the following sub-paragraphs:
- efficient use of chemicals and raw materials;
- efficient use of water;
- resources recovery measures;
- integrated process measures.

4.3.1 Efficient use of chemicals and raw materials

Chemicals are one of the most important issues in the textile industry for both economic and environmental reasons. In the past years many experimentations have been carried out by companies and by research Institutes. In this paragraph the main important achievement in this field are summarised.

4.3.1.1 Ref. Datasheet 2.A.6: Avoiding batch softening: application of softeners by pad mangles or by spraying and foaming application systems

a. Description of the technique
The application of softeners by pad mangles or by spraying and foaming application systems are alternative techniques for softening agent application in batch processing.
These techniques avoid the use of cationic softening agents and minimize chemical losses. Residual liquors are reduced. The concentration of active substance is higher. Due to this aspect, liquors are not appropriate for treatment in a biological system. Positive effects are generated by the application of softeners in separate equipment after the batch dyeing process. The advantage consists in re-using the dyeing or rinse baths since there are no longer problems with the presence of residual cationic softeners.

b. Applicability, operational data and driving force for implementation
This technique can be applied in the textile sector and carpet manufacturing sector.

c. Environmental benefit
This technique allows to achieve water, energy and chemicals savings. In addition the use of less polluting softening agents can be considered an environmental benefit

d. Economic aspects
Economic benefits are determined by water, energy and chemical consumption savings and depend on the costs of these inputs.
In chapter 2 are listed some examples of these costs in Tunisia.

e. Reference literature
4.3.1.2  **Ref. Datasheet 2.A.4: Omitting the use of detergents in afterwashing 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 for 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. Some problems could derive due to accidental stops of the 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 wastewater 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 chemical (mainly detergents) consumption and with the wastewater treatment activities.

**e. Reference literature**

4.3.1.3  **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 bleaching, could determine the presence of oxygen species (e.g. O₂**, OH*/O*-, etc.) of differing reactivity in water. The formation of OH* radicals 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.
Chapter 4

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 auxiliaries suppliers. With the help of dynamic simulation models, they were 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 damage to fibre. This is made possible by not using hazardous sequestering agents, and thanks to 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

4.3.1.4 Ref. Datasheet 2.A.5: Alternative process for continuous (and semicontinuous) dyeing of cellulose 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 the right choice of fabric pretreatment 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.

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 enables higher productivity that can help offset the higher costs.

e. Reference literature

4.3.2 Efficient use of water

Water is a precious resource especially in the Mediterranean Partners Countries. Textile sector has a process where in some phases, as the washing and dyeing, is foreseen a huge consumption of water that usually is pumped directly by the underground reducing the availability of the aquifer for potable uses. For this reason the techniques that aim to reduce the use of water are very important and their dissemination in the textile sector should be encouraged.

4.3.2.1 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.

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 thank 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 to needing treatment.

**e. Reference literature**

### 4.3.2.2 Ref. Datasheet 2.B.2: Aftertreatment in PES dyeing

**a. Description of the technique**
This technique increases 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 sulphonic 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 feed for levelling agents, dispersing agents or detergent. The quantity of dye used is lowered.

The first approach is used in all kind 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% of 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**
4.3.2.3 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; also for fabrics with elastane 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. This kind of machine allows high productivity and repeatability. Another driving force are savings in water, chemicals and energy consumption.
This technique is not yet used in Tunisia.

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 consume less steam and water.

d. **Economic aspects**
This technique can imply investment in new machines.

e. **Reference literature**

4.3.2.4 Ref. Datasheet 2.B.6: Increasing washing efficiency and water flow control

a. **Description of the technique**
The washing efficiency is influenced by some elements (temperature, residence time, etc.). Two principles are applied in modern washing machines: countercurrent washing and reduction of carry-over. The first one means that the least contaminated water from the final wash is used again for the next-to-last wash until the water reaches the first wash stage, after which it is discharged. This technique can be applied for washing after continuous desizing, scouring, bleaching, dyeing or printing. The vertical counterflow washer is a construction that sprays re-circulated water in to the fabric and a roller squeezes waste through the fabric in to a sump,
Chapter 4

where it is filtered and re-circulated. This construction allows high-efficiency washing with low water use, and with energy use decreases. The reduction of carry over allows that water that is not removed is “carried over” into the next step, contributing to washing inefficiency. In continuous washing operation and squeeze rollers is used to minimize carry over.

b. Applicability, operational data and driving force for implementation
Increased productivity is achievable in case of new highly efficient washing machinery. Also the increasing cost of water supplies and wastewater treatment are a driving force for the implementation of techniques allowing a washing efficiency increase.

c. Environmental benefit
This technique leads to lower water and energy consumption.

d. Economic aspects
Detailed information is not made available.

e. Reference literature

4.3.2.5 Ref. Datasheet 2.B.7: Re-use rinse water from process baths in the production process

a. Description of the technique
Chemical residues, particularly Deca-BDE, HBCD, Sb2O3, PFOS and/or PFOA, in rinse water from process baths can be (partly) recovered by separately collecting and re-using them, for example, for preparing chemicals (e.g. via dilution) for the next finishing activity.

b. Applicability, operational data and driving force for implementation
Some elements are essential to apply this technique: storage tank, measurement and modification equipment. The application of this technique is difficult for job-processing companies, compared to integrated textile companies. A Flemish integrated textile company indicates that 70% of rinse waters is re-used in the production process. The large percentage of rinse waters that can be potentially re-used is one of the main driving forces for the implementation.

c. Environmental benefit
This technique allows a reduction of chemicals consumption and of wastewater load.

d. Economic aspects
No significant costs are involved. The company can achieve savings in the costs of chemicals.

e. Reference literature
4.3.2.6 Ref. Datasheet 2.B.8: Dry bleaching using ozone instead of wet washing using chlorine or hydrogen peroxide

a. Description of the technique
This technique consists of placing the garments (jeans) in a dry rotary washing machine.
The machine is connected to an ozone generator. This technique is used to:
- 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 duration of the operation varies from 15 to 60 minutes and depends on the kind of garment and the type of required effect. In general, this technique allows a time saving of about 60%, compared with conventional bleaching followed by squeezing and drying steps.
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 the desired effect.

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
Audit carried out by CITET in the BAT4MED project in the Tunisian companies GTS and GTT (Tunis).

4.3.3 Resources recovery measures

The third paragraph of this chapter aims to describe some techniques to improve the use of resources in the process.

4.3.3.1 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 used only for some kinds of sizing agents: water-soluble synthetic sizing agents such as PVA, polycrylates 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 be derived from higher weaving efficiency and the reduced cost of pretreatment and wastewater treatment.

e. Reference literature
4.3.3.2 Ref. Datasheet 2.C.2: Recovery of alkali from mercerizing

a. Description of the technique
In the mercerizing 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, and the lower the steam consumption and running costs. 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.

c. Environmental benefit
The alkaline load of wastewater is reduced.

d. Economic aspects
The investments cost depends on some factors: the plant size and the purification technique. The cost can vary from 200.000 to 800.000 EUR. The payback time can vary and it depends on some aspects (e.g. plant size, operating time/day). From an economic perspective, the recovery of caustic soda could be attractive.

e. Reference literature

4.3.3.3 Ref. Datasheet 2.C.5: Recovery of printing paste from supply system in rotary screen printing machines and Recycling of residual printing pastes

a. Description of the technique
The technique allows the recovery of printing paste left over in the supply system in rotary screen printing machines at the end of each run. A ball is inserted in the squeegee and transported by the incoming paste to its end. The ball is then pressed back through controlled air pressure, pumping printing paste in the supply back into the drum for re-use. Leftover printing paste can lead to non-optimised equipment. These residues are discharged to effluent and give rise to wastewater problems. Today printing pastes are often prepared with computerized systems and this means they can be recycled. Leftover paste is sent to a storage facility. Computers allow the composition of printing paste to be saved and its formulation to be calculated, considering the durability, the amount and the composition of leftover pastes to be re-used. It is also possible to empty drums with leftover printing paste and sort it by taking into account the type of dyestuff and thickener. The use of a scraper to clean the drum reduces printing paste losses. Then it is washed and used again for new printing paste preparation.

b. Applicability, operational data and driving force for implementation
The recovery of printing paste is applicable to new rotary screen printing machines. Existing machines can be modernized. The technique is applied – as indicated above – in textile finishing mills. The systems to recycle printing pastes are applicable to both existing and new installations. Manual operations require trained personnel.
Chapter 4

The printing paste recovery technique is applied in textile finishing mills, in combination with recycling of recovered printing paste. Leftover printing paste is also recycled in textile finishing mills. In particular, this technique is very efficient in firms using only one or two kinds of printing pastes. When many types of printing paste are used, the management of different mixtures may prove difficult.

The need to reduce printing paste losses for economic and environmental reasons, and the wastewater problems are the main driving forces for printing paste recovery. Economic aspects and other issues linked to leftover printing paste disposal are the main driving forces for the recycling of residual printing pastes. This technique is not yet used in Tunisia.

c. **Environmental benefit**

In the case of printing paste recovery, losses of printing paste are minimized, as is water pollution. In order to obtain these benefits, modern printing machines with minimum-volume feed systems have to be used. The recycling of leftover printing pastes reduces the quantity to be disposed of.

d. **Economic aspects**

Investment to modernize recovery system with the necessary devices could be calculated considering the quantity of printing paste to recover. The companies can achieve savings in printing paste consumption and in the reduction of waste management costs.

e. **Reference literature**


4.3.3.4 **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. This technique is not yet used in Tunisia.

c. **Environmental benefit**


d. **Economic aspects**

At the 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 euros), due to the fact that it is quite a 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€, and with the most well-established technological aspects (calibration of colorants and auxiliaries), a recovery time of between 2 and 3 years is estimated, from a strictly economic point of view.

e. **Reference literature**


4.3.4 **Integrated process measures**

This chapter describes the techniques that in the framework of the resource efficiency measures can be applied to several process steps with an integrated approach and involving several environmental aspects. This sub-class is the last of the category related to resource efficiency and consists of only one technique linked with the batch dyeing process.
4.3.4.1 **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 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 economics 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

4.4 Selection/substitution of chemicals with others more environmentally friendly
If the previous category aims to point out the techniques to reduce the quantitative use of resources, in this case the listed techniques are focused to the qualitative point of view. The use of hazardous chemicals as input in the process is one of the most important causes of the pollution load of wastewater and air emissions. In addition the use of dangerous chemicals increases the risk of contamination of soil and groundwater in case of accidental spillage. Finally the improvement of this aspect replacing dangerous chemicals with not dangerous has positive impact on safety and health issues.

4.4.1 Use of enzymatic treatment/enzymes in processes
The use of enzymes as substitutes for chemicals has been applied in several process steps in the textile industry. Below, we report on a technique used to remove the non-fixed dyestuff that could be interesting for the Tunisian textile sector.

4.4.1.1 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 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

The technique only applicable to exhaust dyeing with reactive dyestuffs at this time. Cost-saving prospective and improved quality (higher fastness) of the final product are the main driving forces.
c. **Environmental benefit**  
   This technique enables savings in water, energy and detergent consumption.

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

**e. Reference literature**  

**4.4.2 Less pollutant dyes**

Dying can in several cases be considered as one of the main causes of 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 not 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 initial phases of their life cycle and also in the last phase (use) they cause dangerous packaging waste to send to disposal. For these reasons the research on how the company can dye with less pollutant chemicals is very important to reduce pollution by the textile industry.

**4.4.2.1 Ref. Datasheet 3.C.1: Dispersing agents with higher bioeliminability 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 sulphonic acid with formaldehyde, which are widely applied as dispersing agents, show COD levels as high as 1200 mg/g (lignosulphonates) and 650 mg/g (naphthalenesulphonic 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.
Chapter 4

110

(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**

4.4.2.2 **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
  - 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
In Tunisia this technique is used only for dark colours such as black because it has a good resistance for washing, light and brightness.
Driving forces for the implementation of this technique are worker health and safety.
Bad smells and presence of sulphides in wastewater that are reduced.

(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**

### 4.4.2.3 Ref. Datasheet 3.C.3: Emission reduction in dyeing wool with metal-complex dyestuffs

**a. Description of the technique**
Afterchrome used in dyeing loose wool fibre and combed top dyestuffs can be substituted by metal-free reactive dyestuffs in many cases. Metal-complex dyes under optimised conditions (especially pH control) are used when substitution is not possible. In the case of 1:2 metal complex dyestuffs, the dyeing process can be improved by:
- using a special auxiliary (mixture of different fatty alcohol ethoxylates with high affinity for the fibre and the dyestuff)
- replacing acetic acid with formic acid

The optimised process is the well-known 'Lanaset TOP process'. This technique reduces dyeing time drastically compared to the conventional process. In addition exhaustion rate is 100% and makes dyeing in a standing bath easier. Also the process enables reproducible dyeings with very high fastness properties.

**b. Applicability, operational data and driving force for implementation**
This technique is principally used for dyeing loose wool fibre and combed top and is applicable in new and old installations. The reduction of chromium content in wastewater required by environmental legislation and the desire to increase productivity are the main driving forces for the implementation of this technique.

**c. Environmental benefit**
This technique causes lower chromium content of the effluent due to lower dye content in exhausted liquor. The substitution of acetic acid contributes to lowering the COD load in the effluent. The reduction of the dyeing cycle time saves energy as well as time.

**d. Economic aspects**
A shorter process time and less rinsing water enable savings.

**e. Reference literature**

### 4.4.2.4 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 4:1 ratio Sera pumps with (alkali solution to dyestuffs solution) are suitable for the application of the product. The main driving forces are:

- better 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

In Tunisia some companies use this technique.

**c. Environmental benefit**

The following 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 wastewater 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 of conventional one,
- 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**

4.4.2.5  **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 containing two similar homogeneous or dissimilar heterogeneous 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.

**c. Environmental benefit**
Significant reduction of unused dyestuff ending in the wastewater. With new dyes (and processes) there is also potential for water, energy and chemicals savings.

**d. Economic aspects**
Polyfunctional reactive dyestuffs are more expensive per kilogram than conventional ones, but they permit a higher fixation efficiency, reducing salt usage and water and energy consumption.

**e. Reference literature**

4.4.2.6  **Ref. Datasheet 3.C.6: Exhaust dyeing with low-salt reactive dyes**

**a. Description of the technique**
The development of innovative dye ranges and application processes means about two-thirds of the amount of salt is required compared to conventional methods to improve exhaustion 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 dying 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 with arid climate conditions and negative water balance and where dyehouses discharge directly to fresh water and there is a need to minimize salination effects.

It helps water recycling decreasing corrosion caused by salt.

**c. Environmental benefit**

Positive effects on effluent salinity and smooth running of wastewater 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**


---

**4.4.2.7 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 bar. 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 125 kg 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. The first production machine started operation at Thailand’s Tong Siang Co Ltd, part of the Yeh Group.

Costs savings and improvement of environmental performance are the main driving forces.

This technique is not yet used in Tunisia and seems unviable for economic reasons (too expensive).

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, energy, and chemical cost savings.

e. **Reference literature**


4.4.3 Other measures

In this class are summarised techniques not included in the previous classes but at the same time important if considered the general aim of the paragraph concerning the substitution of chemicals.

4.4.3.1 **Ref. Datasheet 3.D.2: Substitution for alkylphenol ethoxylates (and other hazardous surfactants)**

a. **Description of the technique**

Many surfactants give rise to environmental concerns due to their poor biodegradability, their toxicity (including that of their metabolites) and their potential to act as endocrine disrupters.

Alkylphenol ethoxylates (APEO) and in particular nonylphenol ethoxylates (NPE) can be replaced with other readily biodegradable surfactants as alcohol ethoxylates (AE).
b. Applicability, operational data and driving force for implementation
This measure is generally applicable in all new and existing wet processing installations.
APEO also have many dry applications and in these cases substitution is possible, but it is expensive and it is not a priority. Indeed, here the presence of APEO can be regarded as a less critical problem since the surfactant does not enter the wet processing line.
No operational or processing difficulties were encountered with APEO-free auxiliaries.
The new washing formulations are reported to be applied in concentrations similar to the conventional ones.
AE are slightly less effective detergents than APEO, which means that higher concentrations and feed rates may be required.
c. Environmental benefit
This technique improves the treatability of the effluent and reduces the amount of potentially toxic endocrine disrupters in the receiving water.
d. Economic aspects
AE are 20–25 % more expensive than APEO. The fact that they appear to be less effective can further increase the operating costs over those of APEO.
e. Reference literature

4.4.3.2 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 also used 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 pretreatment operations and to the mixing of streams containing hypochlorite or chlorine. It is important to avoid mixing hypochlorite bleach wastewater with certain other streams and mixed effluents, in particular from desizing and washing, even when the right sequence of pretreatment and bleaching is adopted. The formation of organohalogens is possible in combined process streams. For chlorite 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. 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 a bleaching agent investment may be required in equipment resistant to the highly corrosive conditions in existing installations.

e. Reference literature

4.4.3.3 Ref. Datasheet 3.D.4: Selection of biodegradable/bioeliminable complexing agents in pretreatment 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 pretreatment processes (e.g. catalytic destruction of hydrogen peroxide) and 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 the fact that they form stable complexes with metals may lead to remobilisation of heavy metals, which 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. The enforcement of regulations at national and European level, together with the PARCOM recommendations and the eco-labelling schemes, are the main driving forces for the implementation of this technique.

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.

d. **Economic aspects**
There are not obvious differences in price but in some case higher quantities of complexing agents may be necessary.

e. **Reference literature**

4.4.3.4 **Ref. Datasheet 3.D.5: Selection of antifoaming agents with improved environmental performance**

a. **Description of the technique**
Antifoaming agents are usually applied in pre-treatment, dyeing (in particular when dyeing in jet machines) and finishing phases, but also in printing pastes. The heavy use of foaming causes irregular dyeing of yarn or fabric. Low foaming properties are very important in jet dyeing, where agitation is intense. The insolubility in water and a low surface tension are good characteristics for antifoaming products.

Decreasing the use of antifoam is possible by:
- using bath-less air-jets, where the liquor is not agitated by fabric rotation
- re-using treated baths

The use of defoamers is not avoided. Indeed they are not always applicable and, in any case, antifoaming cannot be completely avoided. Products free of mineral oils are better from an environmental point of view and are characterized by high bioelimination rates. Alternative products contain active ingredient such as silicones, phosphoric acid esters (esp. tributylphosphates), high molecular alcohols, fluorine derivatives, and mixtures of these components.

b. **Applicability, operational data and driving force for implementation**
There are no particular limitations to the use of this technique.
Silicone spots on the textile and silicone precipitates in the machinery are possible if antifoaming agents based on silicones are used.
The mineral oil-free defoamers can be used in a way similar to conventional products.
The amount of silicone products can be considerably reduced because of their effectiveness.
Minimisation of hydrocarbons in the effluent is the main driving force for substituting mineral oil containing antifoaming agents.
c. **Environmental benefit**

A minimum amount of hydrocarbon in the effluent, lower specific COD and higher bioelimination rate is obtained. Moreover a reduction of VOC emissions during high-temperature processes is provided.

**d. Economic aspects**

Cost of mineral oil-free products is comparable to conventional ones.

**e. Reference literature**


**4.4.3.5 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, heatsetting 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 naphthalene 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. Also water savings could be obtained.

d. **Economic aspects**
Optimised carriers described in this section cost approximately the same as traditional carriers.

e. **Reference literature**

### 4.4.3.6 Ref. Datasheet 3.D.11: Formaldehyde-free or formaldehyde-poor easy-care finishing agents

a. **Description of the technique**
Easy-care finishing agents are mainly compounds synthesised from urea, melamine, cyclic urea derivatives and formaldehyde and they are used on cellulosic fibres and their blends to increase the crease recovery and/or dimensional stability of the fabrics. Cross-linking agents (reactive groups) are composed of free or etherificated N-methylol groups.
Formaldehyde-based cross-linking agents may release free formaldehyde. Formaldehyde is carcinogenic and is a danger to both workers and for the final consumer. Low-formaldehyde or even formaldehyde-free products are a good alternative.

b. **Applicability, operational data and driving force for implementation**
In the carpet sector it is always possible to avoid formaldehyde emissions by using formaldehyde-free easy-care finishing agents, whereas in the textile sector this is not always possible.
The applications of products are similar to conventional ones. The quantity and quality of catalyst have to be controlled, as well as curing time and temperature. Request quantity of formaldehyde-free products is about twice as high as conventional products.
Off-gas regulations and accordance with various codes of conduct concerning consumer health are the main driving forces.

c. **Environmental benefit**
Reduction of emissions. Formaldehyde residues on the textiles can be minimized. Energy consumption can be reduced by using optimized catalysts. If directly-heated stenters are ineffective maintained, they may also emit formaldehyde in the exhaust air.

d. **Economic aspects**
Prices for formaldehyde-free products are significantly higher than conventional ones.
Chapter 4

e. Reference literature


a. Description of the technique
The negative effects determined by chemicals when used for finishing activities, can be reduced through the use of environment-friendly alternatives. Moreover other possibilities can be considered for the prevention and reduction of the use of chemicals in finishing activities, as for example:
- Alternative (fire-proof) fibres,
- Flamer barrier
- Nonwovens

Textile can be made fire-resistant through the following ways:
By carbonising the flammable product by adding organophosphorous compounds, at a particular fire temperature, P compounds from a layer of carbon that closes off the material from air (oxygen).
Organophosphorous (e.g. triphenylphosfate, tricresylphosphate, resorcinol bis, etc.) and chlorine compounds can be alternatives to the use of chemicals in finishing activities. The first ones make textiles fire resistant.
Chlorine compounds make textile fire retardants.
Fire retardants are distinguished based on their permanence in permanent fire retardants and in non-permanent fire retardants.
The following ones include:
- Chemically binding complex organophosphorous compounds to fibres by treating with an ammoniac or a melamine derivate.
- Mixing a flame retardant in melt spinning or in polymer granulates;
- Mixing fibres with polymers or co-polymers that are fire retardant;
- Treating wool with zirconium salts.

Examples of non-permanent fire retardants are:
- Aluminium hydroxide (a water soluble substance);
- Ammonium salts from phosphate, bromide, chloride, sulphonate,
- Boracid acid, borax.
- PFBS (perfluorobutane sulphonate) and PFHA (perfluorohexane acid) are alternatives for PFOS and PFOA

b. Applicability, operational data and driving force for implementation
One of the problems that could appear from the chemical substitution is that the substitutes can have different characteristics with respect to substituted chemicals. Moreover the use of alternatives can determine process-related changes and less efficiency. Organophosphorous compounds are used on the front side of textiles. In some cases they can be used also in the production of mattress textiles. PFOS and PFOA can be used on water-proof textile.
The prevention and reduction of the use of chemicals in finishing activities is the main driving force for the implementation.
c. **Environmental benefit**
   In some cases, alternatives substances do not have a positive impact on the environment, and have a negative impact on human health. In some cases pollution of wastewater is reduced.

d. **Economic aspects**
   In some cases, alternatives are more expensive due to the large quantities that are requested to obtain same properties of replaced chemicals.

e. **Reference literature**

---

4.4.3.8 **Ref. Datasheet 3.D.13: Dry mechanical softening using only solid balls (polyorganosiloxane) instead of wet chemical softening using water and chemical agents**

a. **Description of the technique**
   This operation consists in placing the garments (jeans) in a dry drum (a dryer for example) together with the solid balls (polyorganosiloxane) for about twenty minutes.

b. **Applicability, operational data and driving force for implementation**
   The duration of the operation is about 20 minutes, depending on the kind of fabric. The applicability of this technique requires only the use of balls. It is recommended that this technique be used only for dark colours. The disadvantage of this technique is the generation of noise.
   Some Tunisian companies use this technique.

c. **Environmental benefit**
   No use of water or chemicals. No production of wastewater.

d. **Economic aspects**
   Savings can derive from both process water purchase price, chemical purchase price (softener and acid) and effluent disposal costs.

e. **Reference literature**
   Audit carried out by CITET in the BAT4MED project in the Tunisian companies GTS and GTT (Tunis).

---

4.4.4 **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 wastewater 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.

4.4.5 Wastewater abatement techniques

4.4.5.1 Ref. Datasheet 4.A.1: Treatment of mixed wastewater 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 on the mixed effluent are effectuate the following steps:

- equalisation (about 20 h 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 improve and stabilised biodegradation efficiency which. 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 consists in adding alum sulphate and an anionic polyelectrolyte as flocculants (about 180 g/m³) and an organic cation flocculant 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. After 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 of as hazardous waste. The specific quantity is 5 g/m³ treated effluent. The limitation of ground water supply is the main driving force. Some Tunisian companies use this technique.

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 could be written off over time.

e. Reference literature

4.4.5.2 Ref. Datasheet 4.A.2: Recycling of textile wastewater 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 pre-treatment (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 allow 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.
The 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. Some Tunisian companies use this technique.

**c. Environmental benefit**

The main benefits are water saving and a reduction of wastewater discharge.

**d. Economic aspects**

The cost of 10 m³/h membrane equipment is about 1 million euro inclusive (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. The time for membrane treatment and recycling of rinsing water from dyeing is 8 months.

**e. Reference literature**


---

**4.4.5.3 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 wastewaters 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 and 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. Some Tunisian companies use this technique.
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 €/m$^3$; the variation depends on the different optimizations needed at each site.

e. **Reference literature**

PROWATER Life project results: http://www.tecnotex.it/prowater/.

---

4.4.5.4 **Ref. Datasheet 4.A.4: Water purification tertiary treatment using photo-oxidation**

a. **Description of the technique**

Application of photo-oxidation techniques for the removal of biodegradable and non-biodegradable organic compounds found in textile wastewaters 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 Fe$^{2+}$/H$_2$O$_2$ 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 physical-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 1m$^3$/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 1m$^3$/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 H$_2$O$_2$ as oxidant and Fe$^{2+}$ salts as catalyster, which are converted into Fe$^{3+}$ 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. Practicality in a large-scale plant should be still demonstrated.

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
Chapter 4

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 polluting load. Note that in order to separate iron as precipitate, a basic pH (≈ 8 u pH) is needed because on the contrary, output samples show colour, iron and high turbidity, which entails solids on suspension.

d. Economic aspects
Savings in water and chemical consumption.

e. Reference literature

4.4.5.5 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. 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 radicals 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.

This technique is not yet used in Tunisia.
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.

4.4.5.6 **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.

Some Tunisian companies use this technique.

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, and costs, are determined by discharge situation, wastewater load, and the volume to be treated.

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

4.4.5.7 Ref. Datasheet 4.A.7: Removal of disperse dyes from textile wastewater using bio-sludge

a. Description of the technique
Bio sludge of 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 by the study 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

4.4.6 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 process 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 defined as the biological wriggle bed (BWB), for the aeration was strengthened by increasing the ratio of aeration and wastewater influent. The second reactor defined as O3-BAF, for O3 was utilized to removal 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 gravity flowed 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. This technique is not yet used in Tunisia.

c. **Environmental benefit**
Decrease of COD and SO$_4^{2-}$ load and reduction of pH value in effluent water

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

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 (2011) 3748–3753.

4.4.6.1 **Ref. Datasheet 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**

a. **Description of the technique**
The present study 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 analysed.
The Reactive Orange 16 (RO16) and textile effluent was obtained from textile industry Solapur, India. 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. The bacterial consortium showed complete decolourization of RO16 dye (100 mg l⁻¹) within 48 h incubation at 30°C and pH 7 in static condition, even though under aerobic conditions azo dyes are generally resistant to attack by bacteria.

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 a 250-ml Erlenmeyer flask containing 100 ml of textile effluent (undiluted). The flasks were further incubated to observe the time required for 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 analysed using a UV–Vis spectrophotometer at 490 nm.

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 are achievable if compared with traditional methods.

e. Reference literature


a. Description of the technique
This technique regards the potential of the fungus Aspergillus niger and the alga Spirogyra sp. as biosorbent for the removal of Synazol reactive dye from multicomponent textile effluent. The reactive textile dye selected in this study, Synazol Red and Yellow, is extensively used in textile dying plants in Tenth of Ramadan City (Egypt).

b. Applicability, operational data and driving force for implementation
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 pretreated 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 analysed 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 per cent of dye removal varies with pH ranges. The maximum per cent of dye removal 42% and 36% for fungus and alga biomasses, respectively, was obtained at pH 3. Temperature also is important, the 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-1 for A. niger and Spirogyra sp., respectively. This technique is not yet used in Tunisia.

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

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

e. **Reference literature**

4.4.6.3 *Ref. Datasheet 4.A.15: Chemical coagulation/flocculation technologies for removal of colour from textile wastewaters*

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 is regarded as the most successful pretreatment.

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. This technique is very used in Tunisia.

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

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

e. **Reference literature**

### 4.4.6.4 Ref. Datasheet 4.A.16: Upflow anaerobic sludge blanket reactor in removal of colour and reduction of COD in real textile wastewater

a. **Description of the technique**
   The Upflow Anaerobic Sludge Blanket Reactor (UASB) is a single tank process. Wastewater enters the reactor from the bottom, and flows upward. A suspended sludge blanket filters and treats the wastewater as the wastewater flows through it. The sludge blanket consists of microbial granules, i.e. small agglomerations (0.5 to 2mm in diameter) of microorganisms that, because of their weight, resist being washed out in the upflow. The microorganisms in the sludge layer degrade organic compounds. As a result, gases (methane and carbon dioxide) are released. The rising bubbles mix the sludge without the assistance of any mechanical parts.

![Figure 9. UASB reactor](image)

This study evaluates the UASB 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 for the study. 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 in the study. 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**

Wijetunga Somasiri, Xiu-Fen Li, Wen-Quan Ruan, Chen Jian; Evaluation of the efficacy of upflow anaerobic sludge blanket reactor in removal of colour and reduction of COD in real textile wastewater; Bioresource Technology 99 (2008) 3692–3699.

**4.4.6.5 Ref. Datasheet 4.A.18: Electrochemical oxidation for the treatment of textile industry wastewater**

**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 0.15 m sides and 0.25 m high at laboratory scale in ambient conditions with 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**
No data are available.

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 lignocellulosic content, an effective solution to the problem may lie in the use of the material for the preparation of activated carbon using 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 dose 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**

4.4.7.1  **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 were investigated to represent 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. Two types of reactor configurations were used. The fixed bed reactor was made of plexiglas, three baffles were installed in the reactor. The reactor was filled with 6.0 kg of brown coal. The brown coal had a typical surface area of 300 m\(^2\)/g, approximate particle size of 1–1.5 mm, specific density of 1.093 g/cm\(^3\) and a porosity of 41\%. The surface area of the brown coal was less than the typical values for activated carbon, which are normally higher than 400 m\(^2\)/g. The depth of the bed for the fixed bed reactor was 20 cm with a slight expansion of 2 cm during operation. The overall usable volume of the reactor was 15.4 l. Air was introduced smoothly from the bottom of each compartment by circular sintered glass porous diffusers. The up-flow fluidized bed reactor had a diameter of 11 cm, height of 48 cm and a working volume of 3.3 l, was made of plexiglas and contained 0.5 kg of brown coal. The feed solution was supplied from the bottom by a peristaltic pump. Air was supplied through a sintered glass porous plate placed at the bottom.

Figure 10. Schematic illustration of the laboratory models: (a) fixed bed reactors, (b) fluidized bed reactor
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), having different configurations were set up and operated to treat various concentrations of dye-bath effluents. Brown coal char (lignite), as a low price material, was used in the reactors as packing medium. The fixed and fluidized bed reactor effluents for the 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**

Costs saving by using brown coal char as packing material

e. **Reference literature**


4.5 **General good management practices for textile sector**

4.5.1.1 **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 pipework (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
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 wastewater and off-gas. Workplace conditions can also be improved.

d. **Economic aspects**

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

e. **Reference literature**

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.1.1-.

---

4.5.1.2 **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.

d. **Economic aspects**

These measures have short time pay-backs.

e. **Reference literature**

4.5.1.3 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. Wastewater 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 applied 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 wastewater 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 230000 to EUR 310000. For powder dyes, the investment is between 250000 and 700000 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.

f. Reference literature

4.5.1.4 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. 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: 70/100 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): < 150 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 is needed.

e. **Reference literature**

### 4.5.1.5 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 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: 0.15 EUR/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
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 that 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 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.

4.6.1.3 Techniques for the reduction of entainment of organisms

Database references: technique CV4
The adaptation of water intake devices to lower the entainment of fish and other organisms is highly complex and site-specific. Changes to an existing water intake are possible but costly.

4.6.1.4 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.

4.6.1.5 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, ...
4.6.1.6 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 attenuation wall, application of low noise fans.

4.6.1.7 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 blowdown. 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 ENE5

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 and methane gas) to generate and transfer heat to a given process. 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** is 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 air 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. For every decrease of 20°C in flue-gas temperature, a 1% increase in efficiency can be achieved.
- **Recuperative and 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. Compared with cold air combustion systems, recuperators can be expected to achieve energy savings of around 30%. In the case of regenerative burners, fuel consumption can be reduced by up to 60%.
- **Reducing the mass flow of the flue-gases by reducing excess air**: excess air can be minimised by adjusting the air flowrate in proportion to the fuel flowrate. Depending on how fast the heat demand of the process fluctuates, excess air can be manually set or automatically controlled.
- **Burner regulation and 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. This achieves energy savings by reducing excess airflow and optimising fuel use to optimise burnout and to supply only the heat required for a process. It can be used to minimise NOx formation in the combustion process.
- **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. Some fuels produce less pollutants during combustion, depending on source (e.g. natural gas contains very little sulphur to oxidise to SOx, no metals). There is information on these emissions and benefits in various vertical sector BREFs where fuel choice is known to have a significant effect on emissions.
- **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. An increased oxygen content results in a rise in combustion temperature, increasing energy transfer to the process, which helps to reduce the amount of unburnt fuel, thereby increasing energy efficiency while reducing NO\textsubscript{x} emissions.

- **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 to 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.

### 4.6.2.3 Techniques to optimise the energy efficiency of Compressed air systems (CAS)

**Database references: technique ENE3**

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. The European motor classification scheme is applicable to motors < 100 kW and basically establishes three efficiency classes, giving motor manufacturers an incentive to introduce higher efficiency models:
  - EFF1 (high efficiency motors)
  - EFF2 (standard efficiency motors)
  - EFF3 (poor efficiency motors)
These efficiency levels apply to 2 and 4 pole three phase AC squirrel cage induction motors, rated for 400 V, 50 Hz, with S1 duty class, with an output of 1.1 to 90 kW, which account for the largest sales volume on the market. The figure below shows the energy efficiency of the three types of motors as a function of their output:
• **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;

Customized Energy Management Software is a general term and category referring to a variety of energy-related software applications which may provide utility bill tracking, real-time metering, building HVAC and lighting control systems, building simulation and modelling, carbon and sustainability reporting, IT equipment management, demand response, and/or energy audits. Managing energy can require a system of systems approach.

Energy management software often provides tools for reducing energy costs and consumption for buildings or communities. This customized software collects energy data and uses it for three main purposes: Reporting, Monitoring and Engagement. Reporting may include verification of energy data, benchmarking, and setting high-level energy use reduction targets. Monitoring may include trend analysis and tracking energy consumption to identify cost-saving opportunities. Engagement can mean real-time responses (automated or manual), or the initiation of a dialogue between occupants and building managers to promote energy conservation. One engagement method that has recently gained popularity is the real-time energy consumption display available in web applications or an onsite energy dashboard/display.

Various software calculators have been developed. They can be useful in assisting with calculations, but they have some disadvantages which must be taken into account if they are used:

- They are often based on changing individual pieces of equipment, e.g. motors, pumps, lights, without considering the whole system in which the
equipment works. This can lead to a failure to gain the maximum energy efficiencies for the system and the installation.

- Some are produced by independent sources, such as government agencies, but some are commercial and may not be wholly independent.

Examples of calculating tools can be found in Section 2.17 and in sites such as:
- http://www.martindalecenter.com/Calculators1A_4_Util.html

Calculation methods and software: also known as energy models. These are core component of energy audit schemes, and are associated with analytical energy audit models. Their primary objective is to help the auditor in the quantitative assessment of energy savings potentials and evaluation of investment costs and paybacks. The use (by an auditor) of a recommended or certified calculation tool (provided it is used correctly) assists with achieving quality results for the audited client.

- **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, thermoeconomics, energy models, 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

Database references: technique ENE9

A typical HVAC system comprises the heating 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**: energy savings can be achieved e.g. by reducing the heating needs or improving the efficiency of the system (through recovery of waste heat, heat pumps...);
- **Ventilation**: optimisation of design of a new or upgraded ventilation system is important, but also improving an existing system within an installation;

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 percent 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 flowrate. The choice also depends on the system, the liquid, the characteristic of the atmosphere etc.
- **Pipework system**: the pipework 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.
4.6.3 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, 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 fighting 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 dangerous 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 a shell rupture or a large overfill. 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 pipework 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 pipework.

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 are 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.

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 walled 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.

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 are 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.

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 35 the available environmentally friendly techniques of chapter 4 are tested on 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 wastewater 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 ‘BAT’, but with a clear description of the specified conditions.

It should pointed out that using a BREF approach, techniques with a limited technical applicability, can be considered “emerging techniques”.
### Important remarks for using Table 35:

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 companies’ specific circumstances should always be taken into account.
Table 35. 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 Management and good housekeeping</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>G2 Input/output streams evaluation/inventory</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>G3 Automated preparation and dispensing of chemicals</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>G4 Optimising water consumption in textile operations</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>G5 Insulation of High Temperature (HT) machines</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
</tbody>
</table>

\textsuperscript{10} Investment in new equipment and/or structural modifications are needed. Economic savings depend on the cost price of fresh water. If the owner has to pay high water costs, the technique can be considered economically viable. If the water doesn’t cost so much, the economic savings don’t balance out the investments. In Tunisia both situations are possible depending on the location of the installation.

\textsuperscript{11} Restriction: This technique is BAT with some economic limitations.
Resources efficiency measures

Efficient use of chemicals and raw materials

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.4</td>
<td>Omitting the use of detergents in after washing of cotton dyed with reactive dyes</td>
<td>+</td>
<td>-/+12</td>
</tr>
<tr>
<td>2.A.3</td>
<td>Minimizing consumption of complexing agents in hydrogen peroxide bleaching</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>2.A.5</td>
<td>Alternative process for continuous (and semicontinuous) dyeing of cellulosic fabric with functional reactive dyes</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

12 Only for pale shades.
13 Economic savings are linked to the reduction of chemicals consumption and wastewater treatment.
14 Restriction: this technique is a BAT only for pale shades.
### Chapter 5

#### Technique Technical viability

<table>
<thead>
<tr>
<th>Technique</th>
<th>Technical viability</th>
<th>Environmental benefit</th>
<th>Economic viability</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.A.6</td>
<td>Proven</td>
<td>Applicability</td>
<td>Safety and working conditions</td>
</tr>
<tr>
<td><strong>Avoiding batch softening:</strong> application of softeners by pad mangles or by spraying and foaming application systems</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>
## Resources efficiency measures

### Efficient use of water

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.B.1 Minimization of dye liquor losses in pad dyeing techniques</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>2.B.2 Aftertreatment in PES dyeing</td>
<td>+</td>
<td>-/+</td>
<td>+</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>+</td>
<td>-/+</td>
<td>+</td>
</tr>
<tr>
<td>2.B.6 Increasing washing efficiency and water flow control</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
</tbody>
</table>

15. For blends with elastane fibres the applicability is limited.
16. Restriction: the technical applicability of this BAT is limited with elastane fibres.
17. The technique cannot be used for dyeing linen fabric because the linen lint causes scaling of the machine.
18. Restriction: this technique is a BAT with limited technical applicability.
### Technique Technical viability | Environmental benefit | Economic viability  
---|---|---
| Proven | Applicability | Safety and working conditions | Quality | Global | Water use | Wastewater | Energy | Waste/by-products | Air and odour | Soil and ground water | Noise and vibrations | Raw/auxiliary materials | Global | Cost feasibility and cost effectiveness | BAT?  
| **2.8.7** Re-use rinse water from process baths in the production process | + | -/+ | + | 0 | -/+ | + | + | 0 | 0 | 0 | 0 | 0 | + | + | - | Yes |  
| **2.8.8** Dry bleaching using ozone instead of wet washing using chlorine or hydrogen peroxide | + | + | 0 | 0 | + | + | + | 0 | 0 | 0 | 0 | 0 | + | + | 0 | Yes  

---

19 In Tunisia this technique can be considered not applicable for dyeing processes for quality reasons.

20 Restriction: this technique is a BAT with a limited technical applicability.
Resources efficiency measures

Resources recovery 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>2.C.1 Recovery of sizing agents by ultra-filtration</td>
<td>+</td>
<td>+/-</td>
<td>0</td>
</tr>
<tr>
<td>2.C.2 Recovery of alkali from mercerizing</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>2.C.5 Recovery of printing paste from supply system in rotary screen printing machines and Recycling of residual printing pastes</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
</tbody>
</table>
### Chapter 5

#### Technological Viability

<table>
<thead>
<tr>
<th>Technique</th>
<th>Technical viability</th>
<th>Environmental benefit</th>
<th>Economic viability</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.C.6 Direct re-use of dye baths and auto-control of the process online</td>
<td>Proven</td>
<td>Water use</td>
<td>Low risk</td>
</tr>
</tbody>
</table>

#### Resources Efficiency Measures

**Integrated process 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>2.C.6 Direct re-use of dye baths and auto-control of the process online</td>
<td>Proven</td>
<td>Water use</td>
<td>Low risk</td>
</tr>
</tbody>
</table>

---

24 The RAMAN spectroscopy unit used and other similar ones available on the market are quite expensive. The technique is therefore not considered economically viable. Furthermore, in Tunisia the technique is not widely used for cotton fibres.
### Equipment optimisation in batch dyeing

<table>
<thead>
<tr>
<th>Technique</th>
<th>Technical viability</th>
<th>Environmental benefit</th>
<th>Economic viability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw/auxiliary materials</td>
<td></td>
<td></td>
<td>Cost feasibility and cost effectiveness</td>
</tr>
<tr>
<td>Global</td>
<td></td>
<td></td>
<td>BAT?</td>
</tr>
<tr>
<td>Energy</td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Noise and vibrations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil and ground water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wastewater</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waste/by-products</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air and odour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water use</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety and working conditions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applicability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proven</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For **Equipment optimisation in batch dyeing**, the technical viability includes: Proven (+), Applicability (+), Safety and working conditions (+), Quality (+), Global (+), Water use (+), Wastewater (+), Energy (+), Waste/by-products (0), Air and odour (0), Soil and ground water (0), Noise and vibrations (+), Raw/auxiliary materials (+), Global (+), Cost feasibility and cost effectiveness (0). The economic viability is Yes.
### Selection/substitution of chemicals with others more environmentally friendly

#### Use of enzymatic treatment/enzymes in processes

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>3.B.1</td>
<td>+/-25+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<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>
<td>Proven</td>
<td>Applicability</td>
<td>Safety and working conditions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

25 The technique is only applicable to exhaust dyeing with reactive dyestuffs.

26 Restriction: this technique is a BAT only if applied to exhaust dyeing with reactive dyestuffs.
Selection/substitution of chemicals with others more environmentally friendly

**Less pollutant dyes**

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>3.C.1</td>
<td>Dispersing agents with higher bioeliminability in dye formulations</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>3.C.2</td>
<td>Dyeing with sulphur dyes</td>
<td>+</td>
<td>-/+28</td>
</tr>
<tr>
<td>3.C.3</td>
<td>Emission reduction in dyeing wool with metal-complex dyestuffs</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>3.C.4</td>
<td>Silicate-free fixation method for cold pad batch dyeing</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

---

27 Dispersing agents with higher bio-eliminability in dye formulations are more expensive than conventional one.

28 This technique is applicable for dyeing dark shades only.

29 Water is of a better quality, but the quantity to be treated is larger.

30 According to the TWG members, in Tunisia, this technique is more expensive than the conventional one usually used, especially for dyeing light colours.

31 Restriction: this technique is a BAT with technical applicability limitations.
## Chapter 5

### Technique Technical viability | Environmental benefit | Economic viability
--- | --- | ---

<table>
<thead>
<tr>
<th>Technique</th>
<th>Technical viability</th>
<th>Environmental benefit</th>
<th>Economic viability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proven</td>
<td>Applicability</td>
<td>Safety and working conditions</td>
<td>Quality</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>
<tr>
<td>3.C.6 Exhaust dyeing with low-salt reactive dyes</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>3.C.7 Dyeing without water and chemicals</td>
<td>+</td>
<td>-/+</td>
<td>0</td>
</tr>
</tbody>
</table>

---

32. This technique requires investments.
33. The economic viability depends on specific circumstances such as the market prices of low-salt dyes. In any case low-salt reactive dyes are usually significantly more expensive than conventional reactive dyes and it could cause a negative economic viability.
34. Restriction: this technique is a BAT with economic limitations.
35. This technique is applicable for synthetic fibres only.
36. According to TWG members, in Tunisia, this technique is economically viable if the installation uses tap water. Economic savings depend on the price of fresh water. If the owner has to pay high water costs, the technique is considered economically viable. If the water doesn’t cost so much, the economic savings don’t balance out the investments. In Tunisia both situations are possible depending on the location of the installation.
37. Restrictions: this technique is a BAT for synthetic fibres only. Moreover the technique has economic limitations.


Selection/substitution of chemicals with others more environmentally friendly

**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>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proven</td>
<td>Applicability</td>
<td>Safety and working conditions</td>
</tr>
<tr>
<td>3.D.2</td>
<td>Substitution for alkylphenol ethoxylates (and other hazardous surfactants)</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>3.D.3</td>
<td>Substitution for sodium hypochlorite and chlorine-containing compounds in bleaching operations</td>
<td>+</td>
<td>+</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>
</tr>
</tbody>
</table>

---

38 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.
### 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>Applicability</td>
<td>Safety and working conditions</td>
</tr>
<tr>
<td><strong>Selection of antifoaming agents with improved environmental performance</strong></td>
<td>+ + + + + 0 + 0 0 + 0 0 + + 0</td>
<td>3.D.5</td>
<td>3.D.7</td>
</tr>
<tr>
<td><strong>Exhaust dyeing of polyester and polyester blends with carrier-free dyeing techniques or with use of environmentally optimised carriers</strong></td>
<td>+ + 39 + 0 + + + + 0 0 0 + +</td>
<td>3.D.7</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Formaldehyde-free or formaldehyde-poor easy-care finishing agents</strong></td>
<td>+ +/- 41 + + +/- 0 0 + 0 + 0 0 + + -</td>
<td>3.D.11</td>
<td></td>
</tr>
<tr>
<td><strong>Use environment-friendly alternative chemicals for finishing activities</strong></td>
<td>+ + + +/- 43 +/- + - 0 + 0 0 0 0 0 + + -</td>
<td>3.D.12</td>
<td></td>
</tr>
<tr>
<td>Technique</td>
<td>Technical viability</td>
<td>Environmental benefit</td>
<td>Economic viability</td>
</tr>
<tr>
<td>-----------</td>
<td>---------------------</td>
<td>-----------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>3.D.13</td>
<td>Dry mechanical softening using only solid balls (polyorganosiloxane) instead of wet chemical softening using water and chemical agents</td>
<td>+/- 45</td>
<td>+</td>
</tr>
</tbody>
</table>

45 This innovative softening technique is not applicable if the customer needs a specific touch-feel of the fabric that can’t be achieved by using solid balls.

46 Restriction: this technique is a BAT with some technical applicability limitations.
End of pipe techniques

Wastewater abatement techniques

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>4.A.1</td>
<td>Treatment of mixed wastewater with about 60 % water recycling.</td>
<td>+  +  0  0  +</td>
<td>+  +  0  0  0  0  0  0  0  0  +</td>
</tr>
<tr>
<td>4.A.2</td>
<td>Recycling of textile wastewater by treatment of selected streams with membrane techniques.</td>
<td>+  +  0  0  +</td>
<td>+  +  0  0  0  0  0  0  0  0  +</td>
</tr>
<tr>
<td>4.A.3</td>
<td>Application of physical-chemical processes and cross-flow filtration</td>
<td>+  +  0  0  +</td>
<td>+  +  0  0  0  0  0  0  0  0  +</td>
</tr>
<tr>
<td>4.A.4</td>
<td>Water purification tertiary treatment using photo-oxidation</td>
<td>+/-  47</td>
<td>+  0  0  +/-</td>
</tr>
</tbody>
</table>

47 This technique has only been proven on a semi-industrial scale.
48 Restriction: this technique is a BAT with technical limitations.
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>Applicability</td>
<td>Safety and working conditions</td>
</tr>
<tr>
<td>4.A.5 Purification of Industrial And Mixed Wastewater By Combined Membrane Filtration And Sonochemical Technologies</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>4.A.6 Appropriately treat industrial wastewater by implementing a combination of suitable waste purification techniques</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
</tbody>
</table>

49 The technique has not yet been proven on a full industrial scale (only on pilot scale).
50 The required wastewater treatment technique(s) need to be determined on a plant level, depending on the specific situation e.g. discharge to surface water or sewer, quality of the receiving surface water, contamination of the wastewater, etc.
51 The effect on water use is positive when the treated water is reused as process water.
52 Some of the water treatment techniques require additional energy.
53 Some of the water treatment techniques create a residue (sludge) during the treatment process.
54 When the water treatment system doesn’t function optimally, odour might become a problem.
55 Some of the water treatment techniques require the use of chemicals, e.g. physicochemical removal of phosphorous.
56 Wastewater treatment will always require an additional cost, but this cost is highly depending on the type, design and size of the system.
57 Overall, one can say that there will always be a treatment system suitable for each situation: whether it’s a fully equipped primary + secondary + tertiary treatment system for large companies (e.g. companies with more than 250 employees) discharging their wastewater to surface water, or a simple primary treatment for small companies (e.g. companies up to 50 employees) discharging to the sewer.
58 Restriction: this technique is a BAT with cost limitations.
<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>4.A.7</td>
<td>Removal of disperse dyes from textile wastewater using biosludge</td>
<td>-59</td>
<td>-</td>
</tr>
<tr>
<td>4.A.11</td>
<td>Textiles wastewater treatment using anoxic filter bed and biological wriggle bed-ozone biological aerated filter</td>
<td>-60</td>
<td>-</td>
</tr>
<tr>
<td>4.A.12</td>
<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>-61</td>
<td>-62</td>
</tr>
</tbody>
</table>

59 The technique is not proven use on an industrial scale (only on a research scale).
60 The technique has not yet been proven on an industrial scale (only on pilot scale).
61 The technique is not proven use on an industrial scale (only on research scale).
62 The technique described can be applied to new and existing installations, but it has not yet been tested on an industrial scale.
63 According to TWG members, in Tunisia this technique is viable and applicable.
<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>4.A.13</td>
<td><strong>Biosorption of reactive dye from textile wastewater by non-viable biomass of Aspergillus niger and Spirogyra sp</strong></td>
<td>-64</td>
<td>+</td>
</tr>
<tr>
<td>4.A.15</td>
<td><strong>Chemical coagulation/flocculation technologies for removal of colour from textile wastewaters</strong></td>
<td>+</td>
<td>+ 0 0 +</td>
</tr>
<tr>
<td>4.A.16</td>
<td><strong>Upflow anaerobic sludge blanket reactor in removal of colour and reduction of COD in real textile wastewater</strong></td>
<td>- +/-</td>
<td>0 0 -</td>
</tr>
<tr>
<td>4.A.18</td>
<td><strong>Electrochemical oxidation for the treatment of textile industry wastewater</strong></td>
<td>- -66</td>
<td>- 0 0 -</td>
</tr>
</tbody>
</table>

64 The technique has not yet been proven on an industrial scale (only on pilot scale).
65 The described technique can be applied to new and existing installations.
66 The technique has not yet been proven on an industrial scale (only on pilot scale).
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”.

67 This technique can be applied when waste materials from coir industries are available.
68 The technique has not yet been proven on an industrial scale (only on pilot scale).
5.2 BAT conclusions

Based on Table 35, 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)
- Insulation of High Temperature (HT) machines (G5)

One technique is identified as BAT, but only under certain conditions:

- Optimising water consumption in textile operations (G4)

  This technique is a BAT if it is economically viable for the company/installation concerned.

  The economic viability can only be determined at company/installation level.

5.2.2 Resource efficiency measures

5.2.2.1 Efficient use of chemicals and raw materials

BAT for efficient use of chemicals and raw materials is to implement one or a combination of the following techniques:
• Minimizing consumption of complexing agents in hydrogen peroxide bleaching (2.A.3)
• Alternative process for continuous (and semicontinuous) dyeing of cellulosic fabric with functional reactive dyes (2.A.5)
• Avoiding batch softening: application of softeners by pad mangles or by spraying and foaming application systems (2.A.6)

One technique is identified as BAT, but only under certain conditions:
• Omitting the use of detergents in after washing of cotton dyed with reactive dyes (2.A.4)
  This technique is a BAT for pale shades only.

5.2.2.2 Efficient use of water

BAT for efficient use of water is to implement one or a combination of the following techniques:
• Minimization of dye liquor losses in pad dyeing techniques (2.B.1)
• Increasing washing efficiency and water flow control (2.B.6)
• Dry bleaching using ozone instead of wet washing using chlorine or hydrogen peroxide (2.B.8)

Three techniques are identified as BAT, but only under certain conditions:

• Aftertreatment in PES dyeing (2.B.2)
  For blends with elastane fibres, the applicability is limited.
• 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 (2.B.3)
  This technique is not a BAT for dyeing linen fabric.
• Re-use rinse water from process baths in the production process (2.B.7).
  This technique is not a BAT for dyeing processes, due to quality reasons.

5.2.2.3 Resources recovery measures

A BAT for resources recovery measures is to implement one or a combination of the following techniques:
Recovery of alkali from mercerizing (2.C.2)
• Recovery of printing paste from supply system in rotary screen printing machines and recycling of leftover printing pastes (2.C.5)

One technique is identified as BAT, but only under certain conditions:
• Recovery of sizing agents by ultra-filtration (2.C.1)
  The technique is a BAT, if applicable.
  There are some limitations in the application of this technique. These limitations can depend for example on 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.
5.2.2.4 Integrated process measures

The following technique for integrated process measures is BAT:

- Equipment optimisation in batch dyeing (2.D.4)

5.2.3 Selection/substitution of chemicals with others more environmentally friendly

5.2.3.1 Use of enzymatic treatment/enzymes in processes

One technique is identified as BAT, but only 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.

5.2.3.2 Less pollutant dyes

A 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)
- Emission reduction in dyeing wool with metal-complex dyestuffs (3.C.3)
- 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)

Three techniques are identified as BAT, but only under certain circumstances:

- Dyeing with sulphur dyes (3.C.2)
  This technique is a BAT for dyeing into dark shades.
- Exhaust dyeing with low-salt reactive dyes (3.C.6)
  This technique is a BAT if it is economically viable.
- Dyeing without water and chemicals (3.C.7)
  This technique is applicable for synthetic fibres only. Moreover, this technique is a BAT if it is economically viable.

5.2.3.3 Other measures

The BAT for other measures is to implement one or a combination of the following techniques:

- Substitution for alkylphenol ethoxylates (and other hazardous surfactants) (3.D.2)
- Substitution for sodium hypochlorite and chlorine-containing compounds in bleaching operations (3.D.3)
- Selection of biodegradable/bioeliminable complexing agents in pretreatment and dyeing processes (3.D.4)
- Selection of antifoaming agents with improved environmental performance (3.D.5)
- Exhaust dyeing of polyester and polyester blends with carrier-free dyeing techniques or with use of environmentally optimised carriers (3.D.7)
Three techniques are identified as BAT, but only under certain conditions:

- **Formaldehyde-free or formaldehyde-poor easy-care finishing agents (3.D.11)**
  The technique is a BAT, if applicable: in the carpet sector it is always possible to avoid formaldehyde emissions by using formaldehyde-free easy-care finishing agents, whereas in the textile sector this is not always possible.

- **Use environment-friendly alternative chemicals for finishing activities (3.D.12)**
  The technique is a BAT if it doesn’t have negative effects on the quality of the product: sometimes alternative chemicals could have positive or negative impact on the quality of products.

- **Dry mechanical softening using only solid balls (polyorganosiloxane) instead of wet chemical softening using water and chemical agents (3.D.13).**
  This technique is a BAT if the customer does not need specific touch-feel of the fabric that can’t be achieved by using solid balls.

### 5.2.4 End of pipe techniques

#### 5.2.4.1 Wastewater abatement techniques

BAT for wastewater abatement is to implement one or a combination of the following techniques:

- **Treatment of mixed wastewater with about 60% water recycling (4.A.1)**
- **Recycling of textile wastewater by treatment of selected streams with membrane techniques (4.A.2)**
- **Application of physico-chemical processes and cross-flow filtration (4.A.3)**
- **Chemical coagulation/flocculation technologies for removal of colour from textile wastewater (4.A.15).**

The following techniques are identified as BAT, but only under certain conditions:

- **Water purification tertiary treatment using photo-oxidation (4.A.4)**
  This technique is a conditional BAT, since it has been proven on a semi-industrial scale.

- ** Appropriately treat industrial wastewater by implementing a combination of suitable waste purification techniques (4.A.6)**
  This technique is a BAT if it is economically viable.

Overall, one can say that there will always be a treatment system suitable for each situation: whether it’s a fully equipped primary + secondary + tertiary treatment system for large companies discharging their wastewater in surface water, or a simple primary treatment for small companies discharging in the sewer.
CHAPTER 6 RECOMMENDATIONS

In this chapter a number of general conclusions related to the BAT conclusions are formulated. Also, experiences 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 of 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 based on BAT conclusions

In this chapter the main priorities related to this BAT Report of Textile industry are highlighted. Conclusions aimed to point out how this report can be used by both industrial companies and policy makers.

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 Tunisia. 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:

- 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 Tunisia there is an urgent need for upgrading, development and modernization 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 Tunisian policy institutions to further develop their environmental legislation. In many countries of the south coast of the Mediterranean basin, we can observe an evolution of the environmental
legislation that follows the main important European Directives. Despite this we cannot identify in any of the Arab Countries a legislation inspired by the principles of the 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.

6.1.1 Lack of driving forces for environmentally friendly techniques and measures

Analysing the traditional drivers for eco-innovation, we can point out the Tunisian 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 regulation, market requests, cost of the environmental resources, economic incentives.

*Environmental legislation* can be considered one of the most important drivers for Eco-innovation. Low Emission Limit Values stimulate companies to adopt cleaner technologies to comply with those requirements. In Tunisia, the regulatory and legislative framework does not require companies to consider or to adopt the BAT, whether at the level of the environmental impact studies, decontamination studies or in the classification of unhealthy institutions. These laws impose limit to the emissions and they are still oriented to promote the implementation of end-of-pipe techniques instead of the application of preventive measures. In addition for some environmental aspects (e.g. groundwater use) the legislation doesn’t foresee limits.

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 which has restrictions in regard to environmental aspects and Tunisian textile companies are obliged to apply European standards to products and processes such as: reach, oeko-tex and special customers specifications. On another hand, the pressure of the *market* on textile companies doesn’t represent yet a driver to improve the environmental performance of textile processes for companies that work for the local market. These companies product low quality products and sold at low prices. The local consumer behaviour is not still oriented to select the products with 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 Tunisian 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 Tunisia the costs for some resources are still too low to represent a driver to implement more environmentally friendly techniques. An example is the cost of water and (also the cost of energy is relatively low). The textile industry uses a huge
amount of water. As described in the chapter 4, there are many techniques aiming at
the reduction of water use. Despite this the low cost of water in Tunisia could
represent an obstacle to adopting these techniques. Another example that can be
given is the traditional process that use pollutant chemicals (e.g. sodium hypochlorite).
Several techniques aim to substitute this product with others more environmentally
friendly but the low cost of that chemical impedes the adoption of substitutes.

Finally, in Tunisia there are still no concrete public incentives to promote the adoption
of BAT. However, some funding mechanisms may contribute partially and in their fields
of intervention to encourage companies to adopt clean technologies.
These mechanisms include mainly:
- the Decontamination Fund (FODEP), managed by the National Environment
  Protection Agency, which encourages the adoption of clean and non-polluting
  technologies, at the limits of the investment directly related to the protection
  of the environment (water saving, reduction of pollution, ...). The FODEP
  consists of a subsidy of 20% and an enhanced credit of up to 50% of the cost of
  the eligible investment;
- the National Fund for Energy Conservation (FNME), managed by the National
  Agency for Energy Conservation (ANME), which particularly encourages energy
  efficiency projects.

Other actions can benefit from the advantages granted as part of the industrial
upgrade of enterprises (FODEC).

Policymakers could improve this aspect by granting, for example, tax reductions or
subsidies to companies adopting cleaner production measures.

6.2 Limitations to the BAT evaluation and report.

The 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).
The lack of quantitative data prevented us to perform a quantitative analysis of the
environmental performance and the 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 Tunisian textile industry.

**Value of the report to TWG members**

The Tunisian TWG Members consider the report clear. According to Tunisian TWG Members the report can be used by all parties concerned to increase their knowledge and seek practical references.

This report will certainly be useful to new studies on impacts on the environment and represents a valuable tool to guide companies in the sector to adopt the BAT.

The report is a tool for experts in the field of the environment which will allow them to support companies in the actions of pollution prevention and reduction.

Taking into account that several companies adopt new technologies without knowing the concept of BAT, this report will certainly be useful for them to identify these techniques and eventually to choose the available financing mechanisms.

In addition this report will be useful during the revision of the emission limit values of pollutants and can be a criterion of choice for these limits.

Company representatives, but also other parties (like permit writers and legislators) can use this report as a reference document on the textile industry and its BAT.
MAIN REFERENCES


Main references


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.dyeeco.com/

http://www.tecnotex.it/prowater/

# List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABS</td>
<td>Acrylonitrile Butadiene Styrene</td>
</tr>
<tr>
<td>AE</td>
<td>Alcohol Ethoxylates</td>
</tr>
<tr>
<td>AFB</td>
<td>Anaerobic Filter Bed</td>
</tr>
<tr>
<td>Ag</td>
<td>Silver</td>
</tr>
<tr>
<td>Al</td>
<td>Aluminium</td>
</tr>
<tr>
<td>ANME</td>
<td>National Agency for Energy Conservation</td>
</tr>
<tr>
<td>APII</td>
<td>Agency for Promotion of Industry and Innovation</td>
</tr>
<tr>
<td>APEO</td>
<td>Alkylphenol ethoxylates</td>
</tr>
<tr>
<td>As</td>
<td>Arsenic</td>
</tr>
<tr>
<td>ASP</td>
<td>Activated Sludge Process</td>
</tr>
<tr>
<td>AOX</td>
<td>Absorbable organo-halogen</td>
</tr>
<tr>
<td>BAF</td>
<td>Biological Aerated Filter</td>
</tr>
<tr>
<td>BAT</td>
<td>Best Available Technique</td>
</tr>
<tr>
<td>BAT4MED</td>
<td>Boosting Best Available Techniques in the Mediterranean Partner Countries</td>
</tr>
<tr>
<td>BREF</td>
<td>BAT reference documents</td>
</tr>
<tr>
<td>BWB</td>
<td>Biological Wriggle Bed</td>
</tr>
<tr>
<td>CAS</td>
<td>Compressed Air Systems</td>
</tr>
<tr>
<td>CFD</td>
<td>Computational Fluid Dynamics</td>
</tr>
<tr>
<td>CITET</td>
<td>Centre International des Technologies de l’Environnement de Tunis</td>
</tr>
<tr>
<td>Cd</td>
<td>Cadmium</td>
</tr>
<tr>
<td>CETTEX</td>
<td>Technical Centre for Textiles</td>
</tr>
<tr>
<td>CMC/CMA</td>
<td>Carboxymethyl cellulose</td>
</tr>
<tr>
<td>Cn</td>
<td>Cyanide</td>
</tr>
<tr>
<td>Co</td>
<td>Cobalt</td>
</tr>
<tr>
<td>CO</td>
<td>Carbon monoxide</td>
</tr>
<tr>
<td>CO₂</td>
<td>Carbon dioxide</td>
</tr>
<tr>
<td>COD</td>
<td>Chemical Oxygen Demand</td>
</tr>
<tr>
<td>CPC</td>
<td>Coir Pith Activated Carbon</td>
</tr>
<tr>
<td>Cr</td>
<td>Chromium</td>
</tr>
<tr>
<td>Cr (VI)</td>
<td>Hexavalent chromium</td>
</tr>
<tr>
<td>Cu</td>
<td>Copper</td>
</tr>
<tr>
<td>DT</td>
<td>Tunisian Dinar</td>
</tr>
<tr>
<td>EBP</td>
<td>Environmental Benefit Potential</td>
</tr>
<tr>
<td>EDTA, DTPA, and NTA</td>
<td>Amino Carboxylic Acids</td>
</tr>
<tr>
<td>EED</td>
<td>Energy Efficient Design</td>
</tr>
<tr>
<td>ERFT</td>
<td>External Floating Roof Tanks</td>
</tr>
<tr>
<td>EIA</td>
<td>Environmental Impact Assessment</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>ENEMS</td>
<td>Energy Efficiency Management System</td>
</tr>
<tr>
<td>ETS</td>
<td>Emission Trading System</td>
</tr>
<tr>
<td>EU</td>
<td>Europe/European</td>
</tr>
<tr>
<td>F</td>
<td>Fluorine</td>
</tr>
<tr>
<td>Fe</td>
<td>Iron</td>
</tr>
<tr>
<td>FNME</td>
<td>National Fund for Energy Conservation</td>
</tr>
<tr>
<td>FRT</td>
<td>Fixed Roof Tanks</td>
</tr>
<tr>
<td>HBr</td>
<td>Hydrogen bromide</td>
</tr>
<tr>
<td>H2SO4</td>
<td>Sulphuric acid</td>
</tr>
<tr>
<td>HCl</td>
<td>Hydrochloric acid</td>
</tr>
<tr>
<td>HCN</td>
<td>Hydrogen cyanide</td>
</tr>
<tr>
<td>HF</td>
<td>Hydrofluoric acid</td>
</tr>
<tr>
<td>Hg</td>
<td>Mercury</td>
</tr>
<tr>
<td>HS</td>
<td>Hazards Study</td>
</tr>
<tr>
<td>IED</td>
<td>Industrial Emissions Directive</td>
</tr>
<tr>
<td>IPPCD</td>
<td>Directive on Industrial Pollution Prevention and Control</td>
</tr>
<tr>
<td>K</td>
<td>Potassium</td>
</tr>
<tr>
<td>MAPP</td>
<td>Major Accident Prevention Policy</td>
</tr>
<tr>
<td>Mn</td>
<td>Manganese</td>
</tr>
<tr>
<td>MPC</td>
<td>Mediterranean Partner Country</td>
</tr>
<tr>
<td>Na</td>
<td>Sodium</td>
</tr>
<tr>
<td>NaCl</td>
<td>Sodium chloride</td>
</tr>
<tr>
<td>NaHCO3</td>
<td>Sodium bicarbonate</td>
</tr>
<tr>
<td>NaOH</td>
<td>Sodium hydroxide</td>
</tr>
<tr>
<td>Na2S</td>
<td>Sodium sulfide</td>
</tr>
<tr>
<td>NH3</td>
<td>Ammonia</td>
</tr>
<tr>
<td>Ni</td>
<td>Nickel</td>
</tr>
<tr>
<td>NO2</td>
<td>Nitrogen dioxide</td>
</tr>
<tr>
<td>NOX</td>
<td>Nitrogen Oxide</td>
</tr>
<tr>
<td>P</td>
<td>Phosphorus</td>
</tr>
<tr>
<td>PAH</td>
<td>Polycyclic aromatic hydrocarbons</td>
</tr>
<tr>
<td>Pb</td>
<td>Lead</td>
</tr>
<tr>
<td>PAH</td>
<td>Hydrocarbons Aromatic Polycyclic</td>
</tr>
<tr>
<td>PES</td>
<td>Polyester</td>
</tr>
<tr>
<td>PFBS</td>
<td>Perfluorobutane Sulphonate</td>
</tr>
<tr>
<td>PFHA</td>
<td>Perfluorohexane acid</td>
</tr>
<tr>
<td>PVA</td>
<td>Polyvinyl Alcohol</td>
</tr>
<tr>
<td>PVRVs</td>
<td>Pressure/Vacuum relief vents</td>
</tr>
<tr>
<td>RRM</td>
<td>Risk and Reliability Based Maintenance</td>
</tr>
<tr>
<td>Sb</td>
<td>Antimony</td>
</tr>
<tr>
<td>Se</td>
<td>Selenium</td>
</tr>
<tr>
<td>Sn</td>
<td>Tin</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>SMEs</td>
<td>Small and medium enterprises</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>Sulphur dioxide</td>
</tr>
<tr>
<td>SS</td>
<td>Suspended solid</td>
</tr>
<tr>
<td>SSSUP</td>
<td>Scuola Superiore di Studi Universitari e di Perfezionamento Sant’Anna</td>
</tr>
<tr>
<td>TDS</td>
<td>Total Dissolved Solids</td>
</tr>
<tr>
<td>Te</td>
<td>Tellurium</td>
</tr>
<tr>
<td>Ti</td>
<td>Thallium</td>
</tr>
<tr>
<td>TH</td>
<td>Thorium</td>
</tr>
<tr>
<td>TKN</td>
<td>Total Kjeldahl Nitrogen</td>
</tr>
<tr>
<td>TSS</td>
<td>Total Suspended Solids</td>
</tr>
<tr>
<td>TVSS</td>
<td>Total Volatile Suspended Solids</td>
</tr>
<tr>
<td>TWG</td>
<td>Technical Working Group</td>
</tr>
<tr>
<td>UASB</td>
<td>Upflow Anaerobic Sludge Blanket Reactor</td>
</tr>
<tr>
<td>UF</td>
<td>Ultrafiltration</td>
</tr>
<tr>
<td>US</td>
<td>Ultrafiltration (UF) combined with sonication (US)</td>
</tr>
<tr>
<td>UV-VIS</td>
<td>Ultraviolet-visible</td>
</tr>
<tr>
<td>V</td>
<td>Vanadium</td>
</tr>
<tr>
<td>VOC</td>
<td>Volatile Organic Compounds</td>
</tr>
<tr>
<td>VSD</td>
<td>Variable Speed Drives</td>
</tr>
<tr>
<td>Zn</td>
<td>Zinc</td>
</tr>
</tbody>
</table>
ANNEX
LIST OF THE ANNEXES

Annex 1: Participants to the BAT study
Annex 2: Technical Data Sheets
ANNEX 1: PARTICIPANTS TO THE BAT STUDY

Authors

Istituto di Management - Scuola Superiore di Studi Universitari e di Perfezionamento Sant’Anna (SSSUP, Italy) – www.sum.sssup.it

Tiberio Daddi
Maria Rosa De Giacomo
Fabio Iraldo

Centre International des Technologies de l’Environnement de Tunis (CITET, Tunisia) – www.citet.nat.tn

Kamel Saïdi

Technical Working Group (TWG)

Radhia Mchirgui - Energy expert (3 E, Energy and Environmental Engineering)
Afif Zaguia - Textile expert (Power)
Nizar Belfaiez - Responsible of industrialization (GTS, Gonser Textile Service)
Mourad Ben Moussa - Head of Division at the National Environment Agency Protection - Tunisia
Houcine Beltaief - Sub-director, head of finishing, engineering and sustainable development pole (CETTEX, Technical Centre of Textile)
Samir Gazbar - Environmental Expert (Eco-Process)
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/