

Best Available Techniques (BAT) for the textile industry in Egypt

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Study carried out by

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Chapter 1 Introduction

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

Chapter 2 Socio-economic and environmental-legislative framework of the sector

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

Chapter 3 Process description

This chapter gives a general overview and description of the processes and methods used in the textile sector. For each of the process steps, the associated environmental issues are described. Important sub-processes are: mechanical processes, spinning, weaving, knitting and wet-processes (e.g. pre-treatment, coloration, finishing).

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 processes regarding cotton. This selection could be justified by two main reasons: the environmental relevance of these phases, the characteristics of the Egyptian textile sector made up of many companies that use these processes in production.

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

Chapter 5 Selection of the best available techniques

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

Chapter 6 Recommendations

In this chapter the value of the BAT report is described and recommendations for the future are elaborated.

CONTENT

ABSTRACT	9
CHAPTER 1 INTRODUCTION	11
1.1 Background of this study: the BAT4MED project	11
1.1.1 Context	11
1.1.2 Industrial emissions and best available techniques	12
1.1.3 Main aims of the BAT4MED project	13
1.1.4 Sector-based BAT studies	13
1.2 The BAT study for the Egyptian textile industry	14
1.2.1 Main aims of the study	14
1.2.2 Content of the study	14
1.2.3 Procedure and guidance	15
CHAPTER 2 SOCIO-ECONOMIC AND ENVIRONMENTAL-LEGISLATIVE FRAMEWORK OF THE SECTOR	17
2.1 Description and delimitation of the sector	18
2.1.1 Delimitation and sub-classification of the sector	18
2.1.2 The distribution chain	18
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 and profit	22
2.2.4 Evolution of the investments	24
2.2.5 Production and price setting	25
2.2.6 Conclusion	25
2.3 Sector viability	25
2.3.1 Procedure	25
2.3.2 Competitive position	26
2.3.3 National competition	27
2.3.4 International competition	28
2.4 Environmental-regulatory aspects	29
2.4.1 Other Egyptian legislation	29
2.4.2 European legislation	35
CHAPTER 3 PROCESS DESCRIPTION	41
3.1 Processes for the industry	41
3.1.1 Dry mechanical processes and their environmental impacts	43
3.1.2 Textile wet processing and its environmental impact	50
3.2 General overview of applied process steps and their environmental impacts in some Egyptian textile enterprises	54
3.2.1 EP3 Projects	54
3.2.2 SEAM Project	68
3.3 R&TD Activities	87
3.3.1 Economical and ecological bio treatment/half bleaching of cotton-containing knit fabrics on an industrial scale	87
3.3.2 Pollution prevention of cotton-cone reactive dyeing	89

3.3.3	A multiple-objective environmental rationalization and optimization for material substitution in the production of stone-washed jeans- garments.....	91
CHAPTER 4	AVAILABLE ENVIRONMENTALLY FRIENDLY TECHNIQUES	93
4.1	Introduction	94
4.2	Energy efficiency measures	98
4.2.1	Techniques to reduce energy consumption	98
4.3	Resource efficiency measures	100
4.3.1	Efficient use of chemicals and raw materials (low add-on technique).....	100
4.3.2	Efficient use of water.....	104
4.3.3	Resources recovery measures.....	110
4.3.4	Integrated process measures	113
4.3.5	Reduction of emissions of mothproofer and insect-resist agents.....	115
4.4	Selection/substitution of chemicals with others more environmentally friendly	115
4.4.1	Alternatives to mineral oils	116
4.4.2	Use of enzymatic treatment/enzymes in processes resources recovery measures	117
4.4.3	Less pollutant dyes	117
4.4.4	Other measures	123
4.5	End of pipe techniques	128
4.5.1	Wastewater load abatement techniques.....	129
4.5.2	Air emissions abatement techniques	142
4.5.3	Waste management	143
CHAPTER 5	SELECTION OF THE BEST AVAILABLE TECHNIQUES (BAT)	147
5.1	Evaluation of the available environmentally friendly techniques.....	148
5.2	BAT conclusions	173
5.2.1	General BAT for <i>all</i> textile companies.....	173
5.2.2	Energy efficiency measures.....	173
5.2.3	Resource efficiency measures	174
5.2.4	Selection/substitution of chemicals with others more environmentally friendly	175
5.2.5	End of pipe techniques	176
CHAPTER 6	RECOMMENDATIONS	179
6.1	Priorities in BAT conclusions.....	180
6.1.1	Lack of driving forces for environmentally friendly techniques and measures	181
6.2	Limitations to the BAT evaluation and report	182
MAIN REFERENCES AND SOURCES		183
LIST OF ABBREVIATIONS		187
ANNEXES		189
LIST OF THE ANNEXES.....		191
ANNEX 1: Participants to the BAT study		193
ANNEX 2: Technical data sheets		195

ANNEX 3: General and horizontal techniques for textile sector	199
I. General Techniques.....	199
I.I General good management practices for textile sector.....	199
II. Horizontal techniques.....	203
II.I Best Available Techniques for Industrial Cooling Systems	203
II.II Best Available Techniques on Energy Efficiency.....	205
II.III Best Available Techniques on Emissions from Storage	211

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 Egyptian Environmental Affairs Agency (EEAA) and the TWG members met several times during the project to discuss, share and approve the content of this Report.

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

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

CHAPTER 1 INTRODUCTION

1.1 Background of this study: the BAT4MED project

1.1.1 Context

The Mediterranean region represents one of the most vulnerable environments in the world, accounting for 60% of the world's 'water-poor' population and 8.3% of global carbon dioxide emissions.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, in 2005 the Euro-Mediterranean leaders decided to join forces and launch Horizon 2020, an initiative to tackle the top sources of Mediterranean pollution by the year 2020. Against the background of this initiative, the European Commission included in the 2010 'Work Programme of the Environment (including climate change)' theme of the Seventh Research Framework Programme a specific topic serving the aims of Horizon 2020: 'ENV.2010.3.1.4-1 Integrated Pollution Prevention and Control of industrial emissions in the Mediterranean region'. The topic addressed Mediterranean Partner Countries. It aimed at preparing the ground for the implementation of best available techniques (BAT) to respond to particular health and environmental impacts from industrial emissions, with the overall objective of reducing 'pollution leakage' due to the displacement of polluting industries. The BAT4MED project, Boosting Best Available Techniques in the Mediterranean Partner Countries, arises within this context.

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

¹UNEP/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 preventative environmental measures reduces the consumption of natural resources (raw materials, energy, water, etc.), reduces waste streams and increases the efficiency of the production process. This in turn may contribute to the increase in competitiveness of industrial facilities.

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

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 **dairy industry** and the **textiles industry**.

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

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

²The 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>.

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 state of techniques, e.g. for setting emission limit values at sector level or determining permit conditions. They are also particularly relevant for operators, as they allow them to be kept informed of the available environmentally friendly and eco-efficient techniques in their sector and support the decision making process when changes to the production processes or plants are required or considered.

1.2 The BAT study for the Egyptian 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 Egypt 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 Egyptian textile plants, the available environmentally friendly techniques and the associated environmental aspects;
- to select from this list of environmentally friendly techniques the best available techniques, based on an assessment of economic, technical and environmental aspects;
- to provide suggestions for further data gathering and research, in order to improve any future BAT evaluations.

1.2.2 Content of the study

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

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

In Chapter 4 an inventory is made of environmentally friendly techniques applicable to the textile sector, and based on an extensive literature survey and data from suppliers and plant visits.

Next, in chapter 5, each of these techniques is evaluated with respect to its environmental benefit as well as to its technical and economic viability. A cost-benefit analysis allows us to select the Best Available Techniques.

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

1.2.3 Procedure and guidance

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

To support the data collection and to provide scientific guidance during the study a technical working group (TWG) was set up, composed of government and sector representatives as well as independent technical experts. This working group assembled to discuss content-related matters (17 November 2011, 27 March 2012 and 8 November 2012). A list of members of the sector working group and external 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. 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

Cotton has, for many years, played an immensely important role in the social, economic and political life of Egypt and has been responsible for its prosperity.

Egypt has a very large textile and clothing industry that depends primarily on cotton fibres alone/or in admixture with other natural or manmade fibres.

Cotton is the main cash crop of Egypt. It is the most important natural fibre planted and used in the Egyptian textile and clothing (T&C) sector because of its inherent performance properties.

Egypt is the largest cotton producer in Africa and market leader in LS (long stable) and ELS (extra-long stable) cottons with a 30-40% market share production and trade in the world.

Premium quality cottons are being exported as lint cottons \approx 30% to competing textile producing countries, e.g. India, China, Turkey, the USA.

Egypt imports of SS (short stable) cottons have increased significantly in recent years (\approx 35% of installation consumptions).

2.1.2 The distribution chain

For the abovementioned reasons, this report will focus on the textile and clothing industries based on cotton and cotton blends, taking into consideration that many large-scale companies in Egypt are fully integrated and cover the whole textile chain of cotton processing as is shown in (Figure 1).

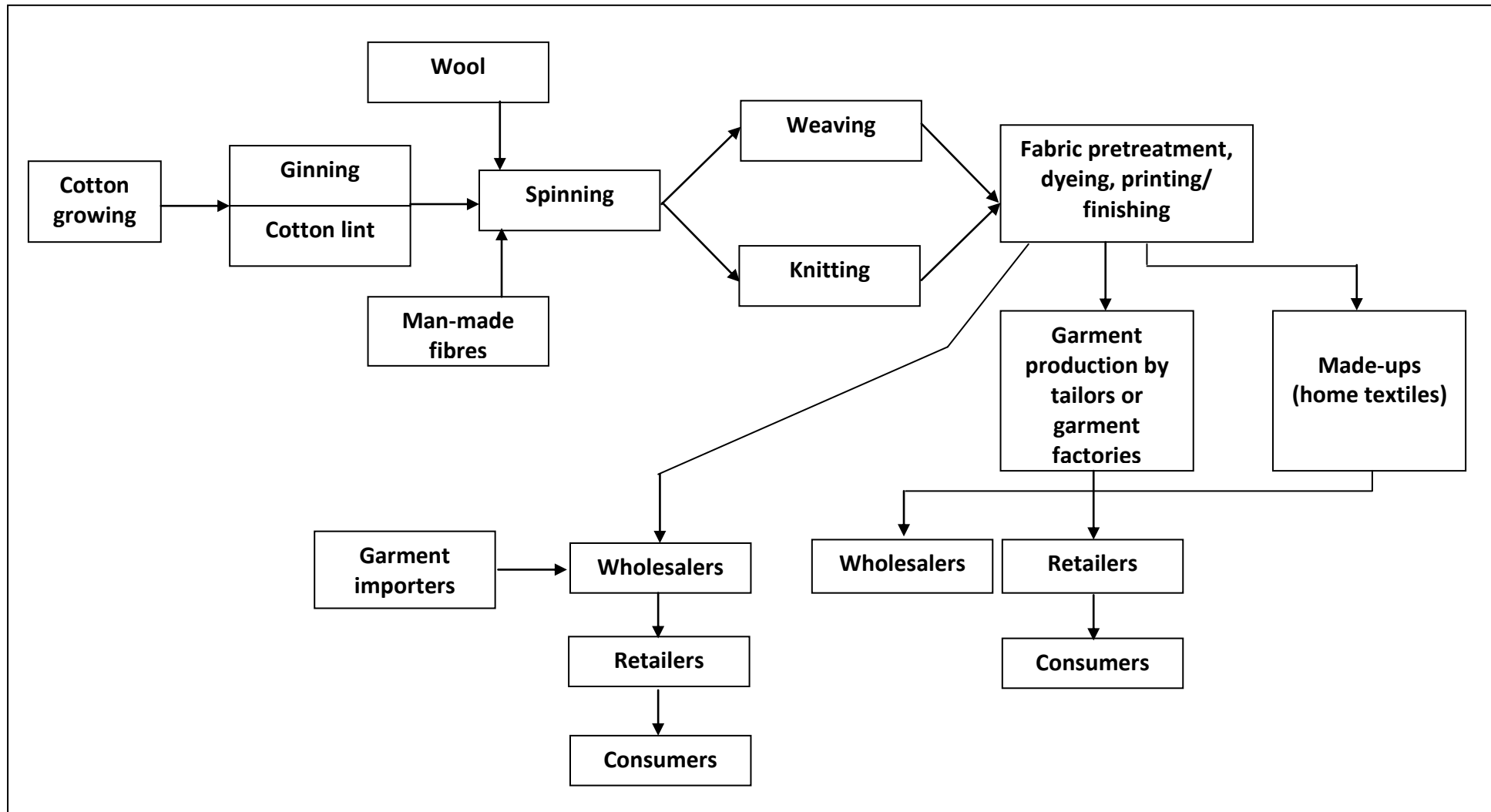


Figure 1. Cotton-based textile chain (processes and products)

The Egyptian textile and clothing (T&C) sector comprises the following subsectors: cotton, textile and garment.

The textile and clothing sector includes 4000-4500 companies, of which 27 companies are public sector, about 400 are export-oriented private sector, and about 4000 are local-market-oriented private sector.

There is a percentage of informal installations in operation supplying the local market.

Geographic distributions as well as industrial activities of these installations are given in Table 1.

Table 1. Geographic distribution of companies in textile and clothing sector

Governorate	Subsector				
	(I) Spinning and weaving manufacturing	(II) Wool, natural and synthetic manufacturing	(III) Dyeing, printing and finishing	(IV) Tricot manufacturing	(V) Ready- made garments
Cairo	132	21	35	301	277
Alexandria	4	10	17	151	72
El-Kaliobia	305	8	16	11	29
El-Gharbeya	128	18	3	15	11
Assyut	2	-	-	2	1
El-Bohaira	19	3	2	-	-
Beni-Suef	2	-	-	-	-
Port Said	1	1	-	1	2
Giza	6	1	1	19	54
El-Dakahlya	21	-	-	27	5
Dumayat	3	-	-	-	1
Sohag	2	1	-	-	-
El-Suez	1	-	-	-	-
El-Sharkeya	2	5	2	3	7
Menofeya	3	3	1	1	1

Source: SEAM text sector study-2001

Currently, there are seven qualifying industrial zones (QIZ), and they are located in the greater Cairo region including 10th of Ramadan City, 15th of May City, Shoubra El-Kheima, Industrial Nasr City, and south Giza, the greater Alexandria region including El-Amerya (Borg El-Arab) and the Suez Canal region, which includes Port-Said Industrial City. On the other hand, new locations were extended to governorates of Gharbia (as Mehalla El-Kobra), Menofia (Quissna, Shebin-El-Kom), along with enlarging some existing ones (ECES-September, 2006). Almost all the companies located in the free zone area are manufacturing garments for exports.

Distribution of manufacturing capacities (values on %) between public and private sectors, in 2001, is demonstrated in Table 2.

Table 2. Distribution of manufacturing capacities

Sector	Manufacturing capacity			
	Spinning	Weaving	Knitting	Garment
Public	90%	60%	40%	30%
Private	10%	40%	60%	70%

Source: GHERZI Inception Report-July 2006

The main textile products are apparel fabrics, terry towels, bed linen, furnishing fabrics, industrial/technical fabrics and non-woven fabrics.

The export-oriented woven (RMG) sector is almost totally dependent on imported finished fabrics.

Integrated knitted (RMG) companies use imported and local yarns.

2.2 Socio-economic characteristics of the sector

The Egyptian T&C industry is of vital importance for Egyptian economy both from:

- i) An economic perspective, as it is among the major contributors to foreign exchange earnings and an absorber of large amounts of domestic and foreign investments, and
- ii) A social perspective, as it is the largest employer in the economy.

In 2008, the Egyptian T&C sector contributed to 5.6% of the Egyptian GDP, 27% of industrial production, and 18% of total commodity non-oil exports.

2.2.1 Number and sizes of the companies

The geographic distribution of formal textile and clothing installations is given in Table 3.

Table 3. Geographical distribution of formal textile installations in textile and clothing sector

Governorate	Cairo	El-Kaliobia	El-Gharbya	Alexandria	El-Giza	El-Sharkya	El-Dakahlya	Others
No. of installations	1,053	779	732	679	379	372	216	14

Source: FEI (Egyptian chamber of textile industries- 2011)

- a) Public sector: 27 installations, 106,247 employees, very large companies, mostly integrated.
- b) Private sector: \approx 4,000-4,500 installations, mostly not integrated.
 - i) 400 installations are exporters

- ii) The export-oriented sector is dominated by the private sector and mostly operated within the Egyptian free zone or in the newly created QIZs.
- iii) 4,000 installations are local market suppliers (mostly small in size and operate for only 1-2 shifts per day)

2.2.2 Employment

In Egypt, the sectors absorb as much as 30% of the country's industrial labour force.

Direct Employment is currently about 700,000 people.

Indirect employment by the sector adds up to over a million people.

The gender structure of employment varies by sector and company size. However, women tend to represent between 65 to 80% of employment in the clothing sector and up to 90% of workers in micro and small companies.

2.2.3 Evolution of turnover, added value and profit

A majority of textile products, from the public or private sector, are targeting the lower and middle market segments in the USA and Europe.

The 400 exporter are focusing on medium quality.

Textile exports with higher added value, such as ready-made garments and clothing, dominated by the private sector, have expanded successfully.

The Egyptian textile industry that is handled completely inside the country is one of the highest value adding industries in the Egyptian economy.

Technical textile sector is expected to continue to grow at a higher rate for attaining higher-added value products.

Production of new Egyptian cotton varieties of high yielding ability, early maturing, upgrading high tint percentage and desirable fibre quality, along with modernization of the whole textile chain will achieve high turnover, added values and profitability.

Rising population figures and economic growth are still regarded as the driving force of the textile garment industries, and the trend of returning to nature, especially in industrialised countries, will increase the demand for cotton.

The expansion of Egyptian textile exports from 2003 to 2008 is shown in Figure 2.

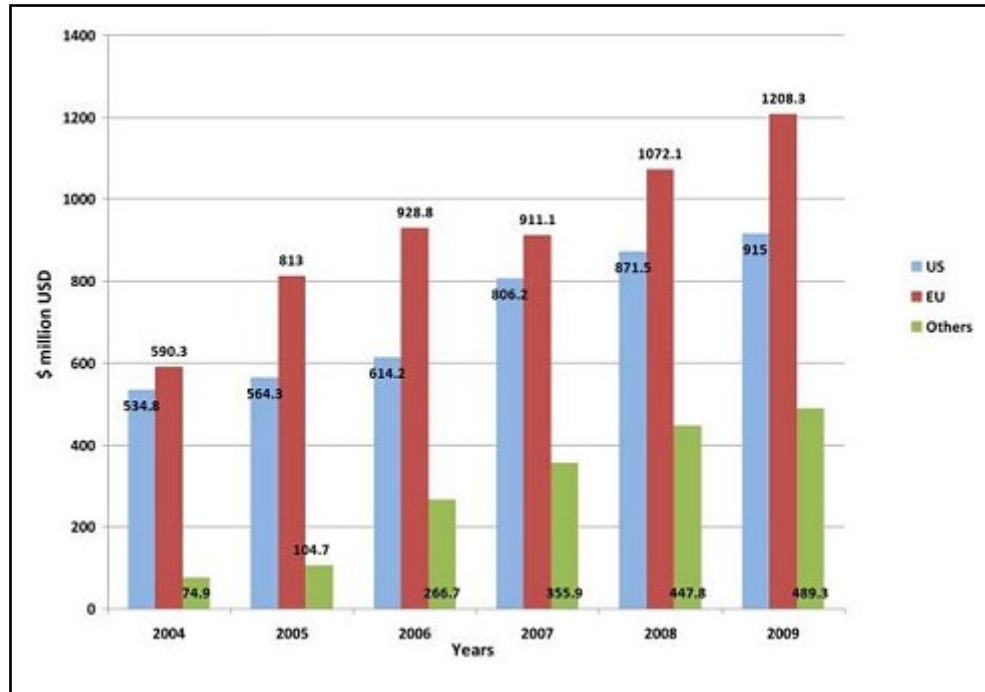


Figure 2. Egyptian textile and apparel exports

Source: General Organization for Export and Import Control (GOEIC)

Egyptian textile exports continued to experience a rapid expansion from 2003 to 2008 increasing by an average of 117% in the following sub-sectors:

- HS 52 (Cotton, Yarn, Woven Fabrics) increased by nearly 200%
- HS 54 (Man-Made Filaments) increased by almost 300%
- HS 55 (Man-Made Stable Fibres) increased by nearly 600%
- HS 57 (Carpets) increased by 200%
- HS 60 (Knitted or Crocheted Fabrics) increased rapidly by 625%
- HS 61 (Article of Apparel and Clothing Knitted or Crocheted) increased by approximately 400%
- HS 62 (Article of Apparel and Clothing/R-M-G) amplified by 700%
- HS 63 (Made-up textile articles NESOI, needlecraft sets, worn clothing) increased by 254%.

VISION 2020

The objective of the 2020 sector strategy is to sustain export growth at 15% to increase from the current level 2.6 billion USD to 10 billion USD in 2020.

VISION 2020 is a policy to grow exports to USD 10 billion, and create over 5 million jobs. In addition to:

- Establishing a Higher Council for Textile and Apparel Industry
- Developing specialist industrial zones for specific sub-sectors
- Investment fund to develop or support the infrastructure for specialist industrial zones
- Upgrading existing factories and improving quality standards
- Development of the domestic supply chain.

2.2.4 Evolution of the investments

The vision of the Industrial Development Authority (IDA) for the attraction of new investment to the sector focuses on the following objectives:

- Strengthen the up-stream supply chain
- Increase focus on the fast delivery of apparel to the EU, enabling entry to a higher value market segment
- Focus upon the following diversified sub-sectors:
 - Denim mills
 - Denim laundries
 - Intimate apparels
 - Premium Knitters
 - Premium fabric, cotton producers
 - Spinning and weaving producers

Foreign direct investment (FDI) is an important vehicle for economic growth in emerging markets countries. Since 2006/2007, Egypt has become the leading attractor of overall foreign direct investment (FDI) on the African continent. Up till 2008, Egypt has attracted 56 foreign investment companies in the textile sector, employing 14,169 workers with total investment value of \$172.3 million, and total production value of \$370.6 million. Furthermore, Egyptian-Foreign joint venture companies total 150; employing 30,635 workers; with an investment of \$515 million, and a total production value of \$509.4 million in 2008 (Figure 3).

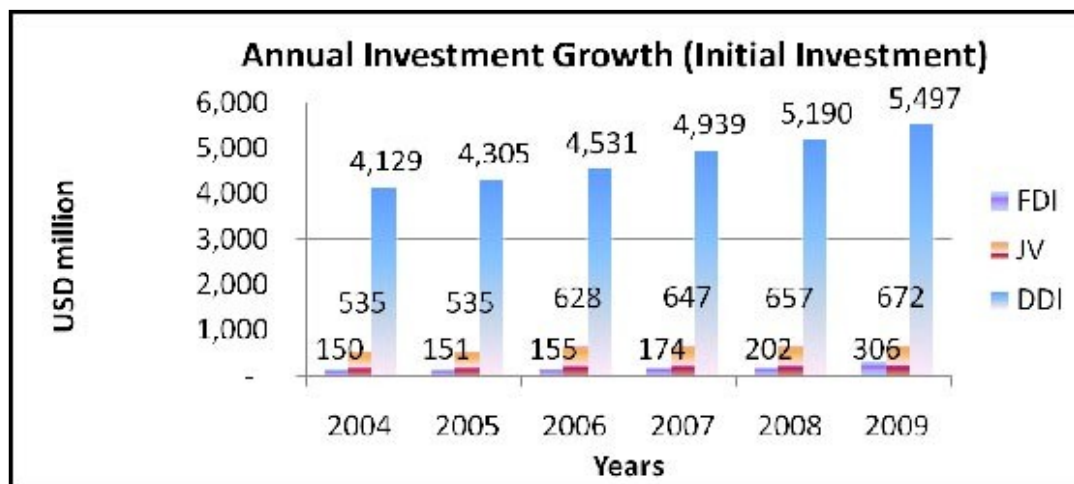


Figure 3. Annual investment growth

Source: Industrial Development Authority (IDA)

During the Period 2004-2009 (Q2), Textile and Garments Investments have increased by USD1.6 billion with a 35% 6-year increase. Whilst FDI has grown by USD156.2 million with a 104% 6-year increase, JV (Joint Venture) increased by only USD137 million. The key message is that the major share of investment growth has come from DDI which grew by USD1.3 billion with a 33.15% 6-year increase.

2.2.5 Production and price setting

Both quality and quantity of production and price setting are largely determined by market factors and expressed in consumer preferences and demands.

2.2.6 Conclusion

From the abovementioned data, we can conclude that:

- i) The Egyptian T&C industry enjoys much significant strength that should be taken in consideration for future development.
- ii) There is an urgent need for upgrading, development and modernization in this sector through short- and long-term plans through connection with cutting-edge technologies:
 - To help SMEs keep up with the high pace of innovation and technological changes in the rapidly changing field.
 - To promote business, technological and research collaborations.
 - To offer new and innovate products for traditional and new market.
 - To confront the rapid developments of market logistic, and social and environmental responsibilities.
 - To invest in new products and processes for its future survival and prosperity.
 - To ensure industrial growth while keeping the environmental and social impacts at a sustainable level.
 - To enhance the country's foreign currency earnings.
 - To focus on higher market segments.
 - To expand textile exports.
 - To recover market share in local markets.
 - To contribute to poverty reduction.
 - To create many thousands of new jobs.

2.3 Sector viability

2.3.1 Procedure

Table 4 shows that the Egyptian T&C sector contributes 3% to overall GDP, absorbs as much as 30% of industrial labour force, and contributes 30% to industrial value added.

Table 4. Contributions of T&C in MENA (Middle East and North Africa)-4 Economics

	Morocco	Tunisia	Egypt	Jordan
Contribution to overall GDP (%)	5.1	5.6	3	9.4
Contribution to industrial value added (%)	17	42	30	20
Employment (number)	203,800	220,00	1,000,000	30,00
Share of clothing in T&C employment (%)	45	nd	30	20
Share of women in clothing employment (%)	65	80	70	70

Source: World bank (2006)

- International competition has extended to local market treating less efficient domestic producers.
- The Egyptian ready-made clothes industry is therefore finding itself in competition with an imported clothes invasion.
- There are many efforts to trace smugglers and confiscate smuggled goods in order to protect the local market.
- On the other hand banning imported clothes would create a market monopoly.
- The private textile sector has proven its ability to innovate, penetrate and compete in the export markets. Most garments and home textiles are exported to USA, Europe and some gulf countries.
- Home textiles which are mainly produced from Egyptian cotton represent 12% of total exports.
- In 2005 Egypt exported 25.4 thousand tons of cotton yarns with a value of EGP523 million.
- Fabric exports in 2005 reached EGP131 million.
- Garment exports in 2005 reached USD918 million.
- Home textiles exports in 2005 reached USD150 million.

2.3.2 Competitive position

Table 5 demonstrates that Egypt enjoys several advantages such as relatively lower manufacturing costs, e.g. labour utilities, energy, etc., along with an integrated T&C industry as compared with other competitors which in turn can help attract new investments to Egypt. Significant investments in this sector are expected from European and Asian investors.

Table 5. Operating costs in Egypt and its competitors

	Egypt	Jordan	Turkey	India	Tunisia	Italy
Labour cost (\$/hr)	0.4	0.9	2.8	0.5	1.2	15
Electricity (cent/KWh)	3	5	7.7	8.6	10	8
Water	21	180	46	70	156	28
Natural gas (cent/m ³)	2.5	–	26	24.5	–	21
Building costs (\$/m ²)	120	200	180	140	400	480

Source: American Chamber of Commerce in Egypt, 2006

The actual situation of Egyptian competitiveness position (strength and weakness) could be discussed in terms of (GHERZI Inception, July-2006):

- Utility, e.g. water, electricity, natural gas, costs are significantly lower than competing countries.
- Egypt are less in the coarser cotton yarn counts, however for the finer counts, Egyptian cotton yarns are significantly cheaper.
- Woven fabrics costs are higher than other competitors, especially in the coarser counts.
- Knitted fabrics (based on imported cheaper yarns) have a clear advantage in Egypt.
- Finished knitted garments costs are higher compared to the others.
- Dress shirt costs are less competitive in Egypt.
- Wages are lower than the others.
- Export value is increasing on a year-to-year basis.
- Investment is increasing significantly.
- Specialized industrial zones.
- Market proximity.
- Preferential market access.
- Attractive export support training is very limited and continuous training is one of the main factor affecting productivity and quality.
- Lower real value added per employee.
- Lack of modern technologies.
- Improper customs and taxation policies.

2.3.3 National competition

- On the national level the total turnover of the four largest companies is around (20–25%) as compared to the rest of the sector. The textile sector have around (25–30%) of the total industrial manpower and income is about 20% from total export of Egypt.

- In 2008 the textile and apparel industry contributed 5.6% of the Egyptian GDP, 27% of industrial production, and 18% of total commodity non-oil exports. Egypt's population is one of its other strengths, as 30% of it was employed in 2008
- In the last few years several companies merged together but the information concerning the number is unavailable.
- Market evolution increased before the revolution, and now is either decreasing or has stopped.
- The strategy adopted by the industry set a target for 2010 of USD5 billion in exports, we believe that this target can be brought further to USD10 billion in 2015, increasing the value of Egyptian exports by almost tenfold and creating over 5 million jobs affecting the lives of 15 million people. (Source: Strategy and Action Plan Project for the Egyptian Textile and Clothing Industry: Report by GHERZI for IMC 2006).
- There are no available data concerning the total turnover of the sector in the next five years. In the meantime, should some environmental measures become obligatory there will be no effect, as environmental measures have been implemented.
- With the new trends of increasing prices, implementing the environmental measures will be included in product pricing.
- In the meantime, the competition between companies is based on both quality and price
- Also due to the economic situation we can say that there is willingness for cooperation between companies in the textile sector technically and from the production point of view.
- It goes without saying that there is no overcapacity concerning exportation and there may be for local production.
- The situation will improve by the end of this instability period.
- Concerning certain regulatory aspects (e.g. general law, environmental law, hygiene issues, etc.) we need more time to be active and more technical and financial support are needed.

2.3.4 International competition

- Over the past 3 years, the US and Europe have been Egypt's textile and clothing exports' primary markets with a market share of 35% and 46%, respectively. The Egyptian textile industry is enhancing its competitive position through new investments adopting the latest technology in all phases of the production process. (Source: Overview of Egypt's Textile Sector, 2009).
- There is no data available concerning the percentage of textile production meant for export.
- China, India, and Pakistan are countries we import textile products from.
- In reality there are many textile suppliers in this sector.
- The following table represents a rough estimate of suppliers companies to the textile sector.

Table 6. Number of suppliers (estimate)

	Raw materials	Chemicals etc.	Machinery	Other
Estimated number of suppliers	5-100	50 -100	20-50	/

- Concerning the suppliers of the different components used in the textile industry we can say that it is easy to switch from one supplier to another based on price or quality of supply needed as the market is opened.
- Suppliers are committed to supplying the biers with detailed environmental safety sheets, especially about chemicals or treated yarn.
- Concerning the customers of the textile companies which have no power over the companies, once again it is an open market.
- If we talk about customers (companies) it is estimated roughly that textile companies have around 10 customers.
- It is not that easy to switch customers (Companies customers). Also, it is possible to pass on some of the additional costs for example environmental measures, to the customers.
- At the moment there is no data available concerning textile products with substitutes which are made from soy or rice and consequently no information available concerning whether there is a big price difference between the textile products and substitutes.
- As it is easy to start new companies, in the last few years several companies have been created in the new free zones area. Also, several companies were created in Jordan and Tunisia.
- The new companies do not create any problems with the existing ones as the local market is open and free.
- Once again the country is in a state of free investments so it is easy to start new companies.

2.4 Environmental-regulatory aspects

2.4.1 Other Egyptian legislation

1) The textile industry has several impacts on environment:

- Water consumption and wastewater effluents
- Air emissions
- Solid wastes
- Energy consumption

As far as chemical processes, i.e. pre-treatment, dyeing, printing, and finishing are concerned, the most important issue is water. A large amount of commodity and specialty chemicals are intensively used in textile wet-processing. The major characteristics of real textile wastewater are given in Table 7.

Table 7. Major characteristics of real textile wastewater studied by various researchers

pH	COD	BOD ₅ (mg/l)	TSS (mg/l)	TDS (mg/l)	Colour	Turbidity (NTU)	References
8.8-9.4	595±131	379±110	276±76	-	-	-	El-Gohary & Tawfik, 2009
11.2	2276	660 ³	-	47.9	-	-	Golob et al, 2005
5-10	1100-4600	110-180	-	50	1450-1475 (ADMI)	-	Dos Santon et al, 2007
6.5-8.5	550-1000	-	100-400	-	7.5-25.50 ^b	15-200	Ciabatti et al., 2010
2.7	7000	-	440	930		2140	Al-Malack et al., 1999
13.56	2968	-	-	-	3586 (C.U)	120	Joo et al., 2007
12-14	1500-2000	-	-	-	Dark Blue	-	Gonzalez-Zarilla et al., 2008
10	1150	170	150	-	1.24 ^{436nm}	-	Selcuk, 2005
9	750	160	-	-	-	-	Schrank et al., 2007
2-10	50-5000	22-300	50-500	-	>300 (C.U)	-	Lau & Ismail, 2009
8.32-9.50	278-736	137	85-354	1715-6106	-	-	Phalakornkul et al., 2010
8.7±0.2	17900±100	5500±100	23900±50	1200±50	-	-	Rodriguez et al., 2008
9,30	3900	-	-	-	-	240	Paschoal et al., 2009
7.8	810±50.4	188±15.2	64±8.5	-	0.15 ^{669nm}	-	Haroun and Idris, 2009
13±1	2300±400	-	300-100	-	-	-	Debik et al., 2010
6.95	3422		1112	-	-	5700	Bayramoglu et al., 2004
7.86	340	210	300	-	>200 (Pt-Co)	130	Merzouk, 2010
7.5±0.3	131±18	-	75±13	1885±80	-	-	Ustun et al., 2007

Source: A. Verma, *Journal of Environmental Management* 93, 154 (2012)

On the other hand strict discharge criteria for water (Table 8) and air (Table 9 and Table 10) and solid waste (Table 11 and Table 12) relevant to the Egyptian textile industry, to improve environmental performance as well as to increase the economic driving force for cleaner production.

The following are the laws concerning environmental protection:

- Wastewater: Law 9/2009, amended by Decree 1095/2011; Law 93/1962; and Law 48/1982, concerning protection of the River Nile Egypt's waterways from pollution.
- Air pollution: Law 4/1994.

Table 8. Egyptian environmental legal requirements for industrial wastewater

Parameter (mg/l unless otherwise noted)	Law 9/2009	Law 93/62	underground reservoir and Nile branches/canal	Law 48/82	Discharge into:	
	Discharge coastal environment Amended by Decree 1095/2011	Discharge to sewer system (as Decree 44/2000)		Nile (main stream)	Municipal	Drain Industrial
BOD (5 day, 20 deg.)	60	600	20	30	60	60
COD	100	1100	30	40	80	100
pH	6-9	6-9.5	6-9	6-9	6-9	6-9
Oil and grease	15	100	5	5	10	10
Temperature (deg.)	<38	43	35	35	35	35
Total Suspended Solids (TSS)	60	800	30	30	50	60
Total Dissolved Solids	+ 5 of the receiving body TDS	-	800	1200	2000	2000
Residual chlorine	-	-	1	1	-	-
Sulphides	--	10	1	1	1	1
Phosphate (inorganic)	--		1	1	--	10
NO ₃			30	30	50	40
Phenol	0.015	0.05	0.001	0.002	--	0.005
Total nitrogen	10	100	--	--	--	--
Ammonia as nitrogen	3					
Total Phosphorus	2	25	--	--	--	--

Parameter (mg/l unless otherwise noted)	Law 9/2009 Discharge coastal environment Amended by Decree 1095/2011	Law 93/62 Discharge to sewer system (as Decree 44/2000)	underground reservoir and Nile branches/canal	Law 48/82 Discharge into:		
				Nile (main stream)	Municipal	Industrial
Cyanide	0.01	0.2	--	--	--	--
Fluorides	--		0.5	0.5	---	0.5
Total heavy metals		<5	1	1	1	1
Hg	0.001	0.2	0.001	0.001		
Pb	0.01	1	0.05	0.05		
Cd	0.01	0.2	0.01	0.01		
As	0.01	2	0.05	0.05		
Cr+6	0.01	0.5	0.05	0.05		
Cu	1	1.5	1	1		
Ni	0.1	1	0.1	0.1		
Fe	1.5	--	1	1		
Ag	0.05	0.5	0.05	0.05	--	---
Mn	0.1	--	0.5	0.5	--	--
Zn	1	--	1	1	--	---
Detergents	--	--	0.05	0.05	--	---
Pesticides	0.2	--	--	--	--	--
Coliform (count/100 m ³)	1000	--	2500	2500	5000	5000

Source: EEAA

Table 9.Limits of air pollutants relevant to the textile industry (Law 4/1994)

Parameter	Max. limits (mg/m ³)
Total Suspended Particles	50
Volatile Organic Matters	50 for drying units 75 for printing units
Chlorine	5
Ammonia	30
Hydrogen Sulphide	5
Carbon Dioxide	150

Table 10.Limits of air pollutants relevant to boilers and electric generators (Law 4/1994)

Type of fuel used	Max. limits (mg/m ³)					
	TSP	CO	CO ₂	NO _x	Pb in TSP	Hg fumes
Natural gas	50	100	150	500		
Coke gas	100	300	350	500		
Solar	100	250	1300	500		
Mazot	100	250	1500	500	2	1
Coke	100	300	1300	500	2	1
Agriculture waste	100	250	100	500		

Table 11.Non-hazardous domestic and industrial solid waste (incinerators)

Pollutants	Maximum emissions limits (mg/m ³)
TSP	20
Hydrochloric Acid	10
Hydrofluoric Acid	1
SO ₂	100
NO _x	400
CO	150
Heavy metals	
Cd and Cd Compounds	0.1
Hg and Hg Compounds	0.1
Lead and lead Compounds	0.1
Total Heavy metals and their compounds	0.5

Table 12. Hazardous solid waste (incinerators)

Pollutants	Maximum emissions limits (mg/m ³)
TSP	10
Vapours and gases in the form of total organic carbon	10
Hydrochloric acid	10
Hydrofluoric acid	2
SO ₂	100
NO _x	200
CO	100
Dioxin and furan	0.1 (Nanogram/m ³)
Cd and Cd compounds	0.1
Hg and Hg compounds	0.1
Lead and lead compounds	0.1
Thallium and compounds	0.1
Antimony and compounds	0.1
Arsenic and compounds	0.1
Cr and Cr compounds	0.1
Cobalt and compounds	0.1
Cu and Cu compounds	0.1
Mn and Mn compounds	0.1
Ni and Ni compounds	0.1
Vanadium and compounds	0.1
Tin and Tin compounds	0.1
Total Heavy metals and their compounds	0.5

Reference Conditions (Oxygen %age is 7%, 273 °K and 1 atmospheric pressure)

Every company must have an environmental register according to Article (17), Chapter (1), Law 4/1994 concerning the environmental register states that:

The owner of the installation shall—according to the provisions of these regulations—maintain a register indicating the impact of the installation's activity on environment, and in which the following data shall be recorded:

- Emissions emanating there from or drained thereby and the limits thereof.
- Specification of the elements resulting from the treatment process, and the efficiency of the treatment units used for the purpose.
- Follow-up as well as environmental safety and self-monitoring procedures applied in the installation.
- Periodical tests and measurements, and the number of samples, together with the time and place of taking them as well as taking measurements and making analyses of the results thereof.
- The officer in charge of follow-up.

The register shall be provided according to the form indicated in Annex no. (3) attached to these regulations.

The owner of the installation or his delegate shall notify the Environmental Affairs Agency forthwith by registered letter with acknowledgment of receipt, of any deviation in the standards, specifications and limits of emitted or drained pollutants, and the procedures taken to correct same.

2.4.2 European legislation

*Industrial Emissions Directive*³

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

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

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

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

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

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

³Source: European Commission – DG Environment:
<http://ec.europa.eu/environment/air/pollutants/stationary/ied/legislation.htm>

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 shall 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 website⁴.

Urban Wastewater Directive⁵

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.

⁴http://europa.eu/legislation_summaries/environment/air_pollution/ev0027_en.htm

⁵http://europa.eu/legislation_summaries/environment/water_protection_management/l28008_en.htm

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.

Emission Trading Scheme (ETS) Directive⁶

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

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

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

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

The Waste Framework Directive⁷

The Directive 2008/98/EC establishes a legal framework for the treatment of waste* within the Community. It aims at protecting 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;

⁶ http://ec.europa.eu/clima/policies/ets/index_en.htm

⁷ http://europa.eu/legislation_summaries/environment/waste_management/ev0010_en.htm

- 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.

Water protection and management: the Water Framework Directive⁸

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.

⁸ http://europa.eu/legislation_summaries/environment/water_protection_management/l28002b_en.htm

REACH Regulation: Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals⁹

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

CHAPTER 3

PROCESS DESCRIPTION

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

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

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

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

3.1 Processes for the industry

General overview

- Textile fibres

Textile fibres are broadly classified into natural, e.g. cellulosic fibres (cotton, flax, jute, etc.), protein fibres (wool, silk, etc.), and man-made fibres, e.g. regenerated fibres such as rayon, lyocell and cellulose acetate, and synthetic fibres such as polyester, polyacrylic, polyamide and polypropylene.

On the other hand, there is an increasing demand for fibre blending most probably due to its positive impacts on enhancing the performance and quality properties, developing novel textile products, expanding utilization as well as to compensate the shortage in natural fibres.

Cotton fibres are the most widely used amongst natural and man-made fibres in Egyptian textile industry. Accordingly this chapter will focus on description of cotton-based textile production processes and environmental aspects.

- The textile chain

The textile and clothing sector is composed of a wide number of subsectors (Figure 4) namely:

- i) harvest or production of raw fibres
- ii) Semi processing sector: spinning, weaving, knitting, non-woven, etc.
- iii) Finishing sector: pre-treatment (desizing, scouring, bleaching, mercerizing), dyeing, printing, chemical finishing (soft finish, easy care finish, antimicrobial finish, water repellent finish, flame proofing finish, soil release finish, UV-protection finish
- iv) Final products sector: clothing, home textiles, industrial textiles

Figure 4. Textile Chain

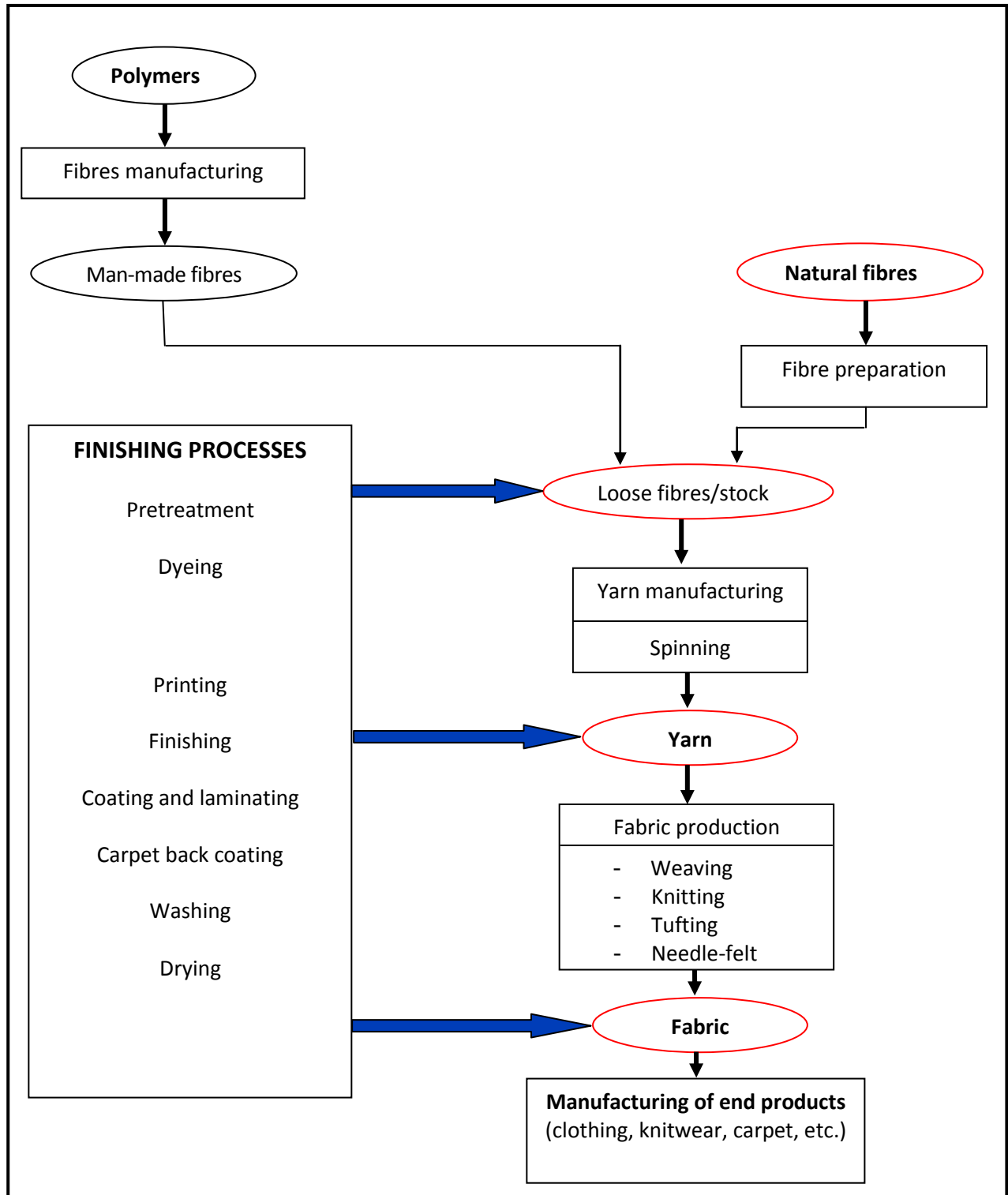


Figure 4 demonstrates the entire production cycle from production and raw materials harvest, to semi processed, using both mechanical and finishing processes, and final products. The sequence of treatment is governed by the requirements of the end user.

3.1.1 Dry mechanical processes and their environmental impacts

The dry mechanical and chemical processes used in the textile industry and their environmental impacts are as follows:

Tables 13 to 20 show the environmental impacts of dry mechanical processes. The environmental issues associated with dry mechanical processes arise from air emissions as well as solid waste

Table 13. Cotton spinning

Process	Input	Function (purpose)	Product	Air emissions	Effluents	Solid wastes	Work environment
Opening and cleaning	Raw cotton different man-made fibres (cotton-type) or both, energy consumption	Opening and cleaning cotton	Flow of cleaned and opened cotton	Cotton dust particulates	----	Fibres	Particulates, cotton, dust, noise
Carding	Layer of cleaned cotton, energy consumption	Further opening and cleaning	Card sliver	Particulates	----	Fibres	Particulates
Combing	Card sliver	Further cleaning and removing neps, parallelizing the fibres	Combed sliver	Particulates	----	Fibres	Particulates, noise
Drawing	Carded silver, combed silver, cotton, man-made or both	Improving regularity, blending different fibres	Drawn sliver	Particulates	----	Fibres	Particulates, noise
Roving	Drawn sliver	Reducing thickness, inserting some twist to strengthen resulting roving	Roving	Particulates	----	Fibres	Particulates, noise
Ring-spinning	Roving	Drafting roving to yarn and inserting final twist	Ring spun-yarn on bobbin	Particulates	----	Yarns	Particulates, noise
Open end spinning	Drawn sliver	Drafting sliver to yarn and inserting final twist	Open-end yarn on cheese package	Particulates	----	Yarns	Particulates, noise

Process	Input	Function (purpose)	Product	Air emissions	Effluents	Solid wastes	Work environment
Cone-package winding	Ring spun yarn on bobbin	Removing yarn defects and winding yarn to cone package	Finished ring-spun yarn on cone packages	Particulates	----	Yarns	Particulates, noise

Table 14Woolspinning

Process	Input	Function (purpose)	Product	Air emissions	Effluents	Solid wastes	Work environment
Selecting and sorting	Raw wool	Classifying wool according to quality	Required quality of raw wool	Particulates	-----	Wool fibres waste	Particulates
Scouring	Raw wool warm soapy water, water consumption, energy consumption	Cleaning wool from natural grease, suint, dirt and dust	Clean wool from grease suint and dust	VOCs (solvent)	High solids, BOD, COD, grease, solvent and detergent residues neutral to high pH, temperature	Wool fibres waste	Particulates VOCs (from drying)
Carbonizing	Scoured wool Sulphuric acid (low concentration), water consumption	Removing vegetable matter	Wool cleaned from vegetable matter	Acid fumes	Normal pH below 7 occasional acid bath dumps		Acid fumes
Mixing and oiling	Pretreated wool oil	Mixed and oiled wool ready for carding	Wool	VOCs (solvent)	-----	Wool fibres waste	Particulates
Carding	Cleaned and oiled wool, energy consumption	Fibre separation and forming fibre rope (roving)	Wool roving	Particulates	-----	fibre waste (typically	Particulates

Process	Input	Function (purpose)	Product	Air emissions	Effluents	Solid wastes	Work environment
Gilling and combing	Carded wool	Parallelism of fibres, separate entanglement	Combed sliver	Particulates	-----	reused) Fibre waste (reused)	Particulates
Roving	Combed sliver	Drafting sliver to form roving	Roving or (top)	Particulates	-----	Wool fibres waste	Particulates, noise
spinning	Roving, energy consumption	Draft and insert twist to form yarn	Woollen yarn (without combing) or worsted yarn (combed)	Particulates	-----	Wool fibres waste	Particulates, noise

Table 15. Weaving Industry

Process	Input	Function (purpose)	Product	Air emissions	Effluents	Solid wastes	Work environment
Warping	Yarn cones, energy consumption	Forming the longitudinal parallel arrangement of warp threads	Warp threads beam	Particulates	-----	Yarn-packaging waste	Particulates, noise
Slashing (sizing)	Warp threads on warp beam Size solution, water consumption	Treating warp threads with size solution	Sized warp	VOCs (methanol from PVA) Particulates (from dry phases)	BOD, COD, metals, size washing residues	Fibre lint, yarn scrap, size residues	VOCs (methanol from PVA) Particulates
Preparing for loom	Sized warp	Threading warp threads in	Warp beam ready for	-----	-----	-----	-----

		harnesses, reed and drop wires to be ready for the loom	waving				
Weaving	Warp threads arrangements, energy consumption	Interlacing warp threads with weft threads to form fabric	Woven fabric	particulates	-----	Yarn and fabric scraps	Particulates, High level of noise

Table 16. Knitting industry

Process	Input	Function (purpose)	Product	Air emissions	Effluents	Solid wastes	Work environment
Warp knitting Warping	Yarns (cotton, wool, blended, man-made, filament, textured, energy consumption)	Preparing warp yarn on warp beam	Warp beam	Particulates	-----	Yarn packaging waste	Particulate
Knitting	Warp beam, energy consumption	Interlooping the warp yarns to form knitted fabric	Warp knitted fabric	Particulate	-----	Yarn and fabric scraps, packaging waste	Particulates, noise
Circular knitting or flat knitting	Yarn cones, energy consumption	Interlooping threads to form weft knitted fabric	Circular knitted fabric	Particulate	-----	Yarn and fabric scraps, packaging waste	Particulates, noise

Table 17. Nonwoven fabric industry

Process	Input	Function (purpose)	Product	Air emissions	Effluents	Solid wastes	Work environment
Web forming	Man-made fibres (polyester, nylon, etc.)	Opening and carding the fibres	Card fibre web	particulates	-----	Fibres	Particulate
Web condensation	Card fibre web	Condensing fibre web to required	Multilayer fibre web	Particulate	-----	Fibres	Particulate

Process	Input	Function (purpose)	Product	Air emissions	Effluents	Solid wastes	Work environment
Needle punching	Multilayer fibre web	weight Mechanical bonding of fibre web	Needled nonwoven felt	Particulate	-----	Fibres	Particulates, noise
Adhesive spraying and drying	Needle punched fabric	Strengthening the fabric coherence	Needle punched nonwoven fabric	VOCs	-----	Fibres, nonwoven fabric scraps	VOCs, fumes from adhesive chemicals

Table 18. Tufting industry

Process	Input	Function (purpose)	Product	Air emissions	Effluents	Solid wastes	Work environment
Tufting	Carpet yarn (wool, man-made fibre)	Inserting rows of tufts on ground fabric	Ground fabric tufted with carpet wool pile	Particulates	-----	Yarns Packaging wastes Fabric scraps	Particulate
Adhesive coating of tuft back	Adhesive resin Jute woven fabric, water consumption	Fixing tufts on ground fabric	Tufted carpet backed with adhesive	Particulate	Chemicals reducing the dissolved oxygen in water	Adhesive spills	Particulate
Covering carpet back with jute fabric and drying	Woven jute fabric and tufted carpet	Sticking the backing to the adhesive coating	Tufted carpet with finished back	Particulate	-----	Fabric scraps	Particulates, noise
Shearing pile surface	Tufted carpet with solidified adhesive	Level the pile surface	Finished tufted carpet	VOCs	-----	Fibres	VOCs, fumes from adhesive chemicals

Table 19. Manufacturing polyester

Process	Input	Function (purpose)	Product	Air emissions	Effluents	Solid wastes	Work environment
Production of ester building unit	Monoethylene glycol Dimethyl terephthelate, water consumption	Reacting the exchange of ester	Diglycol terephthelate	-----	Methanol Glycol	-----	Heat
Polymerization	Diglycol terephthelate	Forming the polymer	Polyester polymer	Methanol vapour Glycol vapour	-----	Waste polymer	Radiation of Cs or Co volatile monomers
Spinning (for producing tow)	Molten polyester polymer, water consumption, energy consumption	Pumping polymer through spinnerets	Polyester filament tow	Volatile finishes other organics	Wastewater with oils additives, finishes organics	Filament waste chemicals, oil residues	VOCs, noise
Tensioning and crimping	Collected filament tow Finishing oil, water consumption, energy consumption	Adjusting filament denier, and crimping the filaments	Drawn and crimped collected filament tow	Volatile finishes	Wastewater with finishing chemicals	Filament waste	VOCs, noise
Cutting	Finished collected tows, energy consumption	Cutting filaments into staple fibres	Staples fibres (cotton type or wool type)	Particulates	-----	Fibre waste	Particulates, noise
Pressing into bales	Bulk of staple fibres Polyethylene sheets Polypropylene strips, energy consumption	Pressing polyester fibre into bales	Bales of polymer fibres (cotton type or wool type)	Particulates	-----	Fibre and ethylene wastes	Particulates, packaging waste
Spinning (polyester filament yarn)	Molten polyester polymer, water consumption, energy consumption	Pumping molten polymer through spinnerets	Pre-oriented filament yarn (POY)	Vapour from finishing oil	Wastewater and finishing oils	Yarn scrap	VOCs, noise
Ring-twisting	POY filament yarn, energy consumption	Drawing and twisting filament yarn	Polyester filament yarn	-----	-----	Yarn scrap	Noise

Texturing	POY yarns	Crimping the filament in the yarn	Textured yarn	-----	-----	Yarn scrap	Noise
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Table 20. Garment industry

Process	Input	Function (purpose)	Product	Air emissions	Effluents	Solid wastes	Work environment
Fabric laying and pattern placing for garment fabric, interlining and lining	Garment fabric Lining fabric Interlining fabric	Forming multilayer of fabric and fixing pattern on fabric	Arrangement of multilayer fabric with patterns positioned and fixed on.	-----	-----	-----	Particulates, dust
Cutting	Multilayer fabric with pattern on, energy consumption	Cutting fabric according to patterns	Garment pieces Lining pieces Interlining pieces	Particulates, VOCs from fabrics	-----	Fabric scrap Lining scrap Interlining scrap Packaging waste	Particulates, VOCs from fabrics, noise
Sticking and interlining pieces to garment pieces	Garment pieces and interlining fabric pieces	Heat pressing interlining to fabric pieces	Garment pieces with interlining stuck on	Adhesive fumes	-----	Fabric scrap	Heat and fumes
Sewing	Garment pieces Lining pieces Sewing threads Buttons Zippers, etc.	Assembling each of garment and interlining and the two together	Complete assembled garment	Particulates, VOCs from fabrics	-----	Yarn scrap	Particulates, noise
Ironing	Complete garment, energy consumption	Finishing the appearance	Finished garment	-----	-----	-----	Steam Noise
Packaging	Finished garments	Packaging garments	Different sizes of carton boxes	-----	-----	Carton scrap, plastic bags	-----

3.1.2 Textile wet processing and its environmental impact

Table 21 shows the negative impacts of textile wet processing especially on air and water pollution. The extent of pollution depends on type and amount of used chemicals, the used finishing regime as well as the production line requirements.

Table 21. Finishing industry

Process	Input	Function (purpose)	Product	Air emissions	Effluents	Solid wastes	Work environment
Singeing (cotton only)	Unfinished woven cotton fabrics	To burn the surface fibres of grey goods to give smooth surface	Fabric with smooth surface, and no protruding fibres	Small amount of exhaust gases from burners	-----	Little or none	Small amount of burning fumes
Desizing	Singed fabric Enzyme Acid (sulphuric), water consumption	To remove size material from woven fabric	Fabric free from size	VOCs from glycol ethers	BOD from sizes, lubricants, biocides, anti-static compound	Fibre lint, yarn waste, cleaning materials	VOCs from glycol ethers
Scouring	Knitted or desized fabric Alkaline or solvent solution, water consumption, energy consumption	Cleaning fabric from impurities	Clean fabric	VOCs from glycol ethers and scouring solvents	High BOD and temperature, very high pH, fats, waxes, detergents, six mix residues, solvent residues	Little or no waste	VOCs from glycol ethers and scouring solvents
Bleaching (for natural fibres)	Scoured fabric Hydrogen peroxide Hypochlorite, water consumption, energy consumption	Eliminating unwanted coloured matter decolorizing coloured impurities	White blocked fabric	Chlorine chemical fumes, acetic acid fumes	Low to moderate BOD, high pH and temperature, bleach and additive residues	Little or none	Chlorine chemical fumes, acetic acid fumes
Mercerizing	Woven or knitted cotton fabric	To give lustre, high strength,	Mercerized woven or	Little or none	Very high pH, dissolved solids,	Little or none	-----

Process	Input	Function (purpose)	Product	Air emissions	Effluents	Solid wastes	Work environment
	Caustic soda (15-20%). Acid, water consumption, energy consumption	more affinity to dye	knitted fabric		some BOD, NaOH		
Dyeing	Woven or knitted fabric Dye stuffs, Auxiliaries Reductants, Oxidants	Add colour and intricacy to fabrics	Dyed fabric	VOCs (ethylene glycol), ammonia	Depending on dye type, dissolved solids, COD, heavy metals causing toxicity, BOD	Chemical residues, fabric scrap	VOCs (ethylene glycol)
Printing	Woven or knitted fabric Pigments and dye. Acid or alkalis. Softener, Binder, emulsifier, solvents, water consumption, energy consumption	Printing colour and pattern on fabrics	Printed fabric	VOCs (e.g. ethylene glycol, urea, formaldehyde, kerosene), ammonia, combustion exhausts	High COD and salt content, solvent, metals, BOD, foam, heat	Chemical residues	VOCs, ethylene glycol, urea, formaldehyde, kerosene), ammonia, noise
Carbonizing (for wool)	Knitted or woven fabric, sulphuric acid, water consumption	Removing vegetable matter	Wool fabric cleaned from cellulose matter	Acid fumes	Normal pH, below 7, occasional acid bath dumps	Little charred, carbon residues	Acid fumes, noise
Special finishes (mothproofing, water repellent, stain resist)	Woven or knitted fabric Mitin, dieldrin and boconise for mothproofing Fluoro chemicals for water and oil repellence, water consumption	Giving fabric special property	Fabric with special finish	Particulates, VOCs, formaldehyde combustion exhausts	COD, BOD, suspended solids, toxic materials, spent solvent	Chemical residues, fabric scrap	Particulates, VOCs, formaldehyde, noise
Brushing and napping	Woven or knitted fabric	Raise surface and change feel and texture of fabric	Fabric with hairy surface	Particulates	-----	Fibre waste	Particulates, noise
Shearing	Woven fabric	Removing surface	Fabric with	Particulates	-----	Fibre waste	Particulates,

Process	Input	Function (purpose)	Product	Air emissions	Effluents	Solid wastes	Work environment
		fibre	smooth surface				noise
Softening by calendaring	Woven fabric	Removing surface fibre, friction between fibres	Soft fabric	-----	-----	-----	Noise
Sanforizing	Woven fabric	Compacting the fabric	Fabric with compressed structure	-----	-----	-----	-----
Addition of lustre	Woven fabric	Adding lustre to fabric surface	Fabric with lustre flattened and smooth yarns	-----	-----	-----	Noise

(Source: EPAP- 2002)

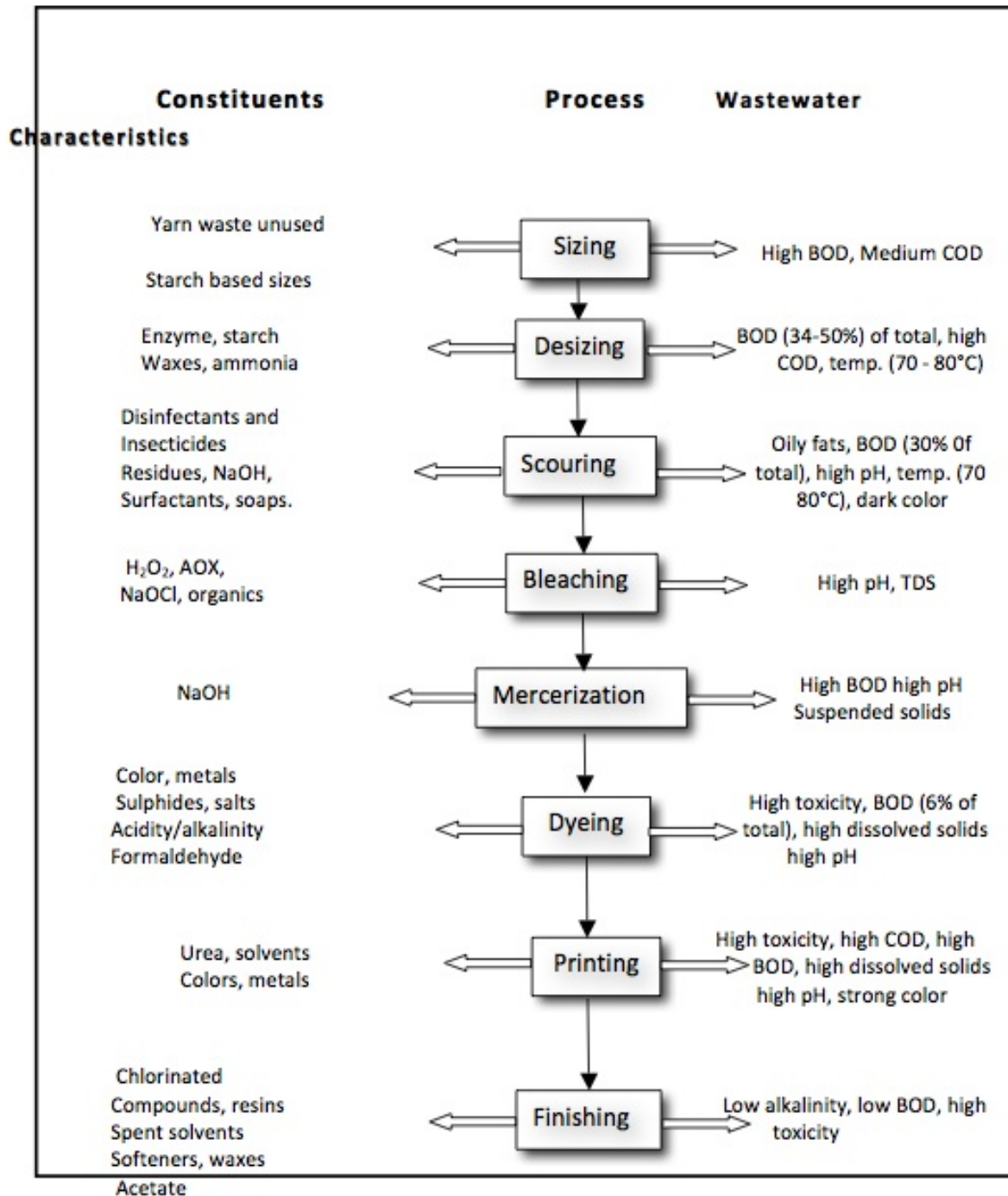


Figure 5. Impact of textile wet processing on effluent characteristics

(Source: A. K. Verma et al., *Journal of Environmental Management* 93, 154 (2012))

Figure 5 shows the impact of the used ingredients, at each stage of the textile wet processing, on the wastewater characteristics, e.g. COD, BOD, TSS, TDS, pH, colour, etc.

3.2 General overview of applied process steps and their environmental impacts in some Egyptian textile enterprises

3.2.1 EP3 Projects

3.2.1.1 Preface

To defend its position, to stay competitive in the long term as well to expand local, regional and international markets, the Egyptian textile and clothing industry has a tremendous need for environmentally friendly, energy-efficient new products and technologies. Practicing cleaner production options in textile sector can help Egyptian business and economy successfully.

Recently many efforts have been made to develop and modernize the Egyptian T&C industry through:

- i) Setting up the base line conditions of the currently used textile processes (dry and wet),
- ii) Identification of environmentally damaging activities,
- iii) Developing of waste minimizing/pollution prevention strategies,
- iv) Better use of natural resources
- v) Applying low-cost/no-cost cleaner production measures
- vi) Implementing better management practices hand by hand with the staff member of the selected textile facilities,
- vii) Complying with local and international environmental legislations and regulations as well as copying with Ecolabel criteria
- viii) Enhancing competitive edge of Egyptian textile products by using innovative technologies, e.g. bio-technology, nano-technology, etc.
- ix) Upgrading the scientific knowledge as well as the technological skills and capabilities of human resources.

Many demonstration projects such as EP3, SEAM, and EBAB have been implemented in the Egyptian textile and clothing sector (4 public and 3 private full integrated companies) focusing on environmental issues including: industrial pollution prevention/cleaner production, environmental impact assessment and waste management.

A general overview of the local characteristics, the processes and techniques applied, their environmental impacts as well as implementation of proper cleaner production opportunities and their positive impacts on both product and environment quality is given here, along with significant financial savings covered in the technical audit reports, guidance manuals, case studies of the aforementioned projects and R&TD activities.

Figure 6 shows the chemicals used as well as the production stages, i.e. NaOCl bleaching followed by H₂O₂- bleaching, to get full bleached **knitted cotton fabrics**.

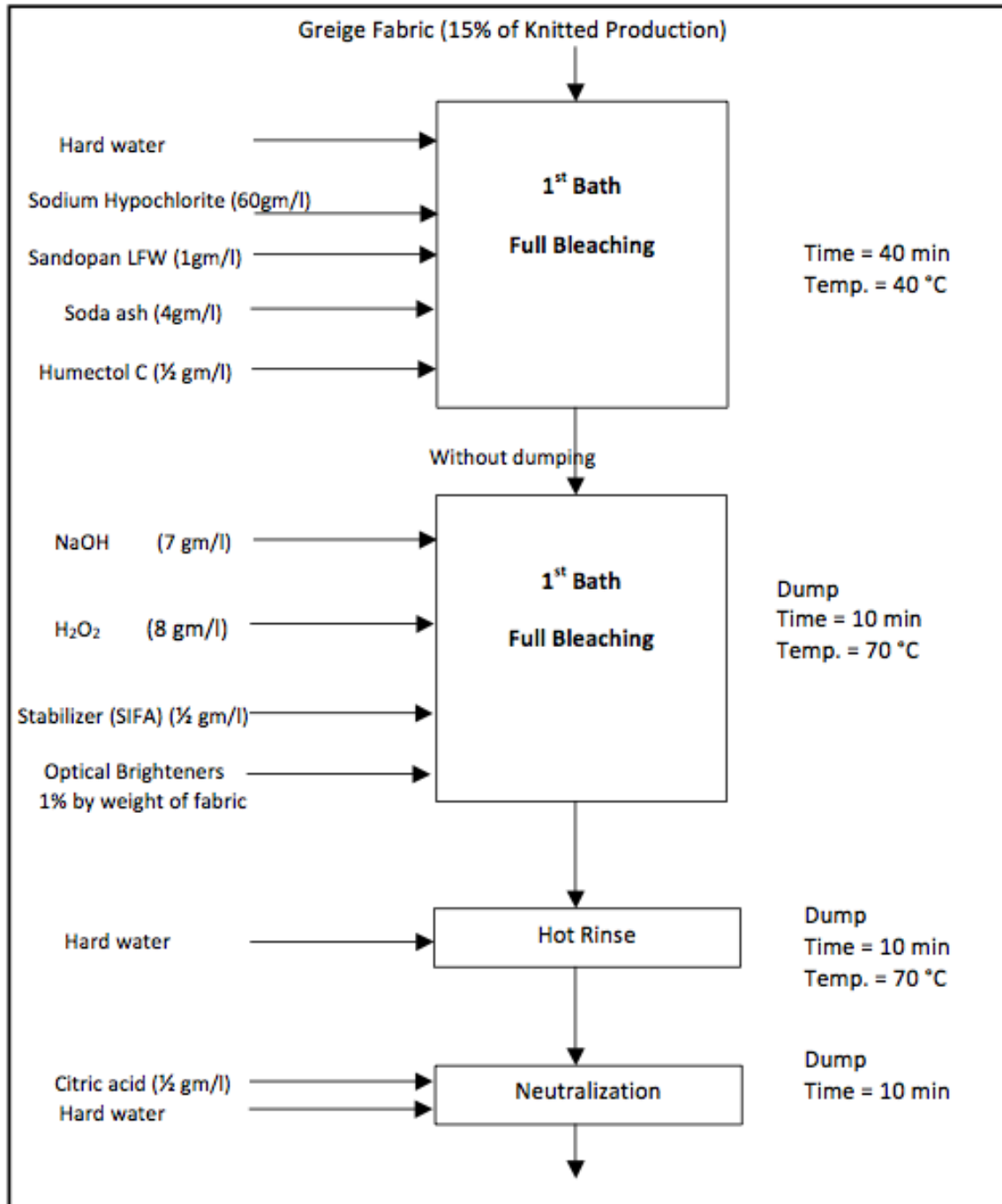


Figure 6. Company A- Full bleaching process – Two bath method in jets

3.2.1.2 Full bleaching of knitted cotton fabric/jet machine

Figure 7 demonstrates the modified full-bleaching regime without using NaOCl to avoid formation of absorbable organo-halogen (AOX).

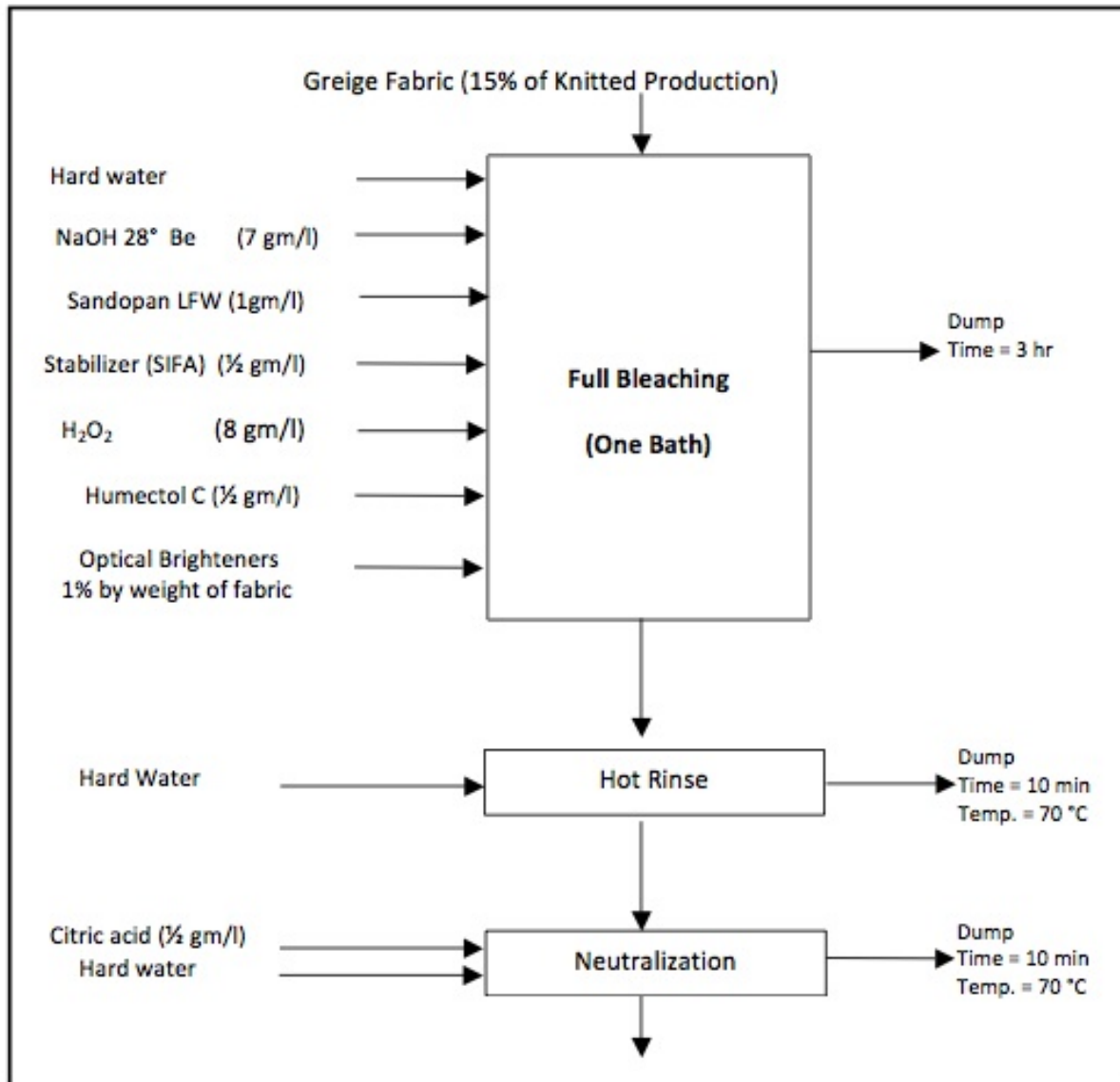


Figure 7. Full bleaching process- One bath method on cotton in jets

3.2.1.3 Combined desizing/scouring of woven cotton fabric

Continuous open width process-preparation range

Figure 8 shows continuous – open width desizing/scouring process of woven cotton fabric using per-sulphate as a desizing agent.

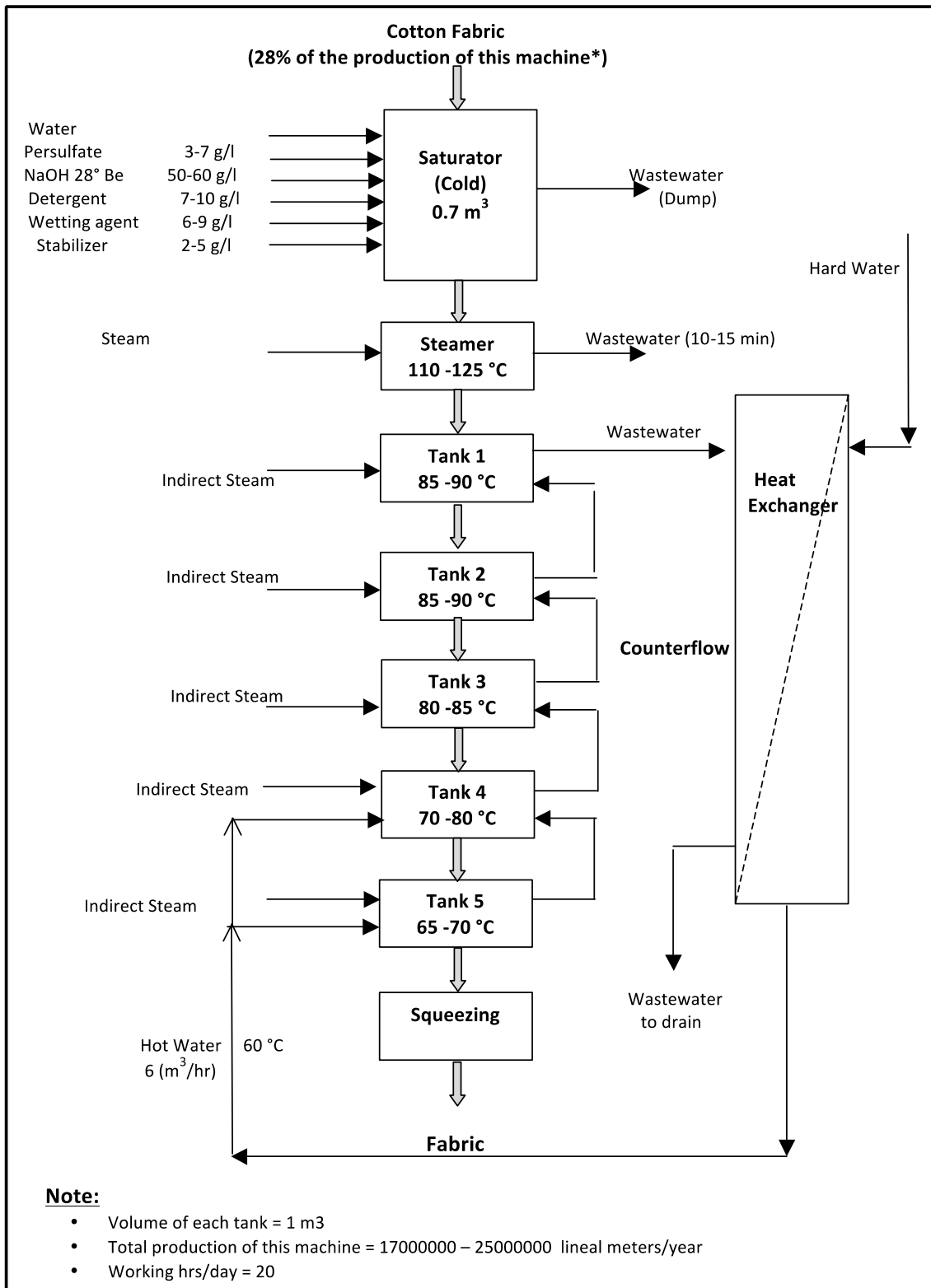


Figure 8.Scouring process flow diagram

3.2.1.4 Scouring/half bleaching of woven cotton fabric.

Continuous open width process-preparation range

Figure 9 shows combined scouring and semi-bleaching continuous open width flow diagram before dyeing.

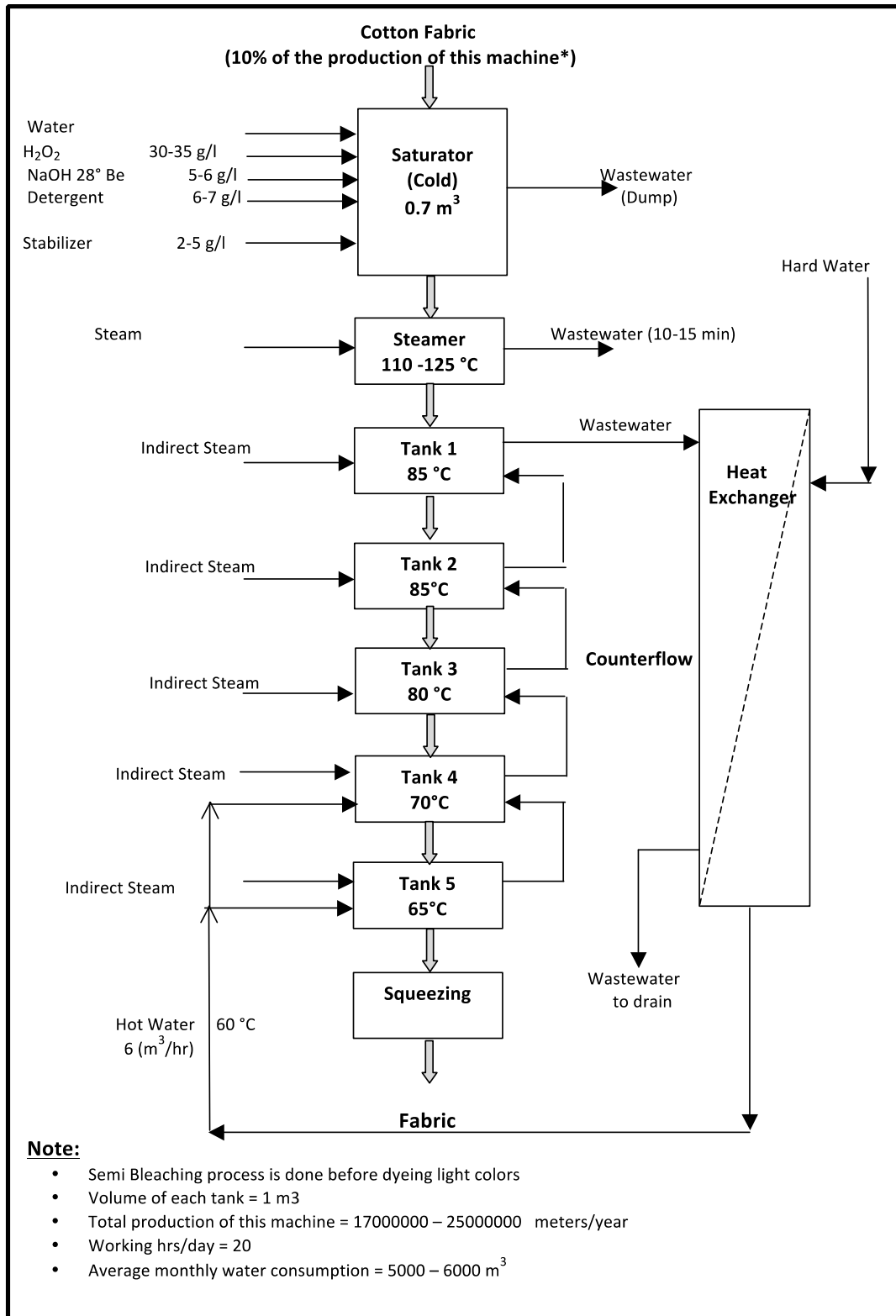
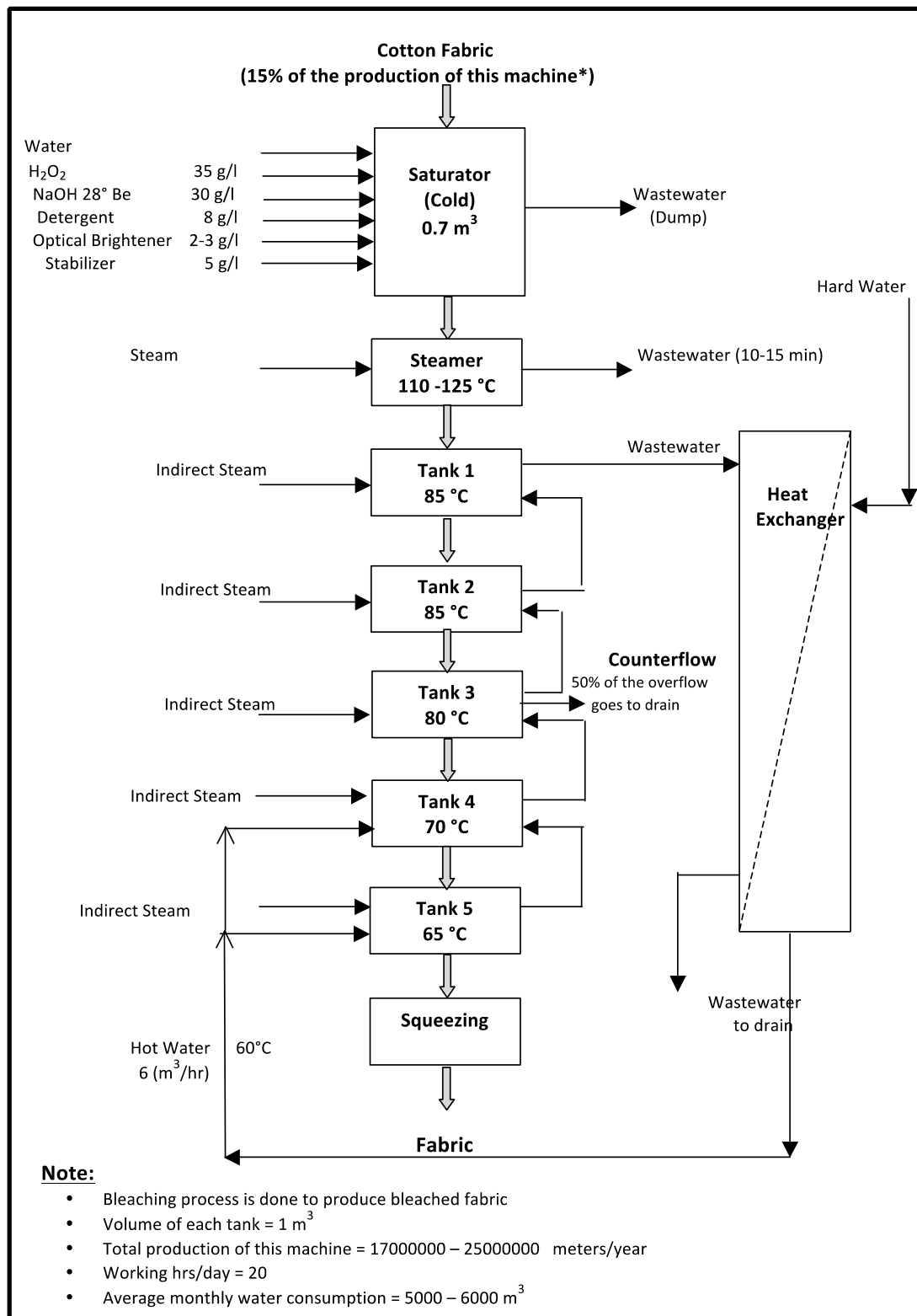


Figure 9. Semibleaching process flow diagram

3.2.1.5 Full-bleaching of woven cotton fabric

Figure 10 shows full bleaching process flow diagram to get full bleached fabric.



Figure

10.Full bleaching process flow diagram continuous open width process-preparation range

3.2.1.6 Combined scouring/half bleaching of cotton fabric.

Continuous open width process - woven factory.

Figure 11 shows combined scouring and bleaching in one step.

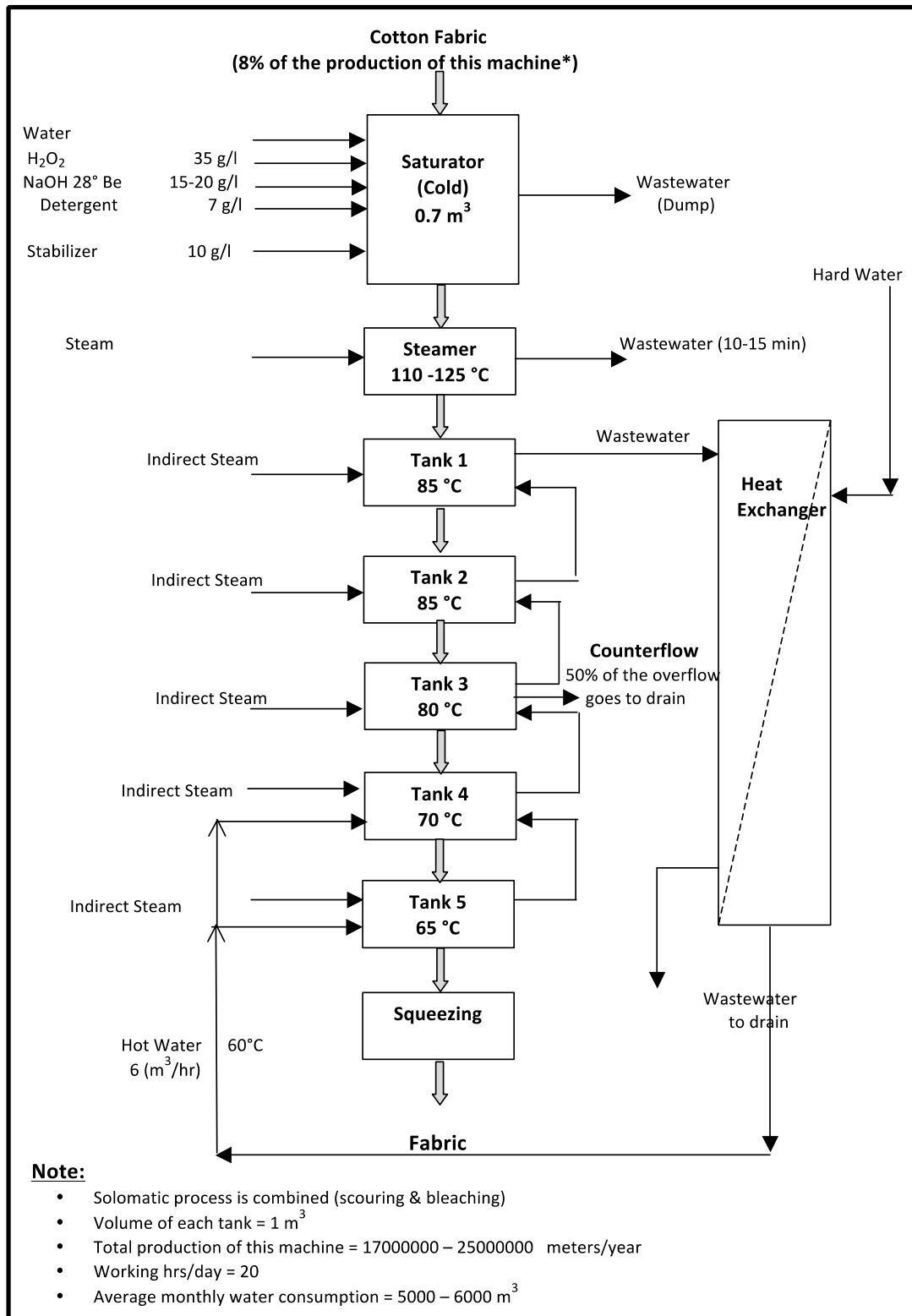


Figure 11.Solomatic process* flow diagram

3.2.1.7 Mercerization of Cotton Fabric

Continuous open width process - woven factory

Figure 12 shows continuous open width mercerization process of cotton fabric.

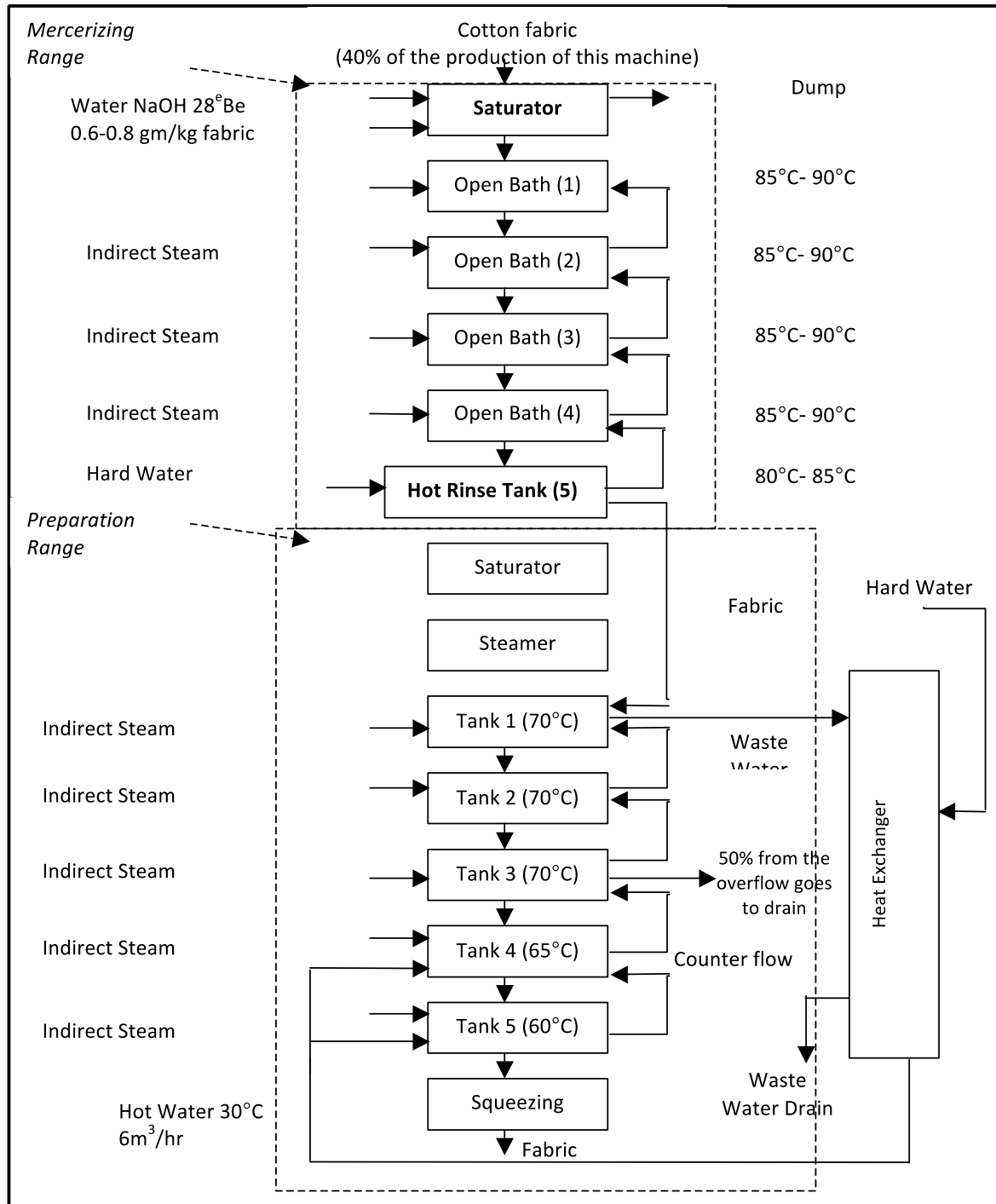


Figure 12. Mercerizing process flow diagram

3.2.1.8 Scouring/half-bleaching of knitted cotton fabric

Figure 13 shows combined scouring/half bleaching of knitted cotton fabric followed by light shade reactive dyeing using Jet machine.

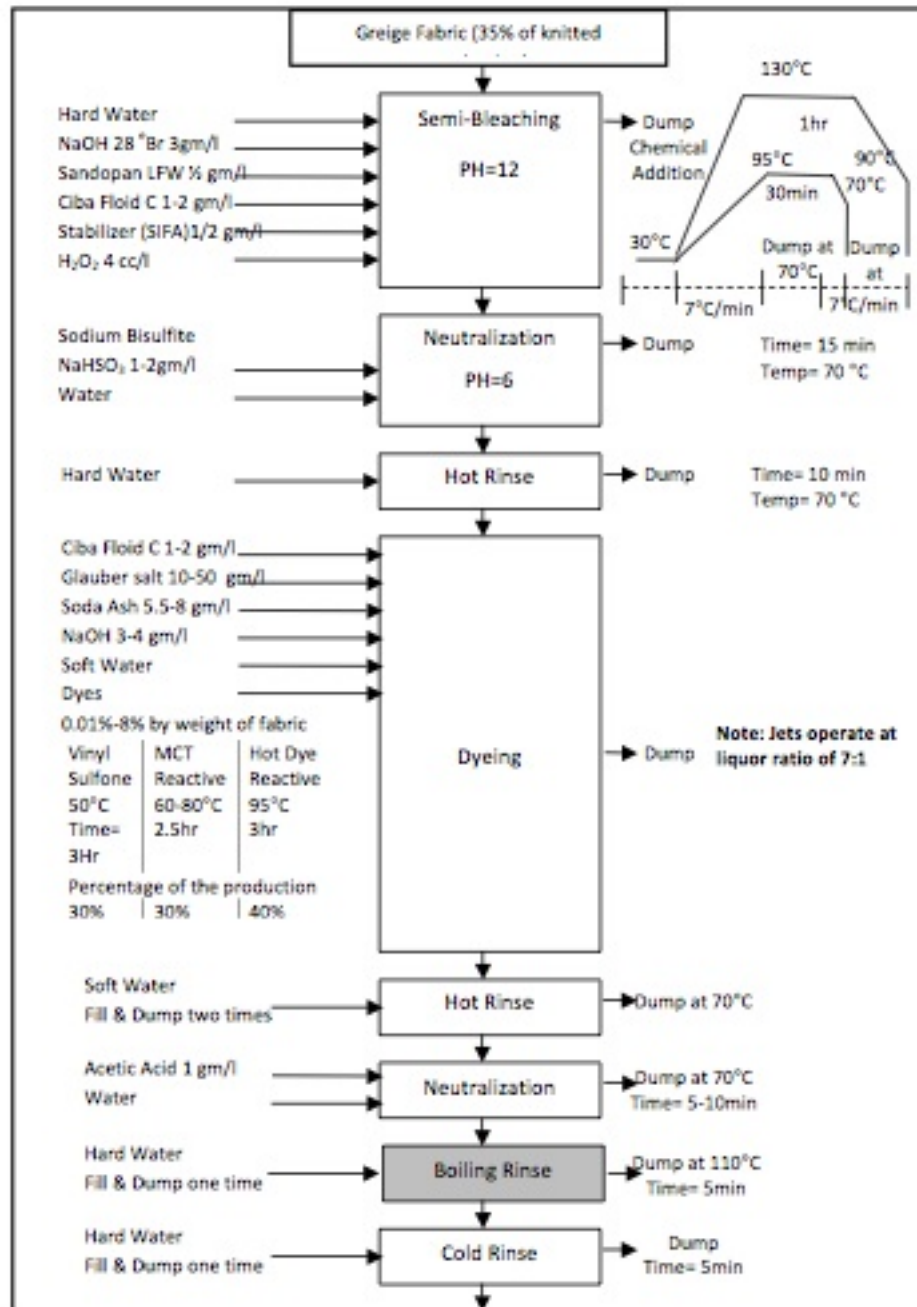


Figure 13. Dyeing process for light shades on cotton in jets

3.2.1.9 Scouring followed by dark reactive dyeing of knitted cotton fabric using jet machine

Figure 14 shows the flow diagram as well as scouring and reactive dyeing formulations to get dark shade-dyeing using a Jet machine.

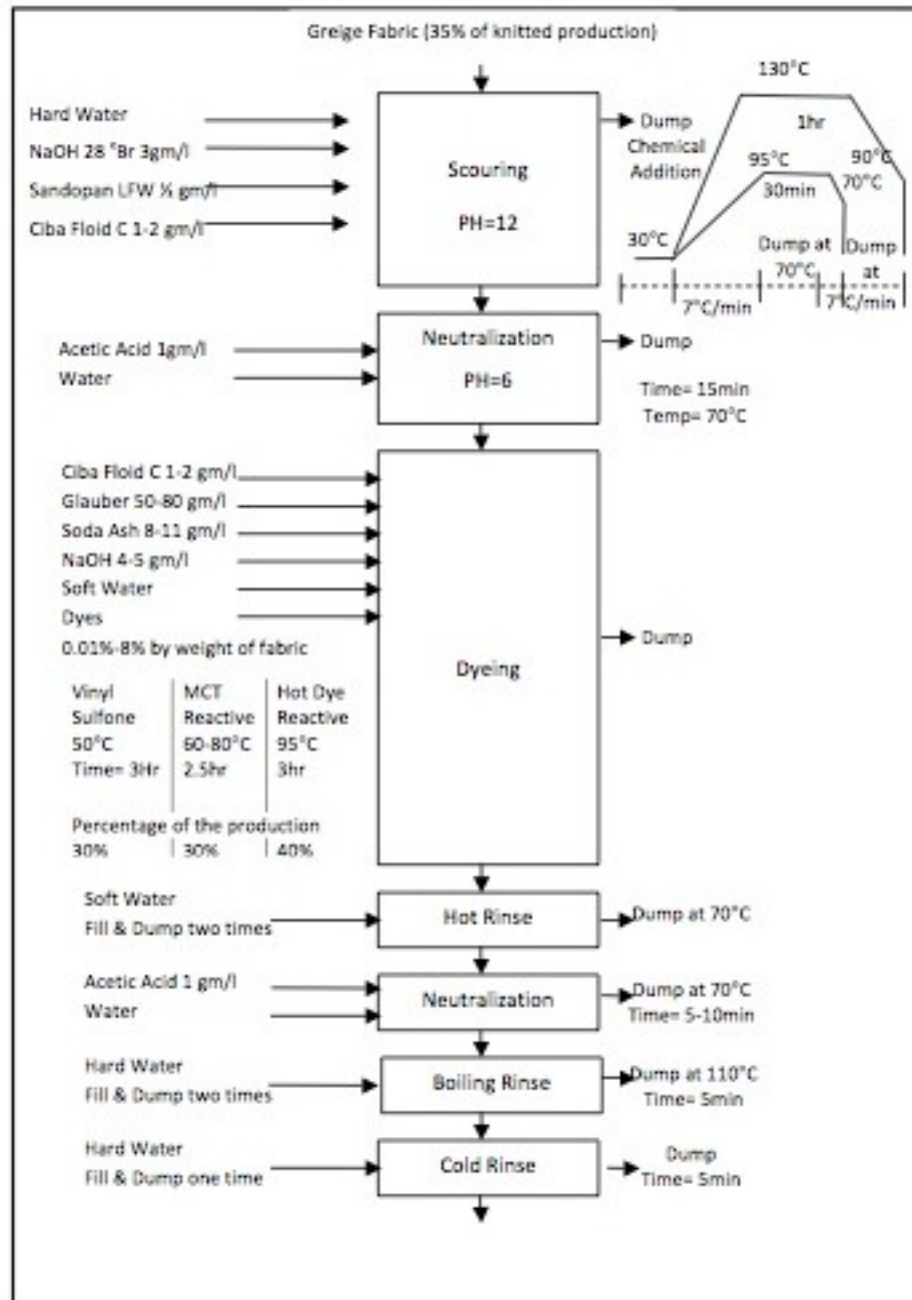


Figure 14. Dyeing process for dark shades on cotton in jets

3.2.1.10 Light and dark shade dyeing using jigger

Figure 15 and Figure 16 show light and dark shades reactive dyeing using Jigger. The production line includes scouring step followed by reactive dyeing (light or dark).

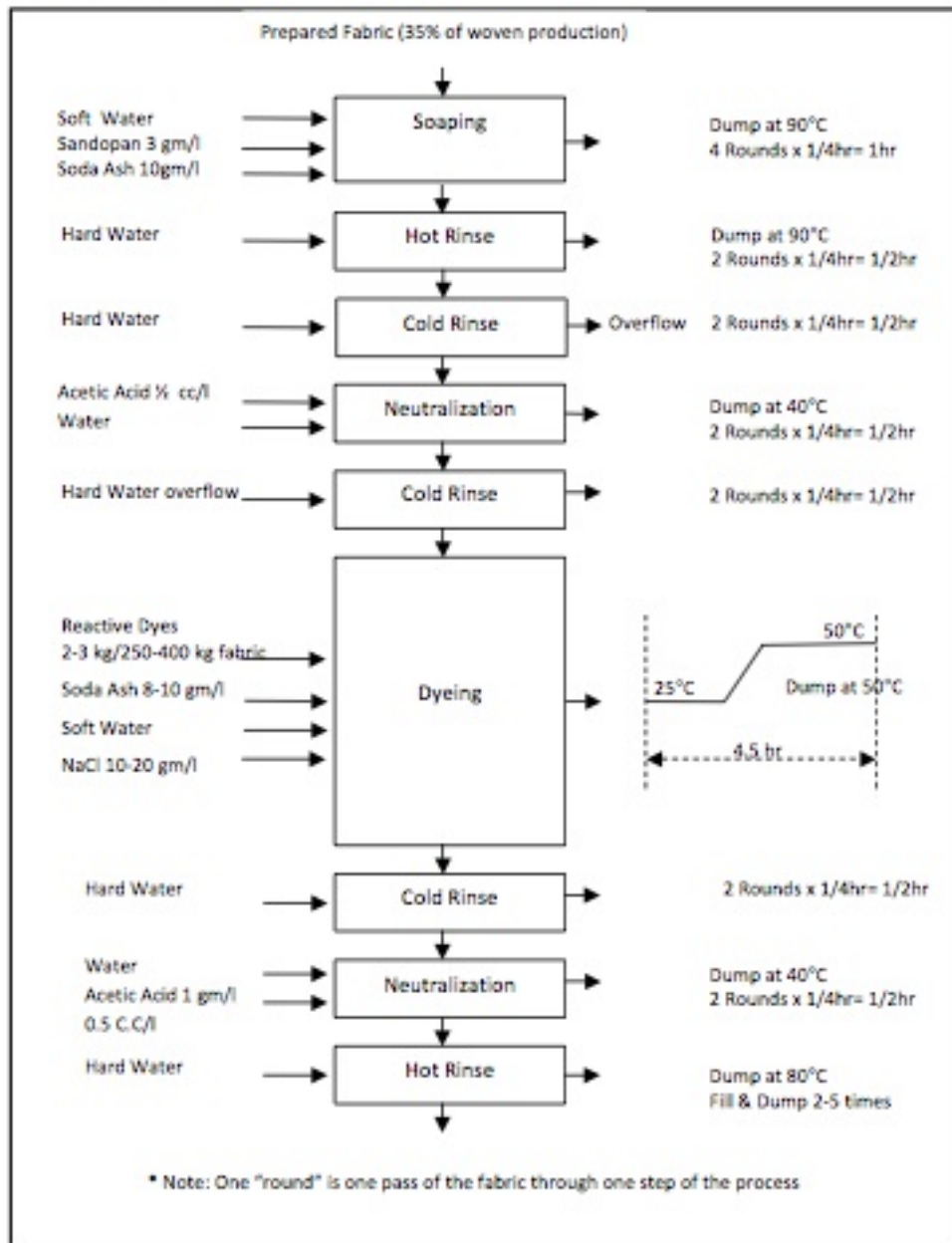


Figure 15. Reactive dyeing process for light shade fabric in jiggers

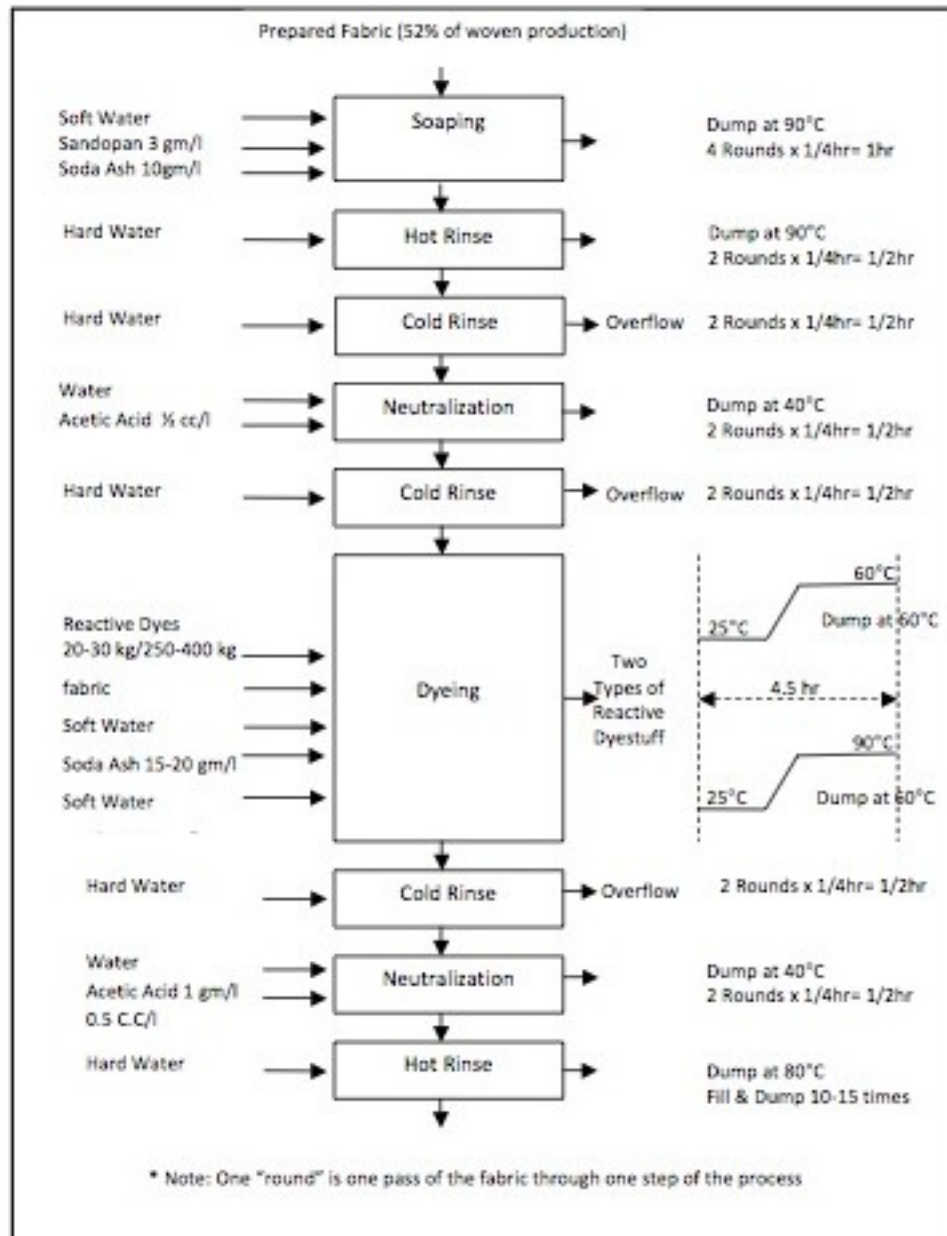


Figure 16. Reactive dyeing process for dark shade fabric in jiggers

3.2.1.11 Sulphur dyeing

Figure 17 shows sulphur dyeing of woven cotton fabric using a Jigger.

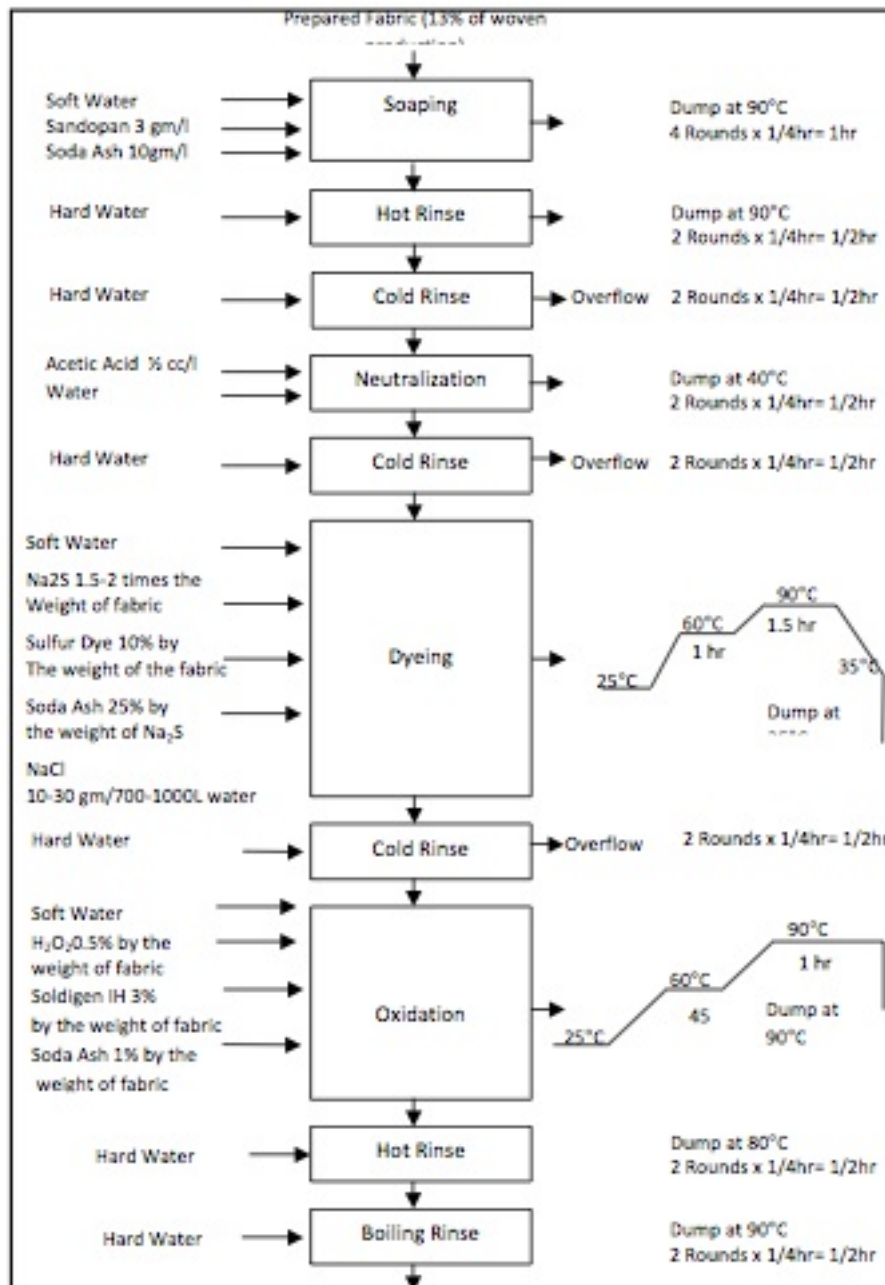


Figure 17. Sulphur dyeing process for dark shade fabric in jiggers

Table 22 shows some pollution prevention options to improve implementation of the concepts and approaches of cleaner production, as well as to minimize the environmental impacts.

Table 22. Summary of pollution prevention option

Pollution prevention recommendation	Environmental benefits	Cost to implement	Annual financial benefits	Payback period
Implement a pollution prevention management system	The most effective pollution prevention options will be implemented with the greatest sum of environmental benefits	None	To be determined	To be determined
Improve the wastewater discharge quality	Reduction of wastewater flow and constituents	To be determined	To be determined	To be determined
Reuse wastewater and recover heat	Reduction of wastewater discharge and fuel used	242,000 ¹ LE	242,000 LE	Less than one year
Recover steam condensate	Reduction of 426 ton/y fuel oil consumption, reducing emission of sulphur dioxide (SO ₂), carbon monoxide(CO), carbon dioxide (CO ₂) and nitrogen oxides (NO ₂)	30,000 ¹ LE	95,000 ¹ LE	4 months
Optimize reactive dyeing in jiggers	Reduction of 7,200 m ³ of water consumption, wastewater discharge and 51.3 tons fuel consumption	None	10,000-20,000 ¹ LE	Immediate
Replace acidic acid with formic acid	Reduction of organic (30-39 tons)/y BOD, 29-58 tons/y COD) discharge in water	None	85,000-169,000 LE	Immediate
Reuse black sulphur dye	Reduction of organic and sulphide discharge	18,200 LE	33,900-77,000 LE	3-6 months
Increase pad-batch dyeing for woven fabrics	Reduction of 80% water consumption, 50% energy consumption, 80% usage of chemicals, discharge of pollutants, and wastewater dissolved salts (TDS)	50,000 to 100,000 LE	55,700 LE	1-2 years
Implement future pollution prevention options	Reduction of wastewater, heat energy, dyes, chemicals, BOD, COD, and toxicity in water	To be determined	To be determined	-----
Total		310,000-360,000 LE	417,000 to 544,000 LE	8-9 months

Capital cost assumed equal for first year benefit.

3.2.2 SEAM Project

3.2.2.1 *Eco-labelling for textiles*

Table 23 gives some non-eco-friendly chemicals and auxiliaries used in the textile wet processing and their eco-friendly substituent.

In addition to diagnosis the project gives explanations and suggestions for corrective and preventive measures.

Table 23. Some non-eco-friendly chemicals and potential substitutes

Non eco-friendly chemical	Use	Alternative chemicals
Pentachlorophenol Formaldehyde	Size preservatives	Sodium silicofluoride
Nonyl phenyl ethylene oxide adducts (APEO)	Detergent, emulsifier	Fatty alcohol ethylene oxide adducts
Silicones and amino silicones and APEO emulsifier	Softening, water-repelling	Anionic/cationic/non-ionic softeners wax emulsions
Bleaching powder Sodium hypochlorite	Cotton bleaching	Hydrogen peroxide
Sodium silicate Phosphorous based compound	Hydrogen peroxide stabilizers	Nitrogen stabilizers
Dichlorobenzene Trichlorobenzene	Carries in polyester dyeing	Butyl benzoate Benzoic acid
Kerosene (as emulsion thickener)	Pigment printing	Water-based thickeners
Formaldehyde	Crease resisting of cotton and its blends	Polycarboxylic acid non-formaldehyde cross-linking agent
	Dye fixing for direct and reactive dyeing	Non-formaldehyde based products
	Dispersing agent for disperse dyeing and vat dyeing	
	Reactive softener (methylol stearamide type)	
Sodium dichromate	Vat dyeing	Hydrogen peroxide

3.2.2.2 Detailed breakdown of operating costs at Company B

a) Replacement of sodium hypochlorite by hydrogen peroxide.

Table 24. Half-bleaching – Comparison of conventional and modified processes (on the basis of 1 ton)

Item	Conventional Half Bleach		Modified Half Bleach		Cost difference (LE)
	Requirement	Cost (LE)	Requirement	Cost (LE)	
Chemicals					
Sodium Hydroxide (kg)					
Scour: 25-28 mg/l	61.8	136.0	38.4	84.50	-51.5
Half beach: 3 g/l					
Espycon 1030 (kg)					
Scour: 2 g/l	7.2	17.1	4.8	11.4	-5.7
Half beach: 3 g/l					
Reductol KB (kg) 2 g/l	4.8	16.8	2.4	8.4	-8.4
NaOC1 (kg)	38.5	5.0	-	-	-5
H ₂ O ₂ (35%) (kg)					
7.5-8 g/l	18.0	31.5	9.6	16.8	-14.7
Organic Stabiliser (kg)					
1 g/l	2.4	13.6	1.2	6.8	-6.8
Sodium Silicate (kg) 3 g/l	2.4	0.9	3.6	1.4	+0.5
Water (m ³)	63.3	28.5	31.1	14	-14.5
Wastewater treatment costs	50.6	20.2	24.9	10	-10.2
Steam (tons)	6.3	160	3.2	81.3	-78.7
Electricity (kWh)	425	80.8	184	35	-45.8
Labour	-	33.3	-	14	-19.3
Time (minutes)	100	-	56	-	-
Total cost	-	543.7	-	283.6	-260.1

It is clear that the implementation of the modified methods results in a significant reduction in energy, water and chemical consumption as well process time, which in turn reduce the total cost of production along with minimize the environmental impacts via replacement of NaOCl and reduction of NaOCl quantity, taking in consideration the product quality.

Table 25. Half-bleaching – Comparison of conventional and modified processes

Item*	Conventional full bleach		Modified full bleach		Cost difference (LE)
	Requirement	Cost (LE)	Requirement	Cost (LE)	
<i>Chemicals:</i>					
Sodium Hydroxide (kg) Scour:25-28 g/l Full Bleach:3g/l	61.8	136	42	92.4	-43.6
Espycon 1030 (kg)3g/l	7.2	17.1	7.2	17.1	0
Reductol KB? (kg)	4.8	16.8	2.4	8.4	-8.4
H ₂ O ₂ (35%) (kg) 10-12 g/l	18	35.5	22.8	39.9	+4.4
Organic stabilizer (kg) 2g/l	2.4	13.6	3.6	20.3	+6.7
Sodium Silicate (kg) 2g/l	2.4	0.9	6	2.3	=+1.4
Water (m ³)	46.6	21	46.6	21	0
Wastewater costs (m ³)	37.3	14.9	37.3	14.9	0
Steam (tons)	4.8	121.9	4.8	121.9	0
Electricity (kWh)	403	76.6	403	76.6	0
Labour	-	20.3	-	20.5	+0.2
Time (minutes)	82	-	82	-	0
Total cost	-	474.6	-	435.3	-39.3

It is evident that the rationalization of the used chemicals in the conventional bleaching is accompanied by a save in total cost as well as a reduction in the alkalinity of the effluent, taking in consideration the quality of final product.

b) Replacement of kerosene with synthetic thickener in pigment printing.

Table 26. Full bleaching- Comparison of conventional and modified process

Constituent	Full emulsion paste (full kerosene)		Low kerosene paste (partial substitution)		Zero kerosene paste (full substitution)	
	Quantity(kg)	Cost (LE)	Quantity (kg)	Cost (LE)	Quantity (kg)	Cost(LE)
Imperon thickener N2282	-	-	20	350	30	525
Ammonium Hydroxide	-	-	5	15	5	15
Imperon Binder MTB	80	412	100	515	100	515
Miner Daico Binder SME	80	409.6	100	412	100	412
Kerosene	675	472.5	150	105	-	-
SolegalWET (emulsifier)	150	120	5	40	-	-
Diammonium hydrogen phosphate (1/2)	30	50	38	63	38	63
Water	120	0.06	582	0.3	727	0.36
Total	1,135	1,464*	1,000	1,500*	1,000	1,530*
%increase in cost (relative to full emulsion paste)	-	0	-	2.5%	-	4.5%

It is clear that full replacement of kerosene in pigment printing with synthetic thickener results in a remarkable improve in working conditions, air emissions and water contamination, i.e. better quality of environment and product, with an increase in total cost (4.5%) compared with the traditional one.

3.2.2.3 Company C (Full bleaching)

a) Process flow diagrams of conventional method

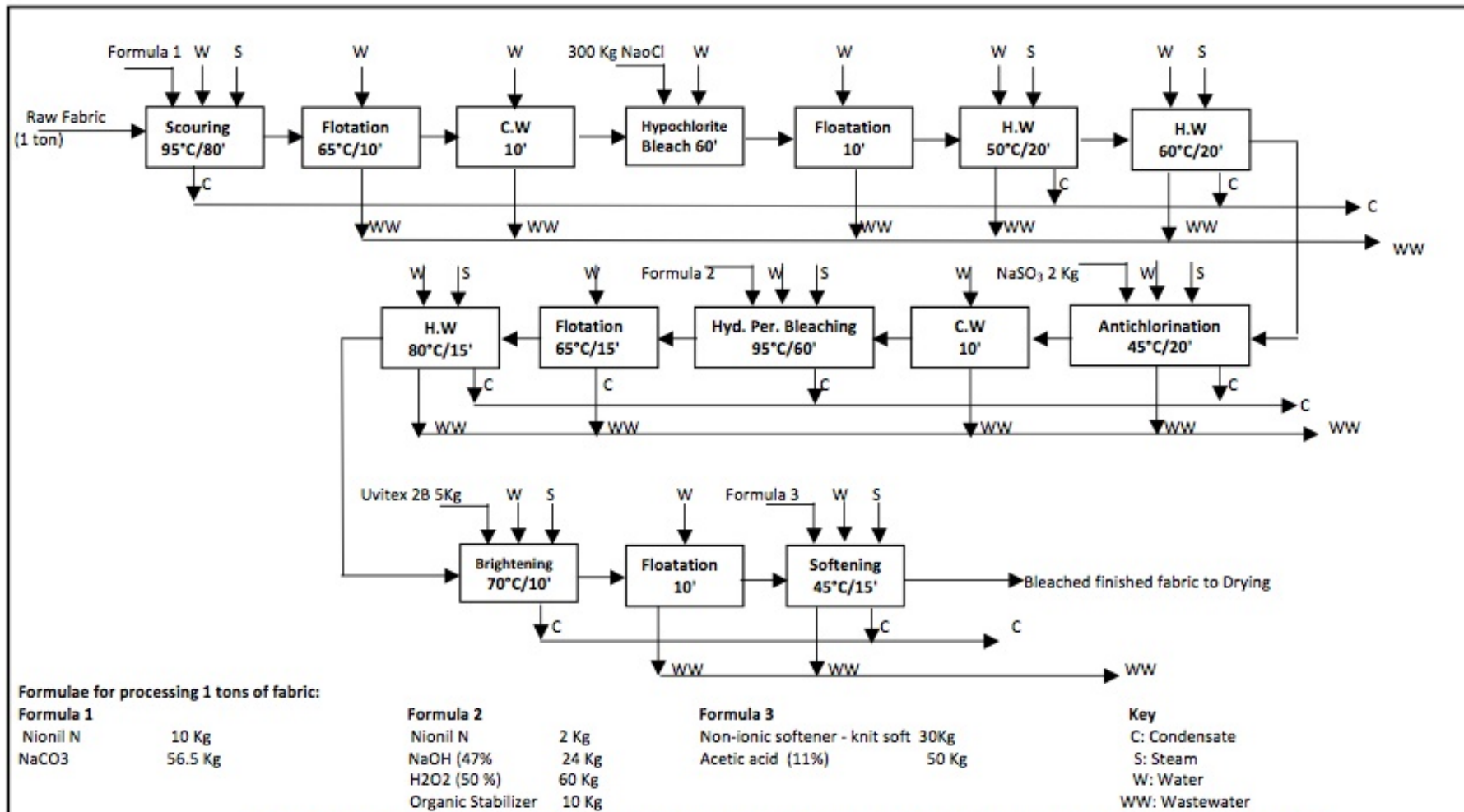


Figure 18. Process flow diagram of conventional full bleaching and finishing 1 ton of knitted fabric at Company C

b) Process flow diagrams of modified method

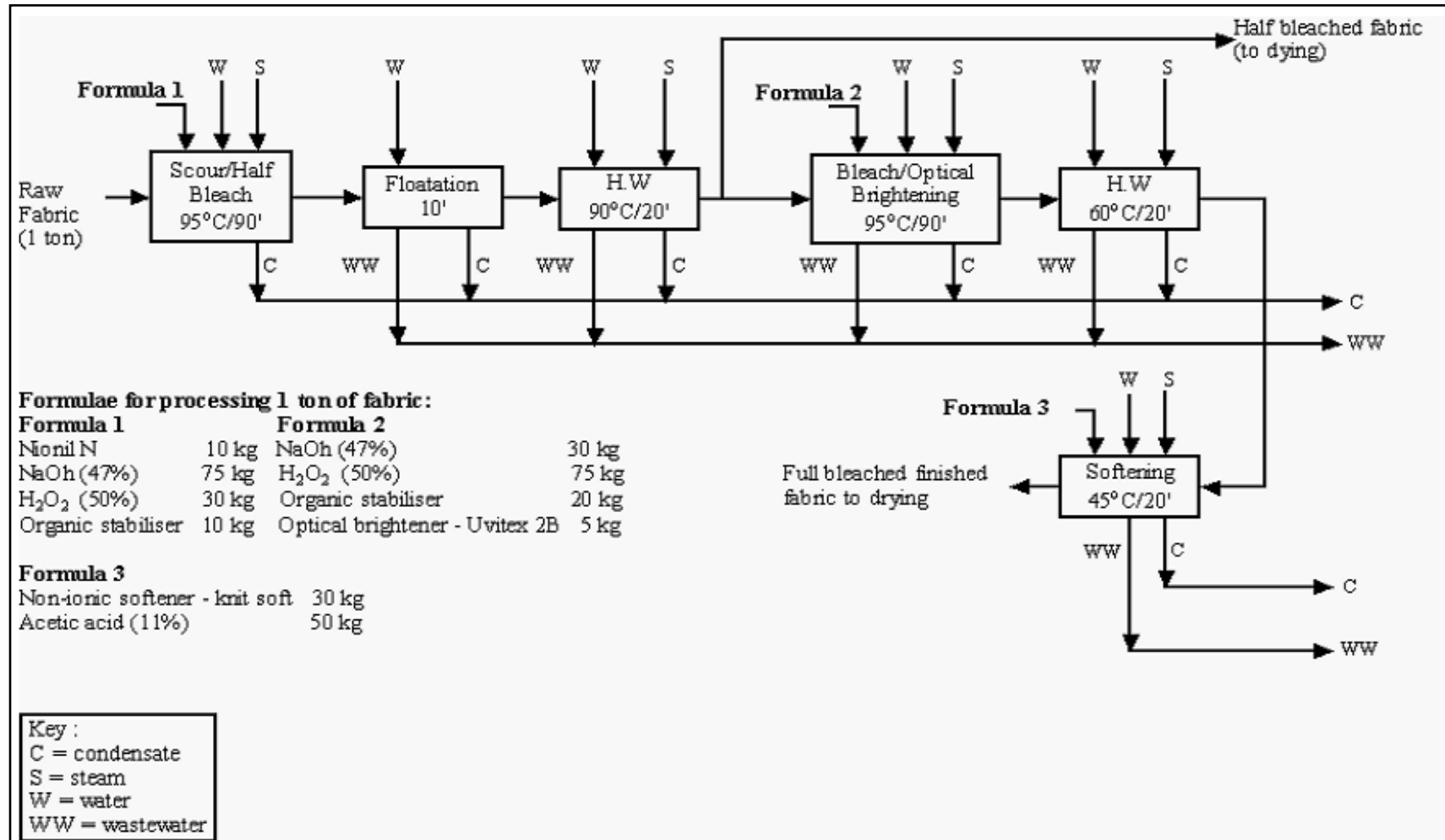


Figure 19. Process flow diagram of the suggested method of bleaching and finishing 1 ton of knitted fabric at Company C

Table 27. Comparison for full bleaching of 1 ton fabric

Company C

Parameter	Conventional method		Modified method		Savings
	Requirement (kg)	Cost (LE)	Requirement (kg)	Cost (LE)	
Chemicals:					
Nionil N	12	30.8	10	25.6	5.2
NaOH (47%)	80.5	48.3	105	63	14.7
NaOCl	300	105	--	--	105
Na ₂ HSO ₃	2	10	--	--	10
H ₂ O ₂ (50%)	60	132	105	231	(99)
Organic stabilizer	10	22	30	66	(44)
Uvitrex 2B	5	57	5	57	0
Knit Soft	30	100.3	30	100.3	0
Acetic acid (11%)	50	37	50	37	0
Cost of Chemicals		542.4		579.9	(37.5)
Water(m³)	151	75.8	58.98	29.4	46.4
Steam(t)	7.8	190.3	6.65	162.1	28.2
Electricity (kWh)	69.2	14.5	5.44	10.6	3.9
Cost of utilities		280.6		202.1	78.5
Time (h)	18.45		13.45		5 hours
Labour		92.2	--	67.3	24.9
Total cost		915.2		849.3	65.9

Table 27 shows replacement of NaOCl with H₂O₂ in full bleaching results in an improvement in product quality, environmental quality and in total cost.

3.2.2.4 Combining preparatory processes

Company D (Desizing and Scouring)

a) Conventional separate desizing and scouring

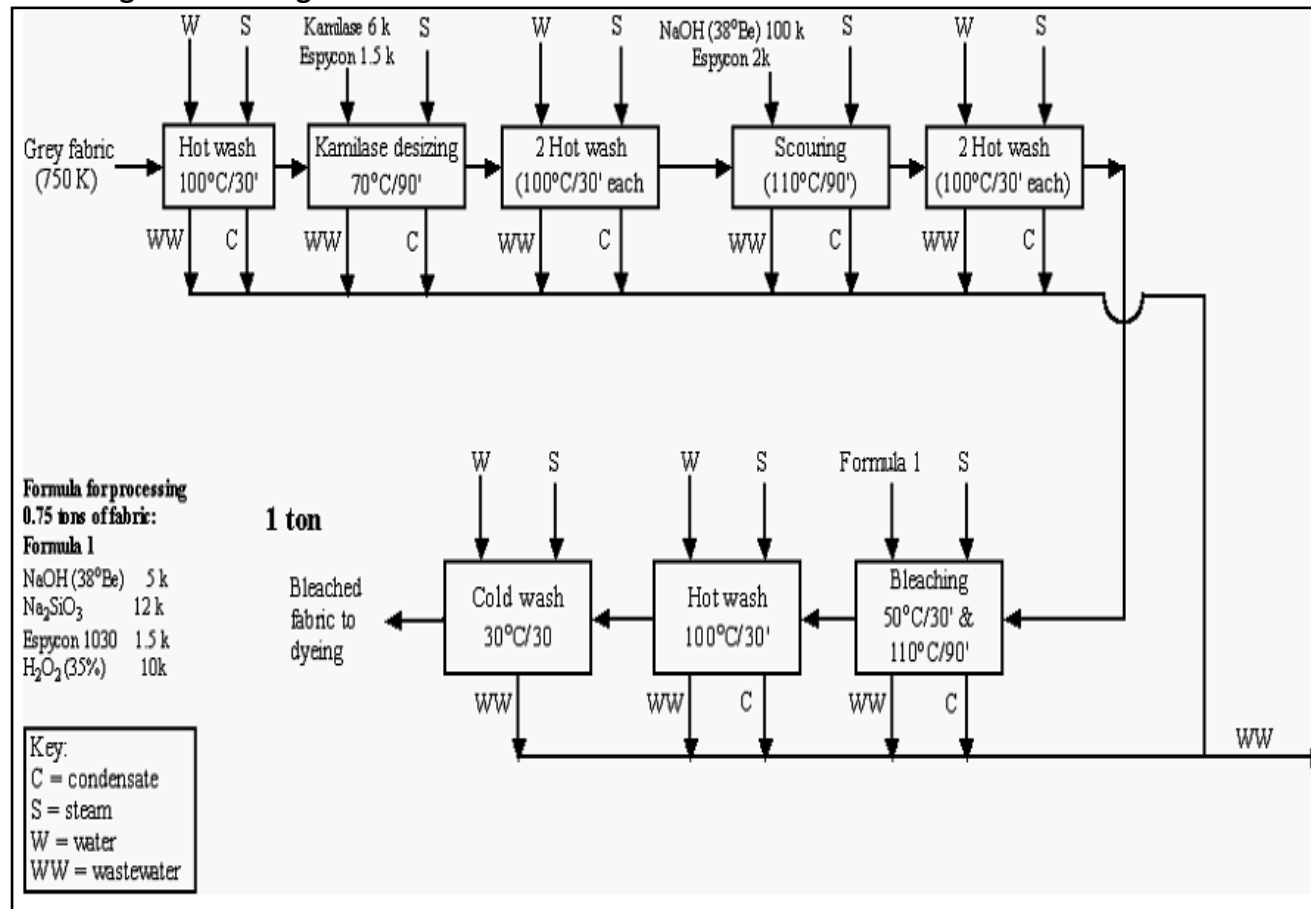


Figure 20. Process flow diagram of conventional separate desizing and scouring process using Kamilase enzyme on valid Henriksen Jigger at Company D for processing 0.75 tons of fabric

b) Conventional combined desizing and scouring

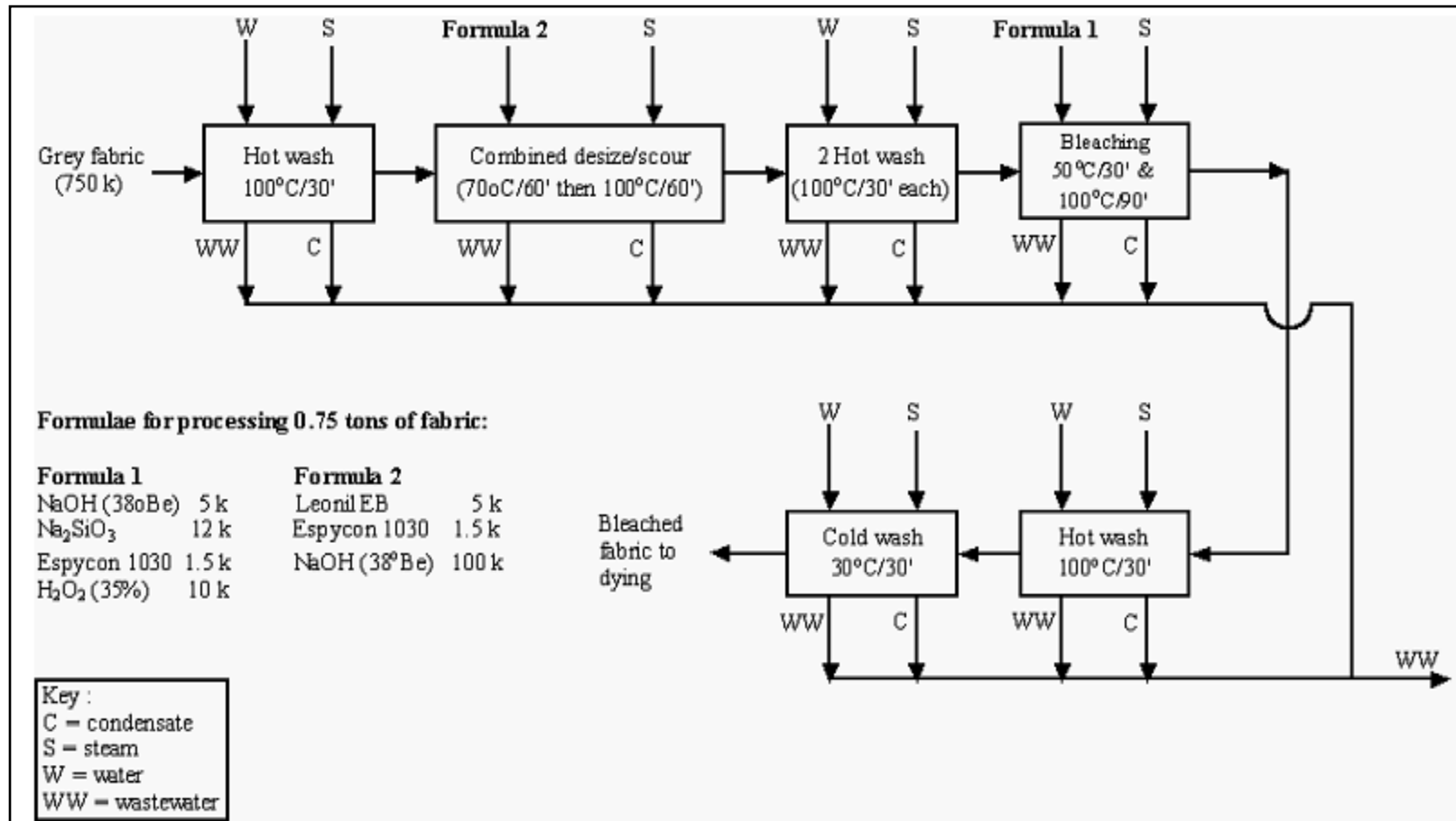


Figure 21. Process flow diagram of conventional combined desizing/scouring process using Leonil EB on Vlad Henrikson Jigger at Company D to process 0.75 tons of fabric

c) Modified combined desizing and scouring

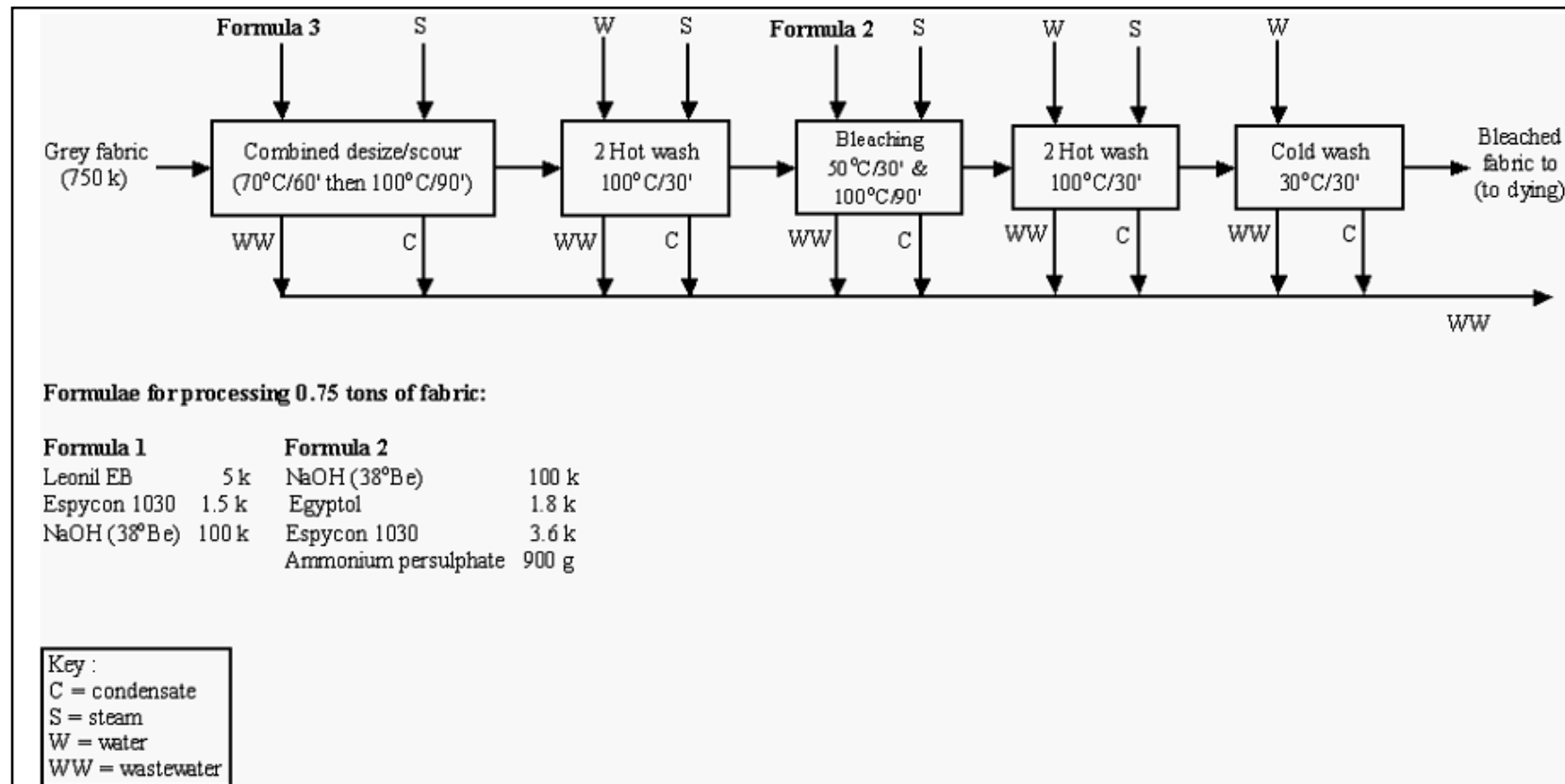


Figure 22. Process flow diagram of modified combined desizing/scouring process using ammonium persulphate on Vlad Henrikson Jigger at Company D to process 0.75 tons of fabric

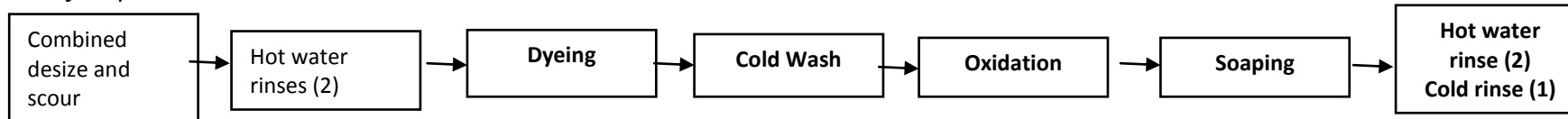
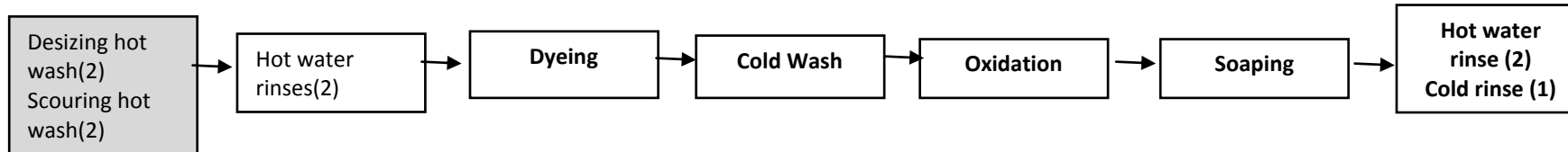
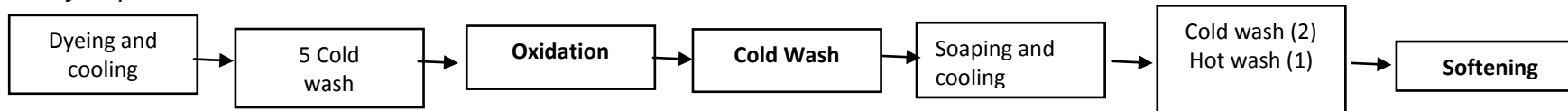
Table 28. Comparison of process for pre-treatment 1 ton of fabric at Company D

Item	Conventional				Modified		Savings	
	Separate (Kamilase)		Combined (Leonil EB)		Persulphate (combined)		Modified method and	
	Require-ment	Cost (LE)	Require-ment	Cost (LE)	Require-ment	Cost (LE)	Conv. (sep.)	Conv. (sep.)
Chemicals (kg)								
Kamilase	8	30.8	--	--	--	--	30.8	--
Espycon1030	6.67	15.8	4	9.5	6.3	15	0.8	(5.5)
Egyptol	--	--	--	--	2.4	15.8	(15.8)	(15.8)
NaOH (38 Be)	140	158.2	140	158.2	140	158.2	0.0	0.0
Leonil EB			6.67	154.3	--	--	--	145.3
Ammonium Persulphate	--	--	--	--	1.2	17	(17)	(17)
Na ₂ SiO ₃	16	6.1	16	6.1	16	6.1	0.0	0
H ₂ O ₂ (35 %)	13.3	23.3	13.3	23.3	13.3	23.3	0.0	0
Cost of chemicals		243.2		342.4		235.4	(1.2)	107
Water (m³)	27.2	12.2	18.8	8.5	18.8	8.5	3.7	0
Steam (t)	4.1	61.5	3	45	3	45	16.5	0
Electricity (kWh)	94	17.9	76.4	14.5	76.4	14.5	3.4	0
Cost of utilities		91.6		68		68	23.6	0
Time (h)	10.67	--	8.67	--	8.67	--	2	0
Labour		48		39		39	9	0
Total cost (LE)		373.8		449.4		342.4	31.4	107

From Figure 20, Figure 21 and Figure 22, as well as data given in Table 28, it is clear that modification of combined desizing/scouring using (NH₄)₂S₂O₈ as an oxidizing agent for starch-sized fabric results in a significant reduction in water, steam, electricity, and total cost compared with the separate process using enzyme (conventional method), along with better quality of the treated fabric.

3.2.2.5 *Sulphur black dyeing*

Simplified flow diagrams showing where modifications were implemented and the associated savings made
(Modified process indicated by shading)

(a) Company E combining the desizing and scouring stages*Modified process**Conventional Process***(b) Company F: elimination of hot, cold and over flow washes***Modified process*

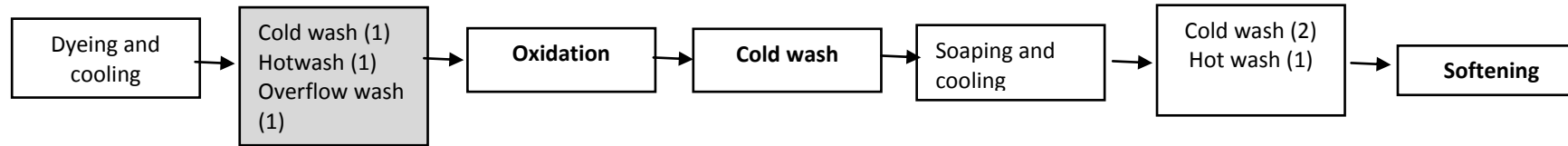
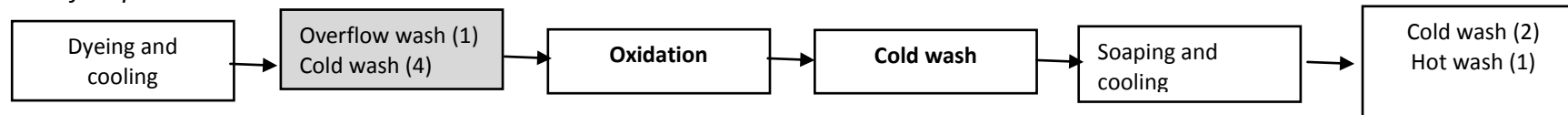
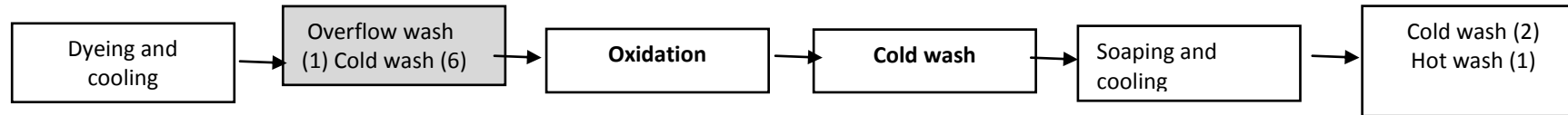
Conventional Process**(c) Company G: elimination of hot, cold and over flow washes***Modified process**Conventional Process*

Figure 23. Simplified flow diagram showing where modifications were implemented and associated saving made

Table 29. The cost and benefits at Company E

Conventional and modified processing costs (LE) for 1 ton of fabric				
Item	Grey shade		Black shade	
	Conventional (sodium sulphide and potassium dichromate)	Modified (glucose and sodium perborate)	Conventional (sodium sulphide and sodium dichromate)	Modified (glucose and hydrogen peroxide)
Chemicals	850	838	1200	1280
Water	46	40	46	40
Steam	88	74	88	74
Electricity	63	49	63	49
Labour	400	310	400	310
Total (LE)	1,447	1,311	1,797	1,753
Difference	136		44	
% Savings	9.4%		2.4%	

Table 30. The cost and benefits at Company F

Conventional and modified processing costs (LE) for 216 kg of fabric		
Item	Black shade	
	Conventional (sodium sulphide and potassium dichromate)	Modified (glucose and hydrogen peroxide)
Chemicals	298.4	301
Water	32.8	20
Steam	75.6	46.3
Electricity	18.5	11.4
Labour	97.5	60
Total (LE)	522.8	438.7
Difference	84.1	
% Savings	16.1%	

Table 31. The cost and benefits at Company G

Conventional and modified processing costs (LE) for 1 ton of fabric			
Item	Sodium sulphide		Glucose
	Sodium dichromate	Hydrogen peroxide	Hydrogen peroxide
Chemicals	1,440	1,400	1,380
Water	110	110	93
Steam	570	450	450
Electricity	13	13	12
Labour	143	143	135
Total (LE)	2,276	2,116	2,070
Difference (LE)		160	206
% Savings		7.0%	9.1%

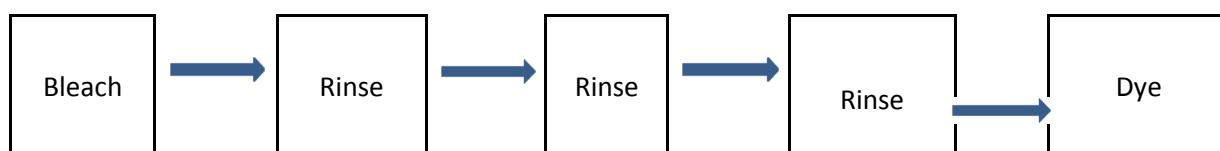
Table 32.Environmental benefits

Effluent characteristics before and after implementation (from the end of the dyeing type)									
Factory	process	BOD (mg/l)		Total Dissolved solids (mg/l)		Sulphides (mg/l)		Hexavalent chromium (mg/l)	
		Before	After	Before	After	Before	After	Before	After
Company E	Grey	360	1275	3385	2690	68	1	26	Nil
	Black	540	2150	3900	3450	117	2.5	27	Nil
Company F		347	1233	1510	1950	40	0.7	NA	NA
Company G	Peroxide	660	1070	--	--	103	1.5	Nil	Nil
	dichromate	530	--	--	--	112	--	8	--

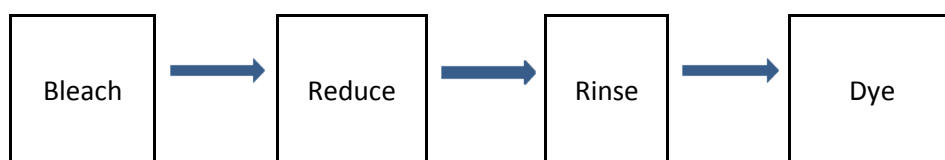
From the given flow diagrams and tables (17-20), it is clear that replacement of hazardous reductant (Na_2S) with glucose and non-eco-friendly oxidant ($\text{Na}_2\text{Cr}_2\text{O}_7$) with H_2O_2 have a positive impact on working conditions, quality of obtained dyeing and on the effluent quality.

3.2.2.6 Bleach Clean-up

Rinsing with water:



Reduction with chemical reducing agents:



Using catalase enzyme

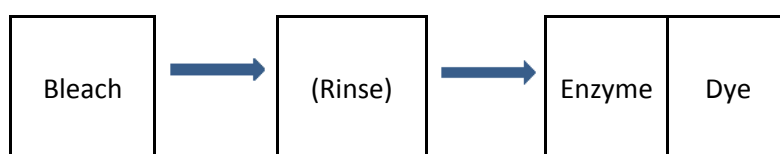


Table 33.A comparison between conventional and enzyme-based bleach clean-up methods

Savings in LE per ton of fabric processed			
Savings in:	Company F		Company G
	Half bleach and dye	Full bleach	Half bleach and dye
Chemical costs	30	5	(40)
Water use	25	29	23
Energy	158	149	120
Total savings (LE/ton)	213	183	103
Annual prod. (tons)	124	473	353
ANNUAL SAVINGS (LE)	26,412	86,559	36,359

Water and Energy Conservation

Table 34. Textile industry water and energy conservation opportunity matrix

Measure	Desizing	Scouring	Bleaching	Mercerization	dyeing	Finishing	Washing	Cooling	Drying	Control
Good manufacturing practices	•	•	•	•	•	•	•	•	•	•
Metering	•	•	•	•	•	•	•	•	•	•
Process supply reduction	•	•	•	•	•	•	•	•	•	•
Good operation and maintenance (e.g. steam, traps, insulation)	•	•	•	•	•	•	•	•	•	•
Pressure, flow, speed and temperature control (e.g. shut-offs)	•	•	•	•	•	•	•	•	•	•
Process combination	•	•	•	•	•	•				
Process bath reuse	•	•	•	•	•	•				
In-process reuse and recycling	•	•	•	•	•	•	•	•		•
segregation	•	•	•	•	•	•	•	•		
Out-of-process Reuse/recycling	•	•	•	•	•	•	•	•		
Counter-current washing	•	•	•	•			•			•
Condensate recovery	•	•	•	•	•	•			•	
Carry-over reduction techniques	•	•	•	•	•		•		•	•
Heat recovery	•	•	•	•	•	•	•	•	•	•
Cold processes	•	•	•	•	•	•				
Enzyme bleach clean-up			•				•			
Foam processing			•		•	•				•
Smart scheduling					•					•
Pad-batch dyeing					•					
Dye bath-reuse					•					•
Continuous knit dye range					•					
Low and ultra low liquor machines	•	•	•	•	•	•	•	•		
Low-add on finishing						•				•
Mechanical finishing						•				
High efficiency extractors							•		•	
Horizontal washers							•			
Incinerator dryers									•	
Automation	•	•	•	•	•	•	•	•	•	•

Table 34 gives a matrix that shows the identified evaluated, selected or implemented opportunities through the SEAM project at Company D and Company E companies.

At Company D and Company E**Table 35. Comparison of economics for water and energy conservation measures**

Measure	Cost (LE)	Annual Savings (LE/year)				Payback period (month)
		Water	Energy	Treatment	Total	
Company E						
Counter-current washing in the Kyoto Range	44,000	47,040	83,700	52,920	183,660	<3
Reuse of condensate from bleaching department	45,000	24,000	84,000	27,000	135,100	<4
Steam network insulation	48,000		135,126		135,126	<5
Reuse of wash rinses from yarn scouring/dyeing	80,000	29,040	45,463	32,670	107,173	<9
Automatic shut-offs (water, steam) on Gaston County Range	36,500	10,800	21,900	12,150	44,850	<10
Total	253,500	110,88	370,289	124,740	605,909	≈5
Measure	Cost (LE)	Annual Savings (LE/year)				Payback period (month)
		Water	Energy	Treatment	Total	
Company D						
Steam trap and valves replacement and maintenance	13,800		144,913*		144,913	<2
Reuse of condensate from bleaching and wool department	44,000	41,850	172,280	74,400	288,530	<2
Automatic shut-offs (water, steam) on pre-treatment ranges	55,000	22,140	72,915	39,360	134,415	<5
Steam network insulation	116,000		237,301		237,301	<6
Reuse of wash rinses from yarn scouring/dyeing	40,000	16,200	33,210	28,800	78,210	<7
Total	268,800	80,190	660,619	142,560	883,369	<4

* This is equivalent to steam savings of 6,200 tons per year and is inclusive of water cost. Of this cost, around 83% is attributed to fuel costs

The results of the cost benefit analysis for the water and energy conservation measures at Company D and Company E. are given in Table 35, in a prioritised order. On the other hand implementing the given options has been reduced emissions to air and water, and improved working conditions as well as production costs.

3.3 R&TD Activities

3.3.1 Economical and ecological bio treatment/half bleaching of cotton-containing knit fabrics on an industrial scale

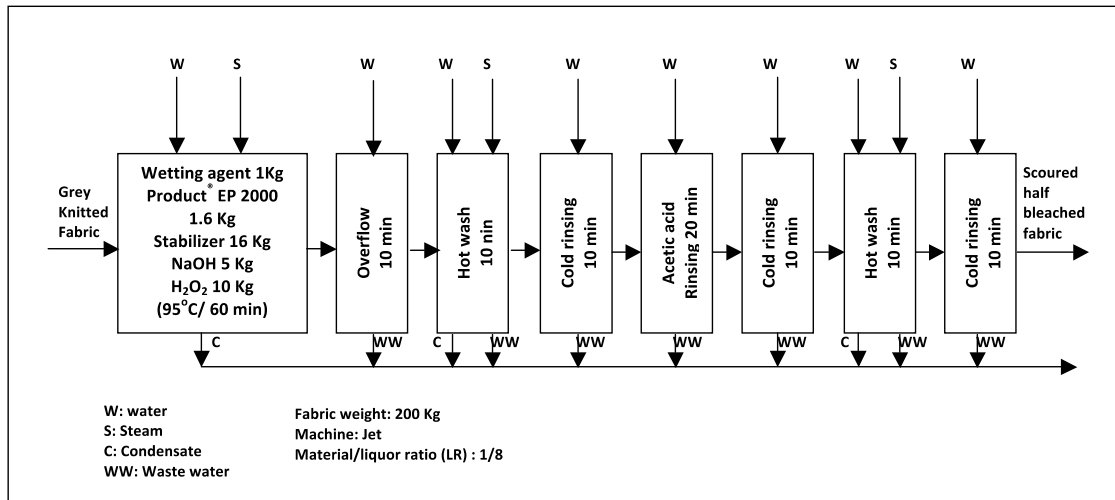


Figure 24. Traditional scouring/half bleaching

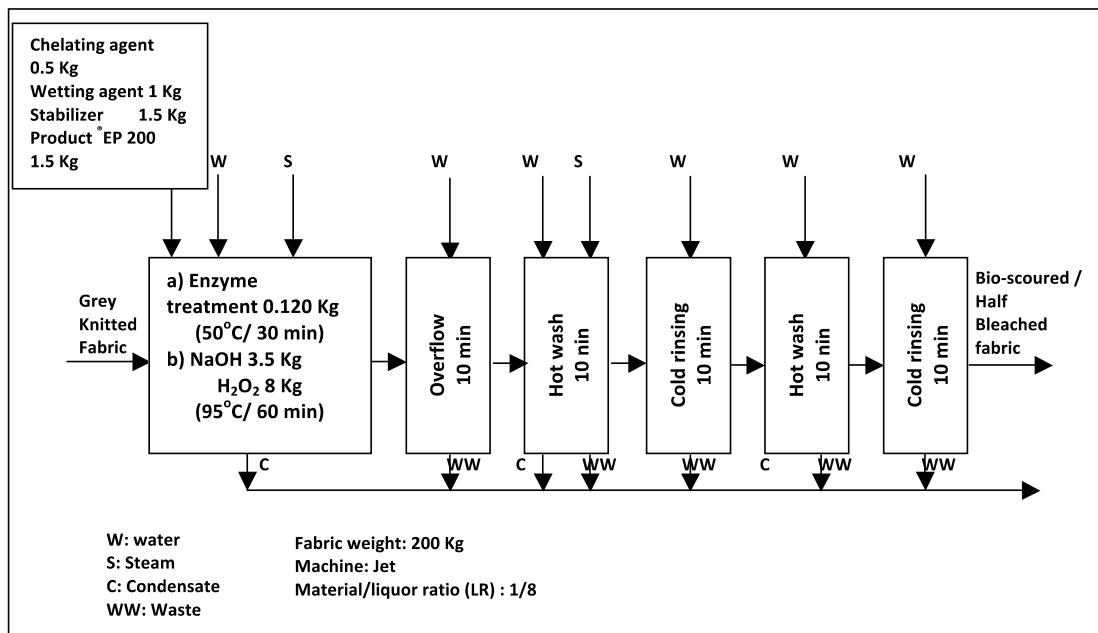


Figure 25. Bio-scouring/half bleaching

**Table 36. Cost analysis per one ton of Jersey knit fabric in Jet machine
(conventional process vs. new process)**

Chemicals	Conventional process		New process	
	Weight (kg)	Cost (LE)	Weight (kg)	Cost (LE)
NaOH (50%)	25	31.25	15	18.75
Bioprep® 3000 L	-	-	0.6	18
H ₂ O ₂ (50%)	50	100	40	80
Chelating agent	25	39.5	2.5	3.95
Product EP-2000	8	39.25	7	34.3
Organic stabilizer	10	52.5	7.5	39.4
Wetting agent	5	36.75	5	36.75
Acetic acid	1.25	4.75	-	-
Total cost (LE/ton)	-	<i>304.00</i>	-	<i>231.15</i>
Saving in chemical costs (%)	<i>23.96%</i>			

(Source: Ibrahim et al., *Polymer-Plastics Technology and Engineering*, 44: 881–899, 2005).

Modification of scouring/half bleaching process of grey knitted cotton fabric by using alkaline – pectinase enzyme along with a less amount of NaOH in addition to H₂O₂ results in: savings in water, energy and chemical consumption, improving the product quality as well as reducing the water pollution.

3.3.2 Pollution prevention of cotton-cone reactive dyeing

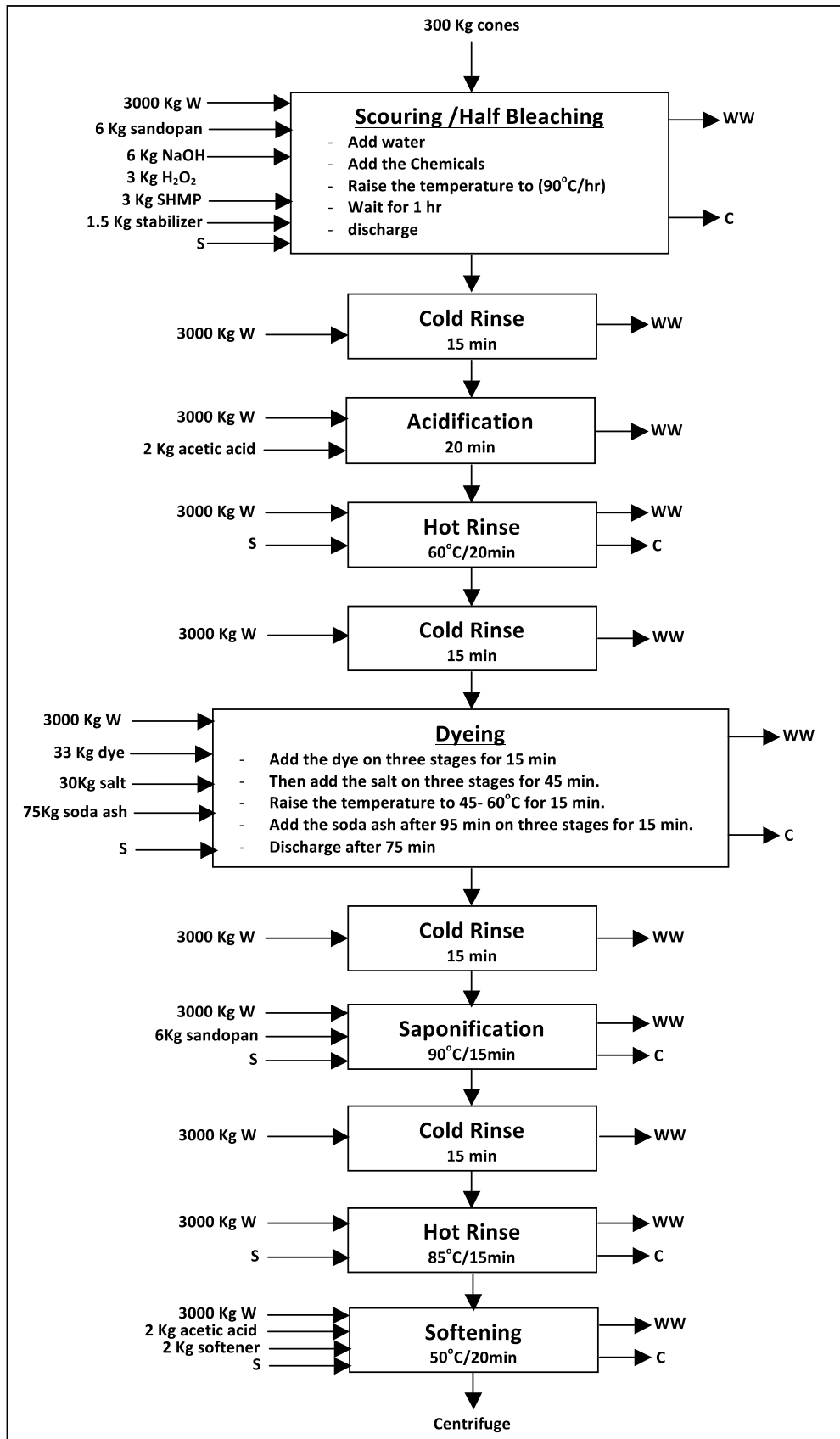


Figure 26. Flow diagram of reactive dyeing of cotton-cones in the plant
(where: w: water, s: steam, ww: wastewater and c: condensate)

The integrated process, i.e. dye reduction, soda ash minimization as well as replacement of acetic acid with citric acid, leads to cost saving as well as improvement in both product quality and effluent analysis.

Table 37. The three CP options implemented for the three employed samples

Dye (% shade)	Soda ash (kg)	Acid
Black sample		
Conv = 11%	Conv = 75	Conv = Acetic
Mod ₁ = 8.8%	Mod ₂ = 70	Mod ₃ = Citric
Blue Sample		
Conv = 7.5%	Conv = 75	Conv = Acetic
Mod ₁ = 5%	Mod ₂ = 70	Mod ₃ = Citric
Red Sample		
Conv = 7%	Conv = 75	Conv = Acetic
Mod ₁ = 6%	Mod ₂ = 70	Mod ₃ = Citric

- (1) Reducing the amount of dye (Mod₁)
 - Black from 11% to 8.8%;
 - Blue from 7.5% to 5%;
 - Red from 7% to 6%.
- (2) Reducing the concentration of soda ash (Mod₂)
 - For the three samples from 75 to 70 kg
- (3) Using citric acid instead of acetic acid (Mod₃), as the former is cheaper and less volatile, such that it does not leave the garment as alkaline as the latter

Table 38. Effluent analysis before and after applying the integrated process for the black sample

Parameter	Treatment		%Reduction	Limit of the Decree 44/2000 ¹⁰ .
	Conv	Mod _{int}		
pH	10.4	10.30	1.0	6-9.5
BOD (mg/l)	750.0	180.00	7.1	600.0
COD (mg/l)	5060.0	840.00	83.4	1100.0
TDS (mg/l)	17,016.0	2.17	-	/
TSS (mg/l)	258.0	0.03	-	800.0

(Source: N. A. Ibrahim, *Journal of Cleaner Production* 16 1321-1326 (2008))

¹⁰Law about discharging to the public sewer system.

3.3.3 A multiple-objective environmental rationalization and optimization for material substitution in the production of stone-washed jeans- garments

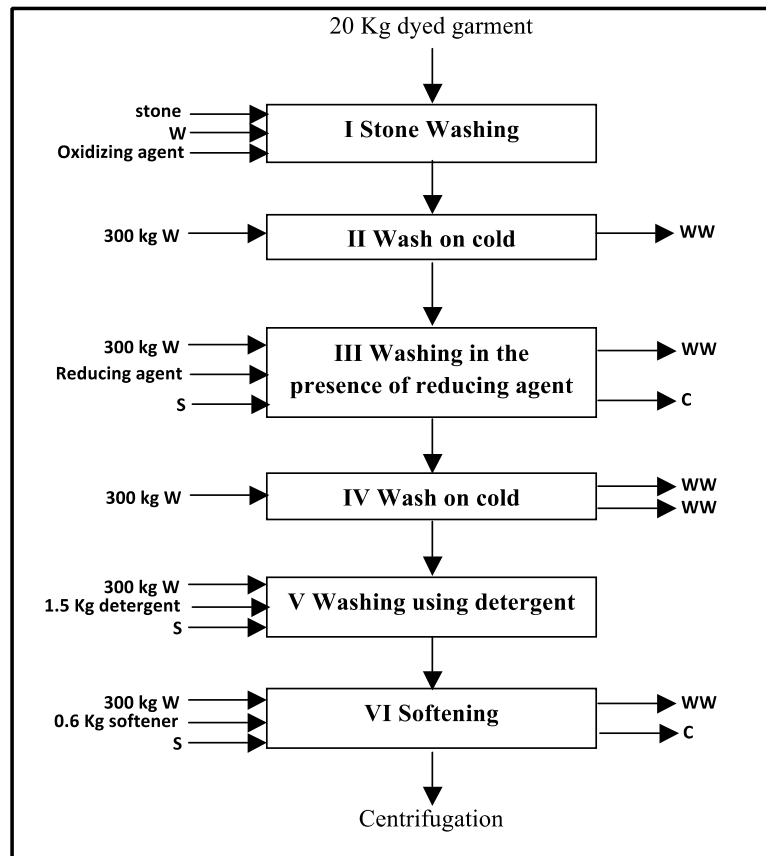


Figure 27. Flow diagram of stone washing of jeans garments (where: w: water, s: steam, ww: wastewater and c: condensate)

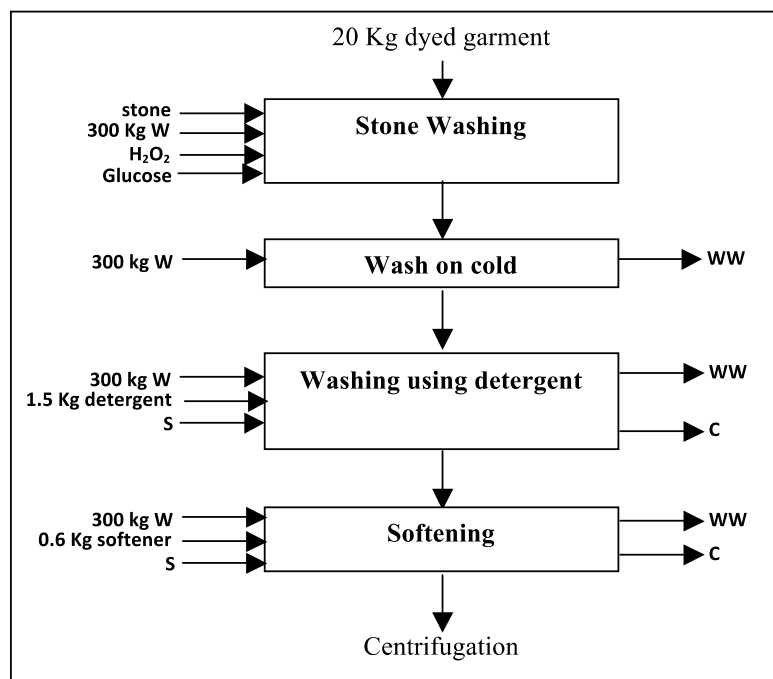


Figure 28. Flow diagram of stone washing of jeans garments by the Redox process (where: w: water, s: steam, ww: wastewater and c: condensate)

Stone washing in presence of H₂O₂/glucose redox system brings about stone-washed Jeans garment with high performance properties along with a noticeable decrease in the pollution load compared with other treatment options.

Table 39. Product quality and effluent analysis for the different treatments

Property		Treatments					
		Conv	Ox/Red	Ox/0	Red/0	Red/Red	Redox
Product quality	Colour Strength	43.8	40.6	42.3	44.4	46.5	27.2
	%Loss in weight	11.3	10.02	12.5	8.5	15.02	7.1
	Wettability (sec)	60.0	10.0	13.0	20.0	4.0	8.0
	%Elongation	18.0	22.0	19.0	17.0	21.0	20.0
	Tensile strength (kg)	71.5	74.0	72.0	54.0	75.5	83.0
	Abrasion resistance (cycles)	37 21.0	4397.0	5143.0	5962.0	7567.0	6782.0
	Crease recovery angle (dry)	75.0	95.0	98.0	89.0	72.0	104.0
	Crease recovery angle (wet)	125.0	167.0	210.0	130.0	153.0	238.0
	Stiffness (mgm)	39 16.0	2848.0	3983.0	3382.0	3204.0	5198.2
	pH-value	7.4	8.1	7.2	8.61	9.0	6.7
Effluent analysis	COD (mg/l)	9 95.0	1 560.0	3541.0	2993.0	3452.0	480.0
	BOD (mg/l)	300.0	890.0	2533.0	1996.5	2185.0	198.0
	TDS (mg/l)	2579.0	6 529.0	4098.0	3692.0	3875.0	2391.0
	TSS (mg/l)	14 90.0	5 272.0	3374.0	2864.0	3162.0	1372.0
	pH	5.84	7.2	6.9	7.5	7.9	6.5

(Source: N.A. Ibrahim, *Proceedings Of World Academy Of Science, Engineering And Technology*, Volume 30 July ISSN 1307-6884, 1053, 2008)

This chapter describes the various measures and techniques which can be implemented in the dairy industry to reduce or, better still, to prevent environmental impact. These environmentally friendly techniques are called “candidate BAT”. The focus of the BAT sector report at hand, and thus the candidate BAT, is on processes regarding cotton. This selection could be justified by two main reasons: the environmental relevance of these phases, the characteristics of the Egyptian 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 Commission Implementing Decision 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 description of the procedure for downloading technical datasheets is included in Annex 4 of this report.

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.

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 does not necessarily mean that the technique is a BAT. In this chapter, each technique will be discussed without prejudging whether it meets all the BAT criteria.

4.1 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 (textile BREF, scientific articles, international projects, EU technical reports) by the authors of the Report. 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). The reason for the selection of a group of techniques is related to the scope of the Report as explained below.

Secondly this chapter contains the techniques linked to specific processes of the textile industry. During the project the Technical Working Group (TWG) (Egyptian experts in the textile sector) has decided to focus on processes for (or linked to) the production of cotton textiles products. This is justified by two main reasons: the high environmental relevance of these processes and large number of companies in Egypt producing cotton.

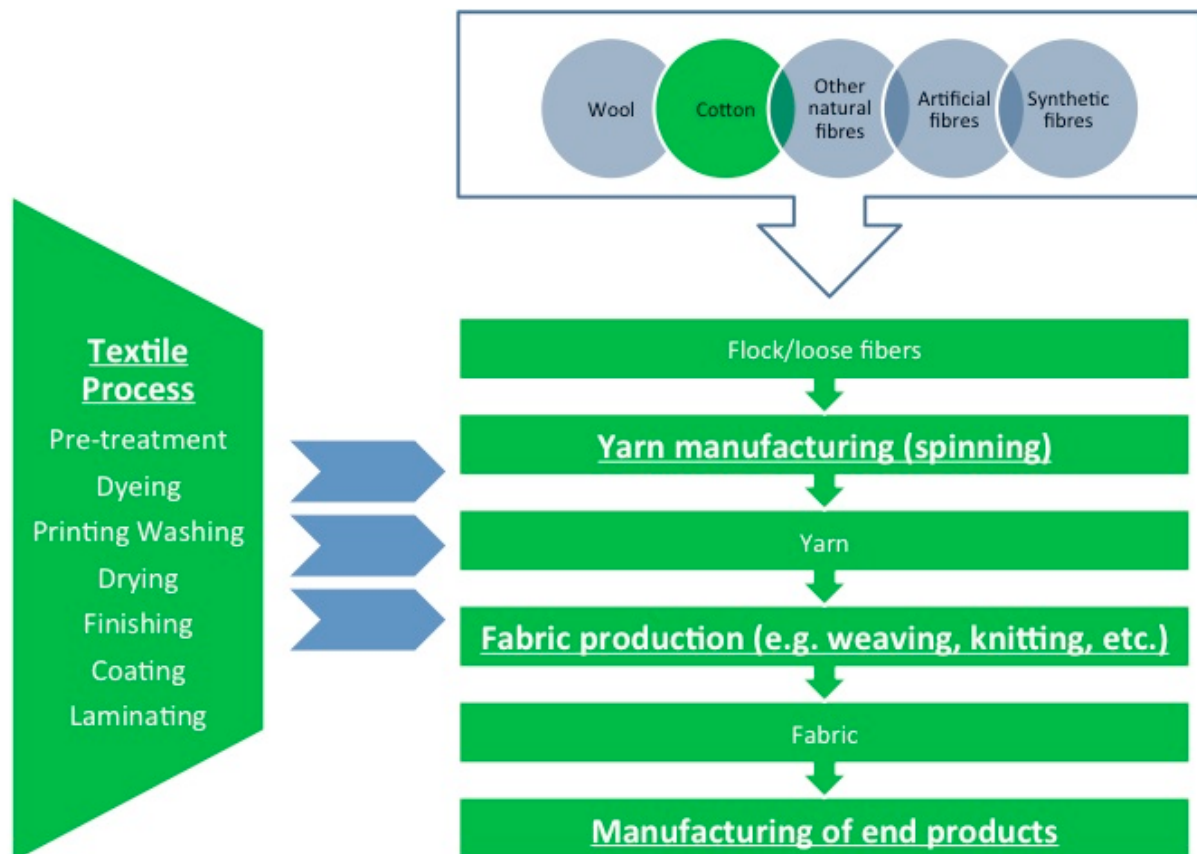


Figure 29. In green the processes selected by the Egyptian Technical Working Group Members.

Finally the information in this chapter 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 does not necessarily mean that the technique is a BAT.

In this chapter the techniques will be discussed according to a specific classification in classes and sub-classes decided by the mentioned TWG.

The table below contains the names of the techniques that will be described in this chapter and their classification.

General and horizontal techniques are included in Annex 3 of this report.

Table 40 Classification of techniques analysed in chapter 4

Measures	Options	Proposed BAT Techniques
1. Energy efficiency measures	Techniques to reduce energy consumption	Minimisation of energy consumption of stenter frames
		pH-controlled dyeing techniques
2. Resources efficiency measures	Efficient use of chemicals and raw materials	Minimizing sizing agent add-on by pre-wetting the warp yarns
		Use of techniques that allow reduced load of sizing agents on the fibre (compact spinning)
		Minimizing consumption of complexing agents in hydrogen peroxide bleaching
		Omitting the use of detergents in after washing of cotton dyed with reactive dyes
		Alternative process for continuous (and semi-continuous) dyeing of cellulosic fabric with reactive dyes
		Avoiding batch softening Application of softeners by pad mangles or by spraying and foaming application systems
	Efficient use of water	After treatment in PES dyeing
		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
		Reduction of water consumption in cleaning operations
		The drain and fill method and smart rinsing systems
		Increasing washing efficiency and water flow control
		Re-use rinse water from process baths in the production process
		Dry bleaching using ozone instead of wet washing using chlorine or hydrogen peroxide
	Resource recovery measures	Recovery of sizing agents by ultra-filtration
		Recovery of alkali from mercerizing
		Direct re-use of dye baths and auto-control of the process online
	Integrated process	One-step desizing, scouring and bleaching of cotton

	measures	fabric
		Optimization of cotton warp yarn pretreatment
		Application of the oxidative route for efficient, universal size removal
	Reduction of mothproofer and insect-resist agent emissions	Proportional overtreatment of loose fibre
		Mothproofer application using dedicated low volume application equipment, incorporating liquor clean-up and recycling
3. Selection/substitution of chemicals with other more environment friendly ones	Alternatives to mineral oils	Mineral oil substitution in knitted fabric manufacturing
	Use of enzymatic treatment/enzymes in processes	Adoption of an enzymatic treatment to remove the non-fixed dyestuff not only from the fibre, but also from the exhausted dye bath
	Use of less pollutant dyes	Dispersing agents with higher bio-eliminability in dye formulations
		Dyeing with sulphur dyes
		Silicate-free fixation method for cold pad batch dyeing
		Exhaust dyeing of cellulosic fibres with high-fixation polyfunctional reactive dyestuffs
		Exhaust dyeing with low-salt reactive dyes
		Dyeing without water and chemicals (DyeCoo system)
	Other measures	Substitution of sodium hypochlorite and chlorine-containing compounds in bleaching operations
		Selection of biodegradable/bioeliminable complexing agents in pretreatment and dyeing processes
		Selection of antifoaming agents with improved environmental performance
		Urea substitution and/or reduction in reactive printing and reactive two-step printing
		Use environmentally friendly alternative chemicals for finishing activities
		Use nanomaterials in textile finishing
4. End-of-pipe techniques	Wastewater load abatement techniques	Purification of industrial and mixed wastewater by combined membrane filtration and sonochemical technologies
		Treat industrial wastewater appropriately by implementing a combination of suitable waste purification techniques
		Anaerobic degradation of textile dye bath effluent using Halomonas sp.
		Colour removal of dyes from synthetic and real textile wastewater in one- and two-stage anaerobic systems.
		Integrating photo biological hydrogen production with dye-metal bio-removal from simulated textile wastewater
		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 <i>Aspergillus niger</i> and <i>Spirogyra</i> sp.
		Use of <i>Chlorella vulgaris</i> for bioremediation of textile wastewater
		Chemical coagulation/flocculation technologies for removal of colour from textile wastewater
		Potential of combined fungal and bacterial treatment for colour removal in textile wastewater
		Utilization of modified silk cotton hull waste as an adsorbent for the removal of textile dye (reactive blue MR) from aqueous solution
		Biosorption of anionic textile dyes by nonviable biomass of fungi and yeast
		Combined biological physical and chemical treatment of mixed wastewater effluent
		Treatment and recovery of wastewater containing pigment paste
		Treatment of selected and segregated, non-biodegradable wastewater stream by chemical oxidation
		Wastewater treatment by flocculation/precipitation and incineration of the resulting sludge
	Air emission abatement techniques	Oxidation techniques (thermal incineration, catalytic incineration), Condensation techniques (e.g. heat exchangers), Absorption techniques (e.g. wet scrubbers), Particulate separation techniques (e.g. electrostatic precipitators, cyclones, fabric filters), Adsorption techniques (e.g. activated carbon adsorption).
		Minimization of dye liquor losses in pad dyeing techniques
	Waste management	Bacterial cellulose production from cotton-based waste textiles: Enzymatic saccharification enhanced by ionic liquid pretreatment

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 literature references given.

4.2 Energy efficiency measures

Energy consumption is one of the most important environmental aspects of textile industry. The sector uses a huge amount of hot water and steam and this requires a lot of energy. Moreover considering that in the most cases the boilers use non-renewable fuels, this aspect is also important from the CO₂ emissions point of view.

4.2.1 Techniques to reduce energy consumption

The paragraph below describes two energy consumption minimization techniques. One considers the energy savings of stenter frames. The other refers to pH-controlled dyeing techniques.

4.2.1.1 *Ref. Datasheet 1.B.1: Minimisation of energy consumption of stenter frames*

a) Description of the technique

Many techniques allow energy savings in stenters.

One such technique is optimizing exhaust airflow through the oven: a part of the energy savings in the stenter can be obtained if the moisture content of the fabric is reduced before it enters the stenter. The automatic adjustment of the exhaust airflow according to the moisture content of the exhaust air or according to the moisture content or temperature of the fabric, allows a reduction of fresh air consumption and as a consequence, energy savings are possible. Another technique is heat recovery: up to 70% of energy savings can be obtained by using air-to-water heat exchangers that allow exhaust heat recovery. An air-to-air heat exchanger can also be used. In this case a 30% saving in energy can be achieved.

Another technique that minimizes energy consumption of stenter frames is insulation: appropriate insulation of stenter reduces heat losses. In this case also energy savings can be obtained.

And then there are the heating systems: through a flue gas/air heat exchanger the heat generated by the burner flame is directly transferred to the circulating air in the stenter. The efficiency is higher than indirect heating systems.

Then burner technology: optimized firing systems and appropriate maintenance of burners in directly heated stenters, allow methane emission reductions to be obtained.

Finally, there are miscellaneous techniques: with optimised nozzles and air guidance systems, energy consumption can be reduced, especially if nozzle systems are installed that can be adjusted to the width of the fabric. .

b) Applicability, operational data and driving force for implementation

All techniques can be applied to new installations.

The reduction of energy consumption in the stenters requires appropriate maintenance.

Another prerequisite for energy saving is appropriate scheduling in finishing that minimises machine stops and heating-up/cooling-down periods.

Minimisation of energy consumption is the main driving force for implementation.

In Egypt other techniques exist and have been applied since 1995.

c) Environmental benefit

The main environmental benefits are savings in energy consumption and as a consequence the reduction of emissions associated with energy production.

d) Economic aspects

Considering drying and heat-setting processes, the return of investment for heat recovery systems (air-water and air/air) goes from a low to a consistent amount.

The pay-back period can be short or long.

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.8.1-.

4.2.1.2 Ref. Datasheet 1.B.2: pH-controlled dyeing techniques (only for wool, silk, and polyamide)

a) Description of the technique

Fibres like wool, polyamide and silk contain weak acid and weak base groups. Just like the parent amino acids from which all proteins are derived, these fibres show zwitterionic characteristics at pH values close to the isoelectric point (i.e. the pH at which the fibre contains equal numbers of protonated basic and ionized acidic groups).

At a pH below the isoelectric point, the carboxylate anions are progressively neutralized by the adsorption of protons and the fibre acquires a net positive charge.

At a low pH the dye becomes attracted to the fibre through coulombic interactions, which furnishes additional bonding forces that cannot be broken by thermal agitation.

At isoelectric pH the dye moves very quickly and with low energy through the fibre.

pH-controlled dyeing is characterized by the fact that in the temperature-controlled dyeing the process is controlled by the dye bath consumption and thermal migration of the dye. Instead, with a pH-controlled profile the dyeing process is controlled by the adsorption of the dye onto the ionic fibre.

b) Applicability, operational data and driving force for implementation

The pH-controlled process is applicable to fibres with zwitterionic behaviour (e.g. wool, polyamide, silk, etc.). This technique is applied in uni-dyeing processes, and also to dyeing acrylic fibres with basic dyes. It is also used for all kind of fibres with 'neutral pH-dyeable' reactive dyes.

pH steering during batch dyeing can be carried out by fitting the machine with dosing systems for acids and alkalis. Selective control of the pH profile becomes difficult with this method. This technique is limited to machines where the goods and liquor are well mixed.

Another alternative technique is the generation of a pH-buffer during the dyeing process. Though this technique is very expensive, it tends to be preferred by textile companies because there is no need to measure the pH in a fully contained system.

Savings in energy and time are the main driving forces for the implementation of this technique.

c) Environmental benefit

Thanks to isothermal dyeing, the use of special organic levelling agents or retarders can be avoided.

With pH-controlled dyeing energy consumption and time are lower than with a temperature-controlled process.

A reduction of energy is possible since dye baths do not need to be heated from room temperature up to the migration temperature. Time is reduced because the heating and cooling phases are shorter.

Moreover, hot spent bath can be recycled.

d) Economic aspects

The bath does not need to be warmed up and cooled down according to a preset temperature profile. The resulting saving in processing time is therefore one major economic advantage of this technique.

Additional benefits in terms of time and energy savings can be achieved when the hot spent dye bath is recycled.

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.6.14.

4.3 Resource efficiency measures

This paragraph discusses some techniques that achieve greater efficiency in the use of resources. In this case the resource is considered from a quantitative point of view. The use of the techniques summarised increases process efficiency.

These techniques are:

- efficient use of chemicals and raw materials;
- efficient use of water;
- resource recovery measures;
- integrated process measures;
- Reduction moth proofing and resist insect agent emissions.

4.3.1 Efficient use of chemicals and raw materials (low add-on technique)

Chemicals are one of the most important issues in the textile industry for both economic and environmental reasons. In recent years many experiments have been carried out by companies and by research institutes. This section summarises the most important achievements in this field.

4.3.1.1 Ref. Datasheet 2.A.1: Minimizing sizing agent add-on by pre-wetting the warp yarns**a) Description of the technique**

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

The warp yarn is dipped into the hot water, and then a squeeze roller removes the excess water before the sizing phase.

Pre-wetting allows a smaller amount of size to be applied to the fibre.

b) Applicability, operational data and driving force for implementation

The technique can be applied to all kinds of cotton yarns and blends of cotton/PES and viscose, and to medium and coarse yarns. Application is possible for batches of more than 5000 m.

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

Considering some aspects of this technique, sizing agent savings, increase in weaving efficiency and reduction of wastewater load are driving forces for its implementation.

c) Environmental benefit

The reduction of sizing agents on the yarn allows a lower load of these agents in wastewater during pretreatment.

d) Economic aspects

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

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

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.2.5.

4.3.1.2 Ref. Datasheet 2.A.2: Use of techniques that allow reduced load of sizing agents on the fibre (compact spinning)

a) Description of the technique

With the technique of compact spinning the fibre strands are compressed after the draft system through pneumatic devices.

Yarn manufactured by means of the compact spinning system compared with classical yarn is characterized by:

- better smoothness,
- higher lustre,
- abrasion fastness improved by 40-50%,
- hairiness 20-30% lower, as measured with the use of the Uster apparatus,
- hairiness 60% lower, as measured with the use of the Zweigle apparatus,
- tenacity and elongation at break higher by 8-15%, and
- smaller mass irregularity

b) Applicability, operational data and driving force for implementation

This technique is applicable to pure cotton yarns.

Positive aspects derived from compact spinning technique are the obtaining of yarns with higher quality and the opportunity to create new effects/design.

c) Environmental benefit

The compact spinning technique allows a compact yarn with better running properties and less thread breakage during weaving.

This allows reduction in wastewater load in desizing.

d) Economic aspects

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

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.2.6.

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. $O_2^{\cdot-}$, $OH^{\cdot}/O^{\cdot-}$, etc.) of differing reactivity in water. The formation of OH^{\cdot} radical causes damage to the fibre. This problem can be prevented through the use of complex formers that inactivate the catalyst (stabilisers). Complexing agents contain N- and P-, and have low biodegradability. The massive use of sequestering agents can be avoided by removing OH^{\cdot} . This reduces fibre damage without the need for complexing agents. The hydroxyl radical OH^{\cdot} is removed by hydrogen peroxide, forming the true bleaching agent. In these circumstances hydrogen peroxide has the role of scavenger and the reaction product is the bleaching agent itself.

b) Applicability, operational data and driving force for implementation

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

c) Environmental benefit

This technique allows bleaching of cellulose in full, without damage to fibres.

This is made possible by not using hazardous sequestering agents, and because of the minimal consumption of peroxide, and the pre-oxidation of the removed substances.

d) Economic aspects

Reduction of peroxide consumption by more than 50% is possible, as is a decrease in organic load.

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.5.6.

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

a) Description of the technique

Experiences from several textile companies and literature show that detergents do not improve removal of hydrolysed reactive dyestuffs from the fabric. Some dye houses already omitted the use of detergents in rinsing after reactive dyeing. In many cases fastness 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 of chemicals and wastewater treatment.

c) Environmental benefit

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

d) Economic aspects

Economic savings are linked with the chemical (mainly detergents) consumption and with the wastewater treatment activities.

Rinsing without detergents requires high temperatures.

This determines more energy consumption and higher energy costs.

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.6.12.

4.3.1.5 Ref. Datasheet 2.A.5: Alternative process for continuous (and semi-continuous) dyeing of cellulosic fabric with Bi functional 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 in this technique 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, improved coverage of dead cotton, minimized migration and control of humidity. Moreover, fabrics could have improved penetration, due to the presence of humidity. 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 in 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-flues is high. This cost is counterbalanced by high savings in energy, chemicals and other auxiliaries. The technique allows a higher productivity that helps to offset the higher costs.

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.6.13.

4.3.1.6 **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 the softening agent's 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 a 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 dye 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. Application technique such as by exhaustion, by padding, by spraying, etc., depends on the equipment available, type of substrate, chemical composition and thermal stability of the softener used as well as the final product properties required. The applicability of this technique is limited to a specific kind of softening agents such as non-ionic, cationic, and anionic amphoteric softeners.

c) Environmental benefit

This technique achieves 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.

Installation of new equipment creates costs.

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.8.3.

4.3.2 **Efficient use of water**

Water is a precious resource especially in the Mediterranean Partner Countries. The textile sector has a process in which some phases, such as washing and dyeing, require a huge consumption of water that is usually pumped directly from 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.2: After treatment in PES dyeing**

a) Description of the technique

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

agent can be metered automatically. It is characterized by low toxicity and by biodegradability.

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

b) Applicability, operational data and driving force for implementation

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

The technique of 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 the aforementioned into account, the drivers to implement this technique are: higher productivity and cost savings and better environmental performance.

c) Environmental benefit

In the case of the first approach, reducing agent can be applied in the acidic pH range, and 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 biochemical oxygen demand in the final effluent. Also lower water and energy consumptions could be obtained.

d) Economic aspects

Many advantages could derive from the first approach: higher productivity, lower energy, and water and chemical use.

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.6.5.

4.3.2.2 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 to or in place 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 a gas stream. The main features of this technique are the bath-less dyeing operation and the separate circuit for liquor circulation with no contact with the textile. Soft-flow dyeing machines use water to keep the fabric in circulation. During the processing cycle there is no stopping of the liquor or the fabric 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 water, steam and time. In addition, airflow jet operating requires fewer auxiliaries and salt.

On the other hand, airflow jet operating requires higher electricity than conventional techniques. The first technique could be used for knit and woven fabric and for all types of fibres. Limitations to the use of this technique can be found with wool and wool blends. The technique cannot be used for dyeing linen fabric. These kinds of machines allow high productivity and repeatability. Another driving force are savings in water, chemicals and energy consumption.

In Egypt this technique is not applicable for high costs.

c) Environmental benefit

The main environmental benefits of airflow jet dyeing technique are lower energy consumption, lower chemical consumption and water savings. Soft-flow dyeing machines generate savings in processing time and lower steam and water consumption.

d) Economic aspects

This technique can imply new investments in new machinery.

In Egypt this technique means very high investment costs, mainly for the kind of equipment requested.

Moreover, in Egypt the conventional use of water jet dyeing determines the same results with low costs.

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.6.21.1 and 4.6.21.2.

4.3.2.3 Ref. Datasheet 2.B.4: Reduction of water consumption in cleaning operations

a) Description of the technique

There are several ways to reduce water consumption when cleaning the printing machine before it can be used for new colours:

- A. start/stop control of cleaning of the printing belt
- B. mechanical removal of printing paste
- C. re-use of the cleanest part of the rinsing water from the cleaning of the squeegees, screens, and buckets
- D. re-use of the rinsing water from the cleaning of the printing belt.

A. Start/stop control of cleaning of the printing belt

A connection between start/stop control of the water dosage and start/stop control of the printing belt can be made avoiding water consumption for the cleaning of the printing belt.

B. Mechanical removal of printing paste.

Improved printing paste removal before flushing squeegees, screens and buckets reduces the amount of water needed for flushing. Physical equipment for removal of dye from buckets are on the market (e.g. scrapers). Modern printing machines have a built-in system which enables mechanical removal of residual printing paste from pipes and hoses.

30°C. Cleaning of the squeegees, screens and buckets by re-use of the cleanest part of the rinsing water

Unlike the first half in the second half of the washing process, clean water must be used. But it can be collected for re-use, potentially as first-rinse water in the next cycle.

D. Re-use of the rinsing water from the cleaning of the printing belt

The rinsing water from cleaning of the printing belts can be mechanically filtered, gathered in an overflow vessel and re-used for the same aim if minor amounts of fresh water are added to the recycling system.

b) Applicability, operational data and driving force for implementation

Start/stop control of cleaning of the printing belt and re-use of the rinsing water from the cleaning of the printing belt, can be used in all printing sections of textile companies. The space is needed for collection tanks (option C and D). However, option B, mechanical removal of printing paste, is not available for older printing machines.

The main driving forces for the implementation of these techniques are reduction of water consumption in cleaning operations and thus fresh water and wastewater discharge savings.

c) Environmental benefit

The reduction in water consumption is the main environmental benefit.

d) Economic aspects

The total cost is about 13,500 euros. It can be divided in the following way:

D-C: 12,825 euros.

A675 euros.

B = negligible

It is important to consider that the total annual fresh water and wastewater discharge savings are about 90,000 euros (Danish case study).

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.7.7.

4.3.2.4 Ref. Datasheet 2.B.5: The drain and fill method and smart rinsing systems

a) Description of the technique

The drain and fill technique allows lower water consumption. Rinsing is possible through fill, run and drain steps. The rinsing efficiency is determined by the liquor ratio¹¹ and the draining time. With a lower liquor ratio, more rinsing steps are necessary to obtain the same dilution effect with a reduced use of water. Most negative aspects of the traditional drain and fill rinsing method can be eliminated. For example, new machines can provide special time-saving devices which allow shorter time cycles compared to traditional rinsing.

Another aspect of new and modern machineries is the combined cooling and rinsing system. It allows cooling and rinsing at the same time.

A machine with a low liquor ratio is a requirement for effective use of smart rinsing systems. Rinsing is possible by feeding clean water into the machine and draining it through an overflow weir set low down in dyeing machine.

The dilution effect in this case is increased, due to the lower volume of contaminated liquor circulating in the machine. The liquor ratio represents an important aspect: the higher the liquor volume, the longer the rinsing time required to obtain the equivalent dilution effect at the same flow rate.

b) Applicability, operational data and driving force for implementation

The drain and fill rinsing technique can be applied for new and existing equipment.

Smart rinsing is able to solve problems with fabric rinsing.

Most of the new machines have a combined cooling and rinsing system.

As regards operational aspects, a complete audit of the utilities is requested.

¹¹This is the weight ratio between the total dry material and the total liquor. For example, a liquor ratio of 1:12 means 12 litres of water on 1 kg textile material.

One of the main important driving forces for implementation is higher productivity, due to a shorter production cycle.

c) Environmental benefit

The main environmental benefits are a lower water and energy consumption in comparison with conventional overflow rinsing.

Moreover, the exhausted dye liquor and the rinsing water can be separated, so they can be re-used or treated separately. Thermal energy can be recovered.

d) Economic aspects

Savings in water and energy consumption, and related costs.

A shorter production cycle and thus a reduction of production costs.

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.9.1.

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

a) Description of the technique

The washing efficiency is influenced by temperature, residence time, etc. Two principles are applied in modern washing machines: counter current 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 into the fabric and a roller squeezes waste through the fabric into a sump, where it is filtered and re-circulated. This construction allows high-efficiency washing with low water use, and energy use decreases. The reduction of carry-over allows the water that is not removed to be 'carried over' into the next step, contributing to washing efficiency. In continuous washing operation squeeze rollers are used to minimize carry-over.

b) Applicability, operational data and driving force for implementation

Increased productivity is achievable with the use 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 that increase washing efficiency.

c) Environmental benefit

This technique allows lower consumption of water and energy.

d) Economic aspects

Detailed information is not available.

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.9.2.

4.3.2.6 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 (Decabromediphenyl ether), HBCD (Hexabromocyclododecane), Sb₂O₃ (Antimony trioxide), PFOS (Perfluorooctane sulphonate or heptadecafluorooctane sulphonate) and/or PFOA (Perfluorooctane acid or pentadecafluorooctane acid), in rinse water from process baths can be (partly) recuperated

by separately collecting and re-deploying 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 high percentage of rinse waters that can be potentially re-used is one of the main driving forces for implementation.

c) Environmental benefit

This technique reduces chemical consumption and wastewater load.

d) Economic aspects

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

e) Reference literature

Best Available Techniques for the Textile Industry, Flemish Centre for Best Available Techniques –VITO-, 2010, paragraph 4.2.2

4.3.2.7 Ref. Datasheet 2.B.8: Dry bleaching using ozone instead of wet washing using chlorine¹² or hydrogen peroxide

a) Description of the technique

This operation consists of placing the garments (jeans) in a dry rotary washing machine.

The machine is connected to an ozone generator.

This technique is used for many purposes:

- lightly bleaching fabric by using ozone instead of wet washing using chlorine or hydrogen peroxide.
- cleaning indigo redeposits on fabric.
- fading jeans to grey.

b) Applicability, operational data and driving force for implementation

The use of this technique requires the installation of an ozone generator and some small modifications in the washing machine. On the other hand, this technique cannot substitute the use of chlorine or peroxide entirely because in some cases the use of chlorine or peroxide is indispensable to obtain the required effects.

In Egypt this technique requires special equipment. Moreover, the equipment requires precautions for operation.

The duration of the operation varies from 15 to 60 minutes and depends on the kind of garment and the type of effect required.

This technique allows a time saving of approximately 60%, compared to conventional bleaching followed by squeezing and drying steps.

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

c) Environmental benefit

Environmental benefits consist in no use of water or chemicals, and no production of wastewater.

d) Economic aspects

Savings can be made in process water purchase price, chemical purchase price, time cost and effluent disposal costs.

¹² In Egypt chlorine is banned due to the emission of carcinogenic material (AOX).

In Egypt, high investment costs can derive from the installation of equipment.

e) Reference literature

Technical audit carried out in GTS company, GTT company (Tunisia).

4.3.3 Resources recovery measures

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

Measures indicated below allow a rational use of resources. This could be achieved with recovery or re-use of some materials or substances, the integration of more sub-processes into a single step, and the optimization of some activities. These kinds of measures allow lower environmental impact and reduce waste.

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 pretreatment. Water-soluble synthetic agents can be recovered from washing liquor by ultrafiltration. The washing liquor is pumped under pressure through membranes in the UF method. The far smaller molecules of the washing water pass through the membrane, while the macromolecules of the size are held back in the process. Thus, the size substance and water are separated. Following 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 from the wastewater. As regards the 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 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 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 can be used only for certain kinds of sizing agents: water-soluble synthetic sizing agents such as PVA, polyacrylates and carboxymethyl cellulose. The recovery of sizing agents requires particular conditions: stock and recovered size should be maintained under sterile conditions when stored and mixed with virgin size. There are some limits to the application of this technique. They may 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. The minting effect can only be achieved 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 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 the USA.

In Egypt this technique can be applied only if specific sizing agents are used, especially when using synthetic sizing agents such as polyvinyl alcohol, polyacrylate, carboxymethylcellulose (CMC).

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 80-85% of sizing agents could be recovered. Moreover the energy consumption is reduced and also the quantity of sludge to be disposed of. 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 made through greater weaving efficiency and the reduced cost of pretreatment and wastewater treatment.

In Egypt this technique is not applicable due to high investment costs and equipment maintenance.

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.5.1.

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 through rinsing. The rinsing water can be concentrated by evaporation for recycling.

b) Applicability, operational data and driving force for implementation

The higher the number of evaporation stages, the more often the heat is re-used, the lower the steam consumption and running costs. The technique described 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.

This technique has been applied in Egypt since 1998.

c) Environmental benefit

The alkaline load of wastewater is reduced.

d) Economic aspects

The investment cost depends on factors such as the plant size and the purification technique used. The cost can vary from 200,000 to 800,000 euros. The payback time can vary and it depends on aspects such as plant size and operating time/day. From an economic perspective, the recovery of caustic soda could be attractive.

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.5.7

4.3.3.3 **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 measuring by spectroscopic laser, by means of which the content of each and every one of the colourants 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 dye 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 dye 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 colourants 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 colourant, but its imprecision increases as the number of colourants increases. Using the RAMAN laser spectroscope, the measurement can be carried out on mixtures of colourants, 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 applied in Egypt since 1996.

c) Environmental benefit

Savings in water, chemicals and energy. Reducing of wastewater emissions.

d) Economic aspects

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

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

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

Nevertheless, the rapid advances in optics and electronics suggest the likelihood of a rapid lowering of the cost of RAMAN units, which can in addition be submitted to redesigning or re-engineering for the specific application proposed, in such a way that, at present day costs, if the price of the measuring unit does not exceed 15,000 - 18,000 euros, and with the

most well-established technological aspects (calibration of colourants and auxiliaries), a recovery time of between 2 and 3 years is estimated, from a strictly economic point of view.

e) Reference literature

DYE BATH REUSE Life project results:

http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.createPage&s_ref=LIFE03%20ENV/E/000166.

4.3.4 Integrated process measures

This paragraph 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.

4.3.4.1 *Ref. Datasheet 2.D.1: One-step desizing, scouring and bleaching of cotton fabric*

a) Description of the technique

In presence of cotton woven fabric and its blends with synthetic fibres, the standard pretreatment process includes: desizing, scouring and bleaching.

The new Flash Steam procedure (possible thanks to new auxiliaries' formulations and automatic dosing and steamers) allows that telescopes desizing, alkaline cracking (scouring) and pad-steam peroxide bleaching are integrated in a single step.

b) Applicability, operational data and driving force for implementation

Companies with new machinery for this process are able to apply the described technique.

The big advantage is that in a range of 2-4 minutes loom-state goods are brought to a white suitable for dyeing.

The sequence of the Flash Steam peroxide bleach is:

1. application of a combined bleaching solution
2. steam 2-4 min.
3. hot wash off.

The productivity increase is the main driving force for implementation of the technique.

c) Environmental benefit

The single integrated process allows water and energy consumption reductions.

d) Economic aspects

No specific information is available.

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.5.3.

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

a) Description of the technique

In white cotton production, cotton yarn is bleached before weaving.

The traditional process includes five steps (wetting/scouring, alkaline peroxide bleaching and three subsequent rinsing steps). The last rinsing water is re-used for making the first bath.

The conventional process can be improved through the combination of wetting, scouring and bleaching in only one step and performing rinsing in two steps, re-using the second rinsing bath for making the bleaching/scouring bath.

The energy consumption of the process is reduced by heat recovery. The heat from scouring/bleaching bath is recovered and used for heating the fresh water for the first rinsing.

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

b) Applicability, operational data and driving force for implementation

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

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

c) Environmental benefit

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

Moreover, energy and chemicals consumption can be reduced.

d) Economic aspects

Savings in time, water, chemicals and energy make the process highly economical. The process requires tanks, heat exchangers, pipes and control devices for energy recovery from wastewater. New equipment for pretreatment is not required.

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.5.8.

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

a) Description of the technique

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

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

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

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

b) Applicability, operational data and driving force for implementation

The technique is particularly suitable for commission finishers (independently of their size), who need to be highly flexible because their goods do not all come from the same source.

Size and the cellulose have a similar molecular structure and therefore an attack of the cellulose polymer from non-selective OH[•] is possible. To avoid damage to the fibre when removing starch-like size, it is essential to add hydrogen peroxide at pH >13. These operating conditions minimize OH[•] radicals, which are responsible for cellulose damage.

c) Environmental benefit

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

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

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

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

d) Economic aspects

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

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.5.2.

4.3.5 Reduction of emissions of mothproofer and insect-resist agents

This chapter describes the techniques that in the framework of the resource efficiency measures can be applied about reduction mothproofer and insect-resist agent emissions.

4.3.5.1 Ref. Datasheet 2.E.2: Proportional overtreatment of loose fibre

a) Description of the technique

An intimate blend of treated and untreated fibres will be resistant to insects if the overall blend treatment level is maintained. Only a proportion of the fibre is treated, the remaining fibre receives no treatment. Mixing of the two fibre types is achieved during mechanical blending. The percentage of fibre that would be treated is between 5 and 20%. In using this technique both the spent dye liquor and the rinse liquor may need to be re-used, which implies the construction of dedicated machinery, a revised drainage system and the installation of liquor storage tanks.

b) Applicability, operational data and driving force for implementation

The technique is not applicable to the majority of dye houses because it needs specially constructed equipment.

c) Environmental benefit

Reduction of wastewater emissions.

d) Economic aspects

On a self-build basis the cost of constructing a dedicated installation from available materials is said to be in excess of EUR130.000.

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.8.4.2.2.

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 are one of the most important causes of the pollution load of wastewater and air emissions. In addition to the use of dangerous chemicals increase the risk of contamination of soil and groundwater in case of accidental spillage. Finally, the improvement of this aspect replacing hazardous with non-hazardous chemicals has a positive impact on safety and health issues.

The paragraph is composed by the following sub-paragraphs:

- alternatives to mineral oils;
- use of enzymatic treatment/enzymes in processes resource recovery measures;
- less pollutant dyes;
- Other measures.

4.4.1 Alternatives to mineral oils

The use of mineral oils in textile industry is very high. But they represent one of the main pollutants deriving by textile industry. In this paragraph some techniques that provide alternatives to the use of these oils, are described.

4.4.1.1 Ref. Datasheet 3.A.1: Mineral oils substitution in knitted fabric manufacturing

a) Description of the technique

This technique consists of using saponifiable oils instead of conventional lubricants to remove oils more easily from final knitted fabric during pretreatment.

With knitted fabrics made of *cotton or cotton blends with synthetic fibres* these hydro soluble oils can be easily washed out with water at 40°C. This makes it possible to scour and bleach the fabric in one single step, thus saving time, water and energy.

After this step the fabric is sent to the stenter and then dyed, washed and finished. In this way emissions of fumes from the stenter are minimized.

b) Applicability, operational data and driving force for implementation

Despite corrosion problems in several existing plants this technique is applicable to new and existing plants.

These kinds of oils can be used for cellulose fibres and blends, synthetic fibres, and blends with natural and synthetic fibres.

The hydro soluble knitting oils described below produce emulsions which are permanent for three days.

Environmental legislation for emissions to air and water is the main driving force for the technique implementation.

c) Environmental benefit

This technique permits to reduce water, energy and chemicals consumption along with processing time. Hydro soluble oils are suitable for treatment in a biological wastewater treatment plant.

d) Economic aspects

The cost of saponifiable oils is comparable with the conventional one.

e) Reference literature

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

4.2.3.

4.4.2 Use of enzymatic treatment/enzymes in processes resources recovery measures

The use of enzymes¹³ as substitutes for chemicals has found the applicability in several process steps in textile industry.

4.4.2.1 *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.

Enzymatic decolourisation of reactive dyestuffs has been proved with Levafix, Remazol, Cibacron, Procion and Synozol types.

b) Applicability, operational data and driving force for implementation

The technique is only applicable to exhaust dyeing with reactive dyestuffs at this time.

The steps of the enzymatic treatment are given below (batch process):

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

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

c) Environmental benefit

This technique achieves water, energy and detergent consumption savings.

d) Economic aspects

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

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.6.8.

4.4.3 Less pollutant dyes

The dyes can, in several cases, be considered one of the main the cause for the pollution of the textile sector. The use of dyes needs water and energy to fix the dyes during the dyeing process. The companies should remove the non-fixed dyes from the bath where they cause the increase of pollutant load of wastewater. Moreover, being produced by chemical sector, they cause indirect pollution in the first phases of its life cycle and also in the last phase of it (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 the pollution of textile industry.

¹³ Such as: α -amylases, cellulases, pectinases, hemicellulases, lipases and catalases, sericinases, proteases, xylanases.

4.4.3.1 *Ref. Datasheet 3.C.1: Dispersing agents with higher bio eliminability in dye formulations*

a) Description of the technique

Dispersing agents are mainly present in disperse, vat and sulphur dye formulations to ensure uniform dispersion throughout the dyeing and printing processes. The lignosulphonates and the condensation products of naphthalene 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 granulates 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 for the implementation.

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

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.6.3.

4.4.3.2 *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 glucose¹⁴

¹⁴ In Egypt only glucose is applicable because it is cheap and available.

- 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

This technique is applied in Egypt since 1998.

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

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.6.6.

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

a) Description of the technique

Silicate-free highly concentrated aqueous alkali solutions have been developed and used instead of sodium silicate in cold pad-batch dyeing, mainly to increase the pad liquor stability and to avoid selva 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 plants. Additional measures for process optimization and control may be needed in order to guarantee constant conditions for existing installations.

Membrane pumps such as the sera-pumps with 4:1 ratio (alkali solution to dyestuffs solution) are suitable for the application of the product.

The main driving forces to implement this technique 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.

c) Environmental benefit

Some environmental advantages are achievable: no residues of alkali in the preparation tank, no formation of difficult-to-wash-off deposits on the substrate and on the equipment, no need for additional auxiliaries in the padding liquor to avoid the formation of deposits, lower electrolyte content in the effluent, possibility of using membrane techniques in 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 economic 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 it 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

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.6.9.

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

a) Description of the technique

Bifunctional (polyfunctional) reactive dyes contain two similar 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 up 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 higher fixation efficiency, reducing salt usage and water and energy consumption.

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.6.10.

4.4.3.5 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 technique offers particular advantage in the most modern low liquor ratio dyeing machines but are applicable to existing dyeing equipment too.

The lower the salt concentration, the more sensitive the system becomes to any change in parameters that influence exhaustion. To give the dyer the high flexibility needed, dye manufacturers have developed trichromatic combination dyes with high mutual compatibility.

Products with very similar application properties are now available, which makes them little affected by changes in dyeing conditions.

One of the characteristics of advanced reactive dyes is the reciprocal compatibility of dyes that are included in each dye range.

It is good for areas having arid climate conditions and negative water balance and where dye houses discharge directly into 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

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.6.11.

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

a) Description of the technique

This technique consists in using carbon dioxide (CO₂) for dyeing of textile-materials instead of water to achieve a water free dyeing process. The dyeing process is completely waterless, using recycled carbon dioxide. When carbon dioxide 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, scCO₂ is heated to 120°C and pressurised to 250 bars. The CO₂ penetrates synthetic fibres, thereby acting as a swelling agent during dyeing and enhancing the diffusion of dyes into the fibres. In particular the glass-transition temperature of the fibres is lowered by the penetration of the CO₂ molecules into the polymer. This accelerates the process for polyester by a factor of two. Finally, the CO₂ is able to transport the necessary heat from a heat exchanger to the fibres. During the dyeing of polymer fibres, CO₂ loaded with dyestuff penetrates deep into the pore and capillary structure of the 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, and 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.

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

c) Environmental benefit

Many environmental benefits are achieved by using this technique. In particular: elimination of water consumption and wastewater discharges, elimination of wastewater treatment process, reduction in energy consumption, reduction in air emissions. Surfactants and auxiliary chemicals in dyes are eliminated, dye utilization is very high with very little dye residue. Unused dye can be recaptured.

d) Economic aspects

Water and energy cost savings.

e) Reference literature

<http://www.dyecoo.com/>

4.4.4 Other measures

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

4.4.4.1 *Ref. Datasheet 3.D.3: Substitution of 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 (absorbable organic halides) emissions.

There is also increasing support for peroxide bleach under strong alkaline conditions, which achieves a high degree of whiteness after careful removal of catalysts by a reduction/extraction technique. The additional advantage claimed is the possible combination of scouring and bleaching.

b) Applicability, operational data and driving force for implementation

This technique is applicable to every installation.

Hydrogen peroxide is used for bleaching cotton and cotton blend knitted fabric. It is used also for woven fabric made of most cellulosic and wool fibres and most of their blends.

Exceptions are flax and other bast fibres.

Particular attention needs to be paid to the combination or sequence of 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 highly possible in combined process streams.

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

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

c) Environmental benefit

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

d) Economic aspects

This technique is no more expensive than old one.

The two-stage bleaching process is two to six times more expensive than the conventional one.

If chlorine dioxide is used as bleaching agent an investment could be needed for equipment resistant to the highly corrosive conditions in existing installations.

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.5.5.

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

a) Description of the technique

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

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

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

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

b) Applicability, operational data and driving force for implementation

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

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

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 environmental benefits are: 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.

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

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.3.4.

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

a) Description of the technique

Antifoaming agents are usually applied in pretreatment, 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.

Insolubility in water and low surface tension are good characteristics for antifoaming products.

The use of antifoam can be reduced 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 products are better from an environmental point of view and are characterized by high bio elimination 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 may appear on the textile and silicone precipitates in the machinery if silicone-based antifoaming agents 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 bio elimination rate is obtained than hydrocarbons.

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

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.3.5.

4.4.4.4 Ref. Datasheet 3.D.9: Urea substitution and/or reduction in reactive printing and reactive two-step printing

a) Description of the technique

Urea can be substituted in reactive prints. A controlled addition of moisture (10 wt-percent for cotton fabric, 20 wt-percent for viscose fabric and 15 wt-percent for cotton blends) can be used. Moisture can be applied either as foam or by spraying a defined quantity of water mist.

The two-step printing method is another option for minimization or substitution of urea. The steps for this method are:

- Reactive Printing
- intermediate drying
- padding with alkaline solution of fixating agents
- fixation by means of overheated steam
- washing steps
- the process is carried out without urea.

b) Applicability, operational data and driving force for implementation

Both foam and spraying systems are applicable to both new and existing plants performing reactive printing. In any case the use of urea with the spraying system cannot be completely

avoided for silk and viscose fine articles. Indeed sometimes spraying systems do not meet the quality standards.

On the other hand, the foaming system has been successfully for viscose in complete elimination of urea. This technique should be technically good also for silk.

Two-step reactive printing can be used for both cotton and viscose substrates. Application of the fixation liquor needs the arrangement of an impregnation device with a steamer. Overheated steam is necessary. Reactive dyes based on monochlorotriazine and vinylsulphone types can be utilized

Avoiding the urea use, the ammonia concentration in mixed effluent decreases. This technique permits a reduction in urea reduction of about 50 g/kg of printing paste for silk and 80 g/kg for viscose, whilst maintaining quality standards. No specific information is available for two-step printing method.

In general, strict limits applied by local authorities for nitrogen-based emissions have stimulated the introduction of these techniques.

The application of these techniques is very attractive for mills discharging to a municipal wastewater treatment plant. Because of the high energy consumption for biological nitrification, many municipalities now charge indirect dischargers for nitrogen emissions.

c) Environmental benefit

Minimizations/elimination of urea at source significantly reduces eutrophication and aquatic toxicity.

A reduction of off-gas problems is obtained by the two-step printing method. Moreover, this technique extends the life of printing pastes provides an opportunity to recycle the remnant printing pastes.

d) Economic aspects

The investment costs are about 30,000 euros. Spray equipment and on-line moisture measurement are included. The foam system is significantly more expensive (200,000 euros). It relates to a production capacity of up to about 80,000 linear metres per day. The foaming technique has been operated under economically viable conditions in plants with capacities of 30,000, 50,000 and 140,000 linear metres per day. No information was made available for reactive two-step printing.

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.7.1-4.7.2.

4.4.4.5 Ref. Datasheet 3.D.12: Use environment-friendly alternative chemicals for finishing activities

a) Description of the technique

The negative effects determined by chemicals when used for finishing activities, can be reduced through the use of environmentally 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 (fireproof) fibres
- Flame barrier
- Non-wovens

Textile can be made fire-resistant in the following ways:

By carbonising the flammable product by adding organophosphorous compounds, at a particular fire temperature, P compounds form a layer of carbon that closes off the material from air (oxygen).

Organo-phosphorous (e.g. triphenylphosphate, 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 ammonia or a melanin 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:

- Aluminiumhydroxide (is a water soluble substance);
- Ammonium salts from phosphate, bromide, chloride, sulphonate,
- Boric acid, borax.

PFBS (perfluoro butane sulphonate) and PFHA (perfluoro hexane 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.

This technique is not commonly applied in Egypt, because usually other techniques are used.

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

Best Available Techniques for the Textile Industry, Flemish Centre for Best Available Techniques –VITO-, 2010, paragraph 4.2.1.

4.4.4.6 Ref. Datasheet 3.D.14: Use nanomaterials in textile finishing

a) Description of the technique

A large company in Germany decided to use a finishing agent for textiles containing nanomaterial in order to improve the quality of its awnings to repel water, dirt and oils by creating a self-cleaning surface. The finishing agent contains silic acid in nano form, with the silic acid particles incorporated as agglomerates.

The finishing agent is procured in containers.

The storage containers are connected to an automated dosage system: the solution is extracted from the container using lances and are directly introduced into the pipe system leading to the mixing vessel.

The different ingredients of the finishing agent for the textile awnings are pumped from the storage containers to a closed vessel for mixing. The vessel is automatically emptied from the bottom and the finishing mixture is pumped to its place of use.

The mixture containing the finishing agent is applied in a foulard. The textile is first continuously submersed and dragged through a bath containing the finishing agent. After that it is fed through a nip roller, which controls the amount of the finishing agent to be applied by squeezing the excess liquor into the submersion bath. Spills do not occur and the process is conducted at room temperature; hence any evaporation is very unlikely.

After the application in the foulard, the textile is dried at high temperatures in stentering frames. These frames are closed systems operating at negative pressure. The volatile substances in the finishing agents and other auxiliaries used, as well as the water vapours, are extracted through an exhaust extraction system, which is connected to a regenerative afterburner. Pollutants and hazardous substances are destroyed and the clean waste gas is emitted.

The awning textile is then reeled in after drying. As part of the quality control, those parts of the textile, which have production mistakes, are cut out and removed.

b) Applicability, operational data and driving force for implementation

This technique was applied in a large company in Germany employing approximately 800 people. The company manufactures awnings, textiles for outdoor use and decorative textiles.

It has been established routines to introduce new products into manufacturing processes, which were applied to the introduction of the nanomaterial as well.

Measurements at the workplaces although no hazardous properties of the used nanomaterial were identified.

The benefits offered by nano-dispersion with regard to product quality (better technical properties, higher environmental performance) are important factors for implementation.

This technique is not commonly applied in Egypt, because usually other techniques are used.

c) Environmental benefit

- Pollutants and hazardous substances are destroyed and the clean waste gas is emitted through the chimney to the environment.
- Higher environmental performance through fewer cleaning requirements of the fabric.

d) Economic aspects

No data are available.

e) Reference literature

https://osha.europa.eu/data/case-studies/use-of-nanomaterials-in-textile-finishing/Nano-case_study_KOOP_Schmitz-Werke_110915_v4.pdf.

4.5 End of pipe techniques

Even if preventive measures should have greater prominence in the identification of techniques to reduce the impact of any industrial sector, end-of-pipe techniques are still relevant in the textile sector for several reasons. Firstly, there are still some chemicals that can't be substituted in the process with other more eco-friendly ones without the product

quality being altered. 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 is some research involving experiments related, for example, to applying the dyeing process without water, but these are very widespread, and some issues are still to be solved from point of view of technical and economic viability. Finally, water is not only important for the sector, but also as a resource in general. For this reason advanced techniques in wastewater treatment allow the textile companies to obtain high quality water after treatment that could be re-used in the process (e.g. first rinsing activities), reducing the water footprint of the textile fabric.

4.5.1 Wastewater load abatement techniques

This paragraph describes some wastewater abatement techniques.

Some of them use integrated technologies.

The source of most of the techniques described is represented by scientific articles from management journals.

4.5.1.1 *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 Baciavallo WWTP which treats part of the effluents of one of the largest textile industries districts 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 radical formation rate, frequency, acoustic power, hydrogen peroxide addition, contact time and pH. According to the experimental results, the best configuration within the Baciavallo WWTP was the sonication of non-ozonated wastewater followed by ultrafiltration. The combined treatment guaranteed compliance with the target values for wastewater reuse in wet textile industries.

Operating the filtration process under optimized conditions is highly desirable for economic 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.

Driving forces for the implementation of the technique are the effectiveness of the technique and cost savings.

c) Environmental benefit

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

The UF will generate a concentrated reject that must be treated and safely disposed of.

Sonication will generate high noise levels that may exceed law limits.

More chemicals will be used for cleaning of the UF and sonic equipment.

d) Economic aspects

Reduction of chemical consumption.

Reduction of laboratory costs.

In Egypt this technique is expensive.

e) Reference literature

PURI FAST Life project results: <http://purifast.tecnorex.it/project.asp>

4.5.1.2 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. Tertiary purification aims to purify wastewater or to remove components from wastewater that are difficult to break down.

Tertiary purification is also used for pre-treating partial flows.

Here are some wastewater purification techniques:

- Anaerobic purification
- Biological purification
- Active carbon dosing in biological purification
- Membrane bio-reactor
- Chemical precipitation (coagulation-flocculation)
- Microfiltration, ultrafiltration
- Nanofiltration, reverse osmosis
- Sand filtration
- Adsorption chemical oxidation
- Ozonisation
- Evaporation
- Incineration

These techniques can be combined for wastewater treatment.

b) Applicability, operational data and driving force for implementation

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

c) Environmental benefit

The implementation of a combination of wastewater purification techniques allows a reduction in 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 do not function optimally.

d) Economic aspects

The cost wastewater purification depends on the case. Type, configuration and size of a wastewater treatment plant, and also 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

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

a) Description of the technique

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

This anaerobic digestion technique uses halophilic and halotolerant *Halomonas* bacteria.

b) Applicability, operational data and driving force for implementation

The technique could be applied to wastewater produced by azo-reactive dye used by a nearby textile industry.

Halophilic and halotolerant bacterial culture *Halomonas variabilis* and *Halomonas glaciei* have been used for degradation in batch-mode static condition. At constant temperature of 30°C and using a CO₂ incubator, maximum degradation was achieved within 144 hours of experimental run. BOD and COD reduction rate were optimal in the concentration of 1297 mg L⁻¹ for time duration of nearly 100 hours.

The environmental benefits deriving by the implementation of this technique are the main driving force for implementation.

Negative aspects for safety could be derived by the anaerobic degradation that will produce H₂S and biogas which are flammable gases.

c) Environmental benefit

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

There is no use of air blower and in large dye houses we can collect the resulting biogas and use it as a source of energy.

Bad odour can derive from the anaerobic processes that produce H₂S.

d) Economic aspects

No data are available.

e) Reference literature

B. Balamurugan, M. Thirumarimurugan, T. Kannadasan. 'Anaerobic degradation of textile dye bath effluent using *Halomonas sp.*' *Bioresource Technology*, 102, 2011, pp. 6365-6369.

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

a) Description of the technique

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

b) Applicability, operational data and driving force for implementation

The technique can be applied in synthetic textile wastewater and in real textile wastewater. No differences between the two treatment systems. Colour removal efficiencies were high for both systems.

This high percentage of colour removal efficiency is the main driver for the implementation.

c) Environmental benefit

COD and dye removal from wastewater.

There is no use of air blowers.

Bad odours can derive from the anaerobic processes that produce H_2S .

d) Economic aspects

No data are available.

e) Reference literature

Paulo Igor M. Firmino a, Marcos Erick R. da Silva a, Francisco J. Cervantes b, André B. dos Santos. 'Colour removal of dyes from synthetic and real textile wastewater in one- and two-stage anaerobic systems.' *Bioresource Technology*, 101, 2010, pp. 7773-7779.

4.5.1.5 **Ref. Datasheet 4.A.10: Integrating photo biological hydrogen production with dye-metal bio removal from simulated textile wastewater**

a) Description of the technique

This technique has the dual purpose of hydrogen production and biosorption of some toxic dyes and heavy metals present in textile wastewater.

To this aim this technique consists in the integration of hydrogen production in photobioreactor with a laboratory scale packed bed biosorption column for the removal of certain pollutants.

b) Applicability, operational data and driving force for implementation

This technique has been applied to simulated textile wastewater.

Sustained and enhanced hydrogen production at average rates of $101 \mu\text{mol/h/mg Chl}$ for 15 d was achieved by glucose supplement and anoxic gas sparging using free cyanobacterial biomass.

The achieved environmental benefits are the main driving force for the implementation.

Hydrogen gas is highly flammable with risks for safety.

c) Environmental benefit

Removal of pollutants from wastewater.

Bed packing material will be polluted with heavy metals.

d) Economic aspects

No data are available, but expensive in Egypt.

e) Reference literature

Anubha Kaushik, Sharma Mona, C.P. Kaushik

'Integrating photo biological hydrogen production with dye-metal bioremoval from simulated textile wastewater.' *Bioresource Technology journal*, 102, 2011, pp. 9957-9964.

4.5.1.6 ***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

This technique is focused on the characterization and decolourization of local textile mill effluent and RO16 dye by three bacterial consortia at laboratory scale. Enzymes involved in the degradation of RO16 were assayed and metabolites formed after degradation was analysed.

The effluent predominantly contained a mixture of reactive azo dyes ¹⁵viz.

A novel bacterial consortium DAS capable of decolorizing textile effluent was isolated from soil samples of the textile industry effluent site by an enrichment culture technique. DAS consists of 3 bacterial strains: SUK1, LBC2 and LBC3 were able to grow and degrade various textile dyes.

b) Applicability, operational data and driving force for implementation

The described technique can be applied to new and existing installations.

A loopful of each microbial culture was inoculated for 24 h in 10 ml culture tubes containing 5 ml nutrient broth to develop the consortium. A 24-h culture of each bacterial isolate (5 ml) was added to 250- ml Erlenmeyer flask containing 100 ml of textile effluent (undiluted). The flasks were further incubated to observe the time required for the decolourization. Aliquots (3 ml) of the culture media were withdrawn at different time intervals, centrifuged at 7 669 g for 15 min to separate the bacterial cell mass. Decolourization of the textile effluent was analysed using a UV–Vis spectrophotometer at 490 nm.

Costs savings and less toxicity of textile effluent are the main driving forces for the technique implementation.

c) Environmental benefit

After inoculation, the COD analysis of the textile effluent supernatant carried out at various time intervals, showed a decrease in COD from 6 760 mg to about 1 440 mg in 48 hours 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 recovery of metals. Moreover a less toxicity and genotoxicity is achieved by using this technique.

d) Economic aspects

Costs savings compared with traditional methods.

¹⁵The European Commission published legislation that prohibits the marketing of textile and leather articles that come into direct contact with the skin which contain one of the hazardous amines. This kind of legislation limits the use of azo dyes which can release specified hazardous amines. This legislation is laid down in Directive 76/769/EEC on the marketing and use of dangerous substances and preparations. Amending Directives are 2002/61/EC and 2004/21/EC (on azo colourants topic).

e) Reference literature

J.P. Jadhav, D.C. Kalyani, A.A. Telke, S.S. Phugare, S.P. Govindwar; 'Evaluation of the efficacy of a bacterial consortium for the removal of colour, reduction of heavy metals, and toxicity from textile dye effluent.' *Bioresource Technology* 101 (2010) 165–173.

4.5.1.7 Ref. Datasheet 4.A.13: Bio sorption of reactive dye from textile wastewater by non-viable biomass of *Aspergillus niger* and *Spirogyra sp*

a) Description of the technique

This technique shows 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.

b) Applicability, operational data and driving force for implementation

The described technique can be applied to new and existing installations.

After washing the fungal and algal biomasses with deionised water, they were dried at 80°C for 20 hours. The dried biomasses were ground in a mortar and pestle before use, to obtain larger surface area and were termed as the raw biomasses. Also, the washed biomasses were pre-treated by autoclaving (121°C for 20 min) or gamma radiation (5 kGy, sufficient dose for inactivate fungal biomass) before drying. The pretreatment 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 percentage of dye removal varies with pH ranges. The maximum percentage of dye removal 42% and 36% for fungus and alga biomasses, respectively, was obtained at pH 3. Temperature 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.

Cost savings and less toxicity of textile dyes are the main driving forces for implementation of this technique.

c) Environmental benefit

Improvement of water quality of dyes that may be toxic, carcinogenic and even mutagenic. In Egypt, the non-viable produced biomass will be disposed of as hazardous waste as it will contain heavy metals.

d) Economic aspects

Costs savings compared with traditional methods.

e) Reference literature

Mahmoud A. Khalaf. Biosorption of reactive dye from textile wastewater by non-viable biomass of *Aspergillus niger* and *Spirogyra sp.* *Bioresource Technology* 99 (2008) 6631–6634.

4.5.1.8 **Ref. Datasheet 4.A.14: Use of *Chlorella vulgaris* for bioremediation of textile wastewater**

a) Description of the technique

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

b) Applicability, operational data and driving force for implementation

The described technique can be applied to new and existing installations.

Ten microalgae were screened for their ability to grow in TW (Textile Wastewater) and remove colour from the wastewater using flask cultures.

Three azo dyes were used, namely Supranol Red 3BW, Lanaset Red 2GA, Levafix Navy Blue EBNA and the textile wastewater (TW) was collected from a garment factory located at Senawang Industrial Estate, Negeri Sembilan (Malaysia).

Ten millilitres of exponential cultures, standardised at an optical density at 620 nm (OD₆₂₀) of 0.2, were inoculated into 90 ml of TW in 250 ml conical flasks in triplicate. The cultures were grown for 10 days in an incubator shaker (150 rpm) set at 25°C, with an irradiance of 40–60 $\text{Imol/m}^2/\text{s}$ on a 12:12 h light–dark cycle. Initial pH of the TW was adjusted to 7.0 prior to inoculation.

Pollutant reduction in textile wastewater is the main driving force for the technique's implementation.

c) Environmental benefit

Reduction of pollutants such as COD, $\text{NH}_4\text{-N}$ and $\text{PO}_4\text{-P}$ in textile wastewater.

d) Economic aspects

No data are available.

e) Reference literature

Sing-Lai Lim, Wan-Loy Chu, Siew-Moi Phang; 'Use of *Chlorella vulgaris* for bioremediation of textile wastewater.' *Bioresource Technology* 101 (2010) 7314–7322.

4.5.1.9 **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 of the coagulant itself. Another result of chemical addition is a net increase in the dissolved constituents in the wastewater. Coagulation is used for removal of the waste materials in suspended or colloidal form that do not settle out on standing or may settle by taking a very long time. In water treatment, coagulation as pretreatment is regarded as the most successful pretreatment.

b) Applicability, operational data and driving force for implementation

To improve the efficiency of the coagulation process, the number of high molecular weight compounds such as polymers from synthetic or natural origin may be recommended. These polymers can function as coagulants themselves or in the form of coagulant aids/bio flocculants, 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 because they produce small volumes of sludge, whereas inorganic polymers and chemical coagulants generally involve higher cost, less biodegradability and toxicity.

Less toxicity of textile wastewater is the main driving force.

c) Environmental benefit

Improvement of wastewater quality.

d) Economic aspects

No data are available

e) Reference literature

Akshaya Kumar Verma, Rajesh Roshan Dash, Puspendu Bhunia; 'A review on chemical coagulation/flocculation technologies for removal of colour from textile wastewaters.' Journal of Environmental Management 93 (2012) 154-168.

4.5.1.10 Ref. Datasheet 4.A.17: Potential of combined fungal and bacterial treatment for colour removal in textile wastewater

a) Description of the technique

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

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

b) Applicability, operational data and driving force for implementation

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

The initial treatment with the fungal culture lasted 3–8 days. Subsequently, the liquid from the 1st step was transferred to the second reactor containing the immobilized bacteria for a 9–12-d treatment.

Less toxicity in wastewater is the main driving force for the implementation of this technique.

In Egypt is difficult to apply this technique.

c) Environmental benefit

Improved wastewater quality is the main benefit.

d) Economic aspects

No data are available.

e) Reference literature

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

4.5.1.11 Ref. Datasheet 4.A.20: Utilization of modified silk cotton hull waste as an adsorbent for the removal of textile dye (reactive blue MR) from aqueous solution

a) Description of the technique

In view of the high cost and associated problems of regeneration, there is a constant search for alternate low cost adsorbents to treat textile wastewater. This technique dealt with the removal of commercially used textile dye, reactive blue MR (RBMR) from aqueous solution using carbon prepared from silk cotton hull as an adsorbent (SCHC).

The removal increases with time and attains equilibrium within 75 min for all concentrations studied (10–40 mg/l) and it increases with increasing carbon dosage while adsorption of dye decreased with increasing pH and the percentage desorption increased with increasing NaOH concentration in the aqueous medium and attained a maximum desorption at 0.6 N NaOH solution.

b) Applicability, operational data and driving force for implementation

The silk cotton hull was collected from Coimbatore, India. The dye used was commercially available textile dye (RBMR) obtained from Diamond Dyes, Mumbai, India.

Cost saving and less use of hazardous chemicals are the main driving forces for the implementation of the technique.

c) Environmental benefit

Minimize hazardous chemicals in textile industries.

d) Economic aspects

Cost saving by using this kind of adsorbent.

e) Reference literature

K.S. Thangamani, M. Sathishkumar, Y. Sameena, N. Vennilamani, K. Kadirvelu, S. Pattabhi, S.E. Yun; 'Utilization of modified silk cotton hull waste as an adsorbent for the removal of textile dye (reactive blue MR) from aqueous solution.' *Bioresource Technology* 98 (2007) 1265–1269.

4.5.1.12 Ref. Datasheet 4.A.22: Bio sorption of anionic textile dyes by nonviable biomass of fungi and yeast

a) Description of the technique

The nonviable biomass of *Aspergillus niger*, *Aspergillus japonica*, *Rhizopus nigricans*, *Rhizopus arrhizus*, and *Saccharomyces cerevisiae* were used for biosorption of textile dyes. The selected anionic reactive dyes were C.I. Reactive Black 8, C.I. Reactive Brown 9, C.I. Reactive Green 19, C.I. Reactive Blue 38, and C.I. Reactive Blue 3. Experiments were conducted at initial dye concentration of 50, 100, 150 and 200 mg/l. *S. cerevisiae* and *R. nigricans* were good biosorbents at initial dye concentration of 50 mg/l, 1 g% (w/v) biomass loading and $29 \pm 1^\circ\text{C}$. *R. nigricans* adsorbed 90–96% dye in 15 min, at 20°C and pH 6.0. The data showed an optimal fit to the Langmuir and Freundlich isotherms. The maximum uptake capacity (Q_0) for the selected dyes was in the range 112–204 mg/g biomass. Adsorption kinetic studies showed *R. nigricans* to be the best adsorbent with 90–96% adsorption of the

selected dyes at the specified conditions: pH 6, 20 °C, 120 rpm shaking at 50 mg/l initial concentration of the dye and 1 g% biomass loading.

b) Applicability, operational data and driving force for implementation

The described technique can be applied to new and existing installations.

For Egypt, the technique has been applied only on pilot scale.

Powdered nonviable biomass of *R. nigricans*, *Rhizopus arrhizus*, *Aspergillus niger*, *Aspergillus japonica*, and *Saccharomyces cerevisiae* were the selected biosorbents. These microorganisms are produced in large quantities as unwanted by-products of fermentation industries, which make them an interesting target for examination of their dye biosorption potential.

Costs savings and less toxicity of textile effluent are the main driving forces for implementing the technique.

c) Environmental benefit

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

d) Economic aspects

Costs savings compared with traditional methods.

e) Reference literature

Kumud Kumari, T. Emilia Abraham; 'Biosorption of anionic textile dyes by nonviable biomass of fungi and yeast.' *Bioresource Technology* 98 (2007) 1704–1710.

4.5.1.13 Ref. Datasheet 4.A.23: Combined biological physical and chemical treatment of mixed wastewater effluent

a) Description of the technique

An approach for improving the performance of the activated sludge treatment is the Powdered Activated Carbon treatment. This consists in combining different technologies (biological, physical, chemical), thus allowing simultaneous biodegradation, adsorption and coagulation. The process was introduced in the early seventies and industrialised with the commercial name of PACT and PACT® systems.

In this system, powdered activated carbon and bacteria are maintained in an aerobic/anoxic treatment process for symbiotic activity. The excess sludge from the aerobic aerator is regenerated by a hydrothermal treatment (wet oxidation). This is a liquid phase reaction in water using dissolved oxygen (or air) to oxidise soluble and suspended oxidisable contaminants. When air is used as the source of oxygen the process is referred to as 'Wet Air Oxidation'. The oxidation reaction is carried out at moderate temperatures of 150–315 °C and at pressures from 10 to 207 bars. The process destroys the large molecules in wastewater, converting them predominantly to carbon dioxide, water and short chain organic acids, which are highly biodegradable and more suitable for biological treatment. This regeneration process provides continual re-use of the activated carbon and ensures high levels of waste treatment.

A first application of the PACT® system in the European textiles industry appeared in 1975. The process was later improved by integrating it with simultaneous coagulation treatment (the system is called PACT+, a cryptic term to indicate a first improvement).

A second improvement (the so-called PACT++) could only be achieved by changing and extending the conventional activated sludge process with a nitrification/denitrification step followed by a filtration of the effluent to retain suspended solids.

Another technique is the PACT3+ system. This concept is a combination of different available techniques, with the aim of improving performance, flexibility and economy of scale of the PACT® system.

In the PACT3+ system, activated carbon is added to the aerobic aerator together with iron, which is used as a coagulant to precipitate phosphate and increase the binding of dyes into the sludge. The reactivation of the spent sludges containing powdered carbon and iron, is carried out at low temperature (below 130°C) if hydrogen peroxide is used.

b) Applicability, operational data and driving force for implementation

The technique is applicable to existing and new installations where a biological treatment is available and where solids are fully retained in the clarification system. A micro filter is to be added when there is a risk that solids could escape with the effluent.

E. With PACT® and PACT3+ treatments good filtration is very important to separate the sludge from the treated effluent efficiently.

PARCOM Recommendations 94/5 supports the implementation of PACT3+ as one of the most promising upcoming technologies.

c) Environmental benefit

- The production of excess sludge is reduced.
- Potentially hazardous substances are removed.
- The risk of displacement of dyes and other adsorbed substances is lower.
- The excess solids produced are dense and retain the remaining substances, which can therefore be sent to easier dewatering and incineration.
- The mineralisation of the organic pollutants is improved.
- Energy use is lower.

d) Economic aspects

The following additional equipment is needed: dosing systems for powdered carbon and iron sulphate, dosing system for peroxide · microfiltration, reactor for reactivation of concentrated streams. Costs depend on the dosage (less than 100 g/m³ of mixed effluent is needed, when reactivation of the activated carbon is carried out).

Hydrogen peroxide is consumed in stoichiometric amounts to transform the concentrated substances into bioeliminable substances. Iron is added as iron sulphate.

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.10.3.

4.5.1.14 Ref. Datasheet 4.A.24: Treatment and recovery of wastewater containing pigment paste

a) Description of the technique

This technique refers to membrane treatment of wastewater containing pigment printing pastes with full re-use of the resulting permeate.

Wastewater comes from the printing paste preparation kitchen. The pigment pastes contain organic dye pigments, organic thickeners, organic binders, fixation agents, catalysts and softening agents.

Treatment consists of the following steps:

- coagulation to de-activate the organic dyes, binders and fixation agents
- precipitation of the resulting coagulates with bentonite at pH 6
- microfiltration of the precipitate.

The applied membranes consist of polypropylene and have a cut off of 0.2 μm . The sludge is sent for physico-chemical treatment offsite. The permeate is totally free of suspended solids and can be re-used for cleaning operations.

b) Applicability, operational data and driving force for implementation

The technique is applicable to existing and new installations.

COD of input water to the treatment plant varies between 4 000 and 10 000 mg/l. COD in the permeate is about 600 mg/l, which means a removal efficiency of about 90%.

The European company considered in this reference is discharging the wastewater to a municipal wastewater treatment plant with strong limitations imposed on flow and COD

c) Environmental benefit

More than 90% of the water is recycled. Non-biodegradable compounds are completely removed and can then be mineralised by incineration. It should be noted, however, that due to the presence of chlorides, there is a potential for the production of hazardous substances when the sludge is incinerated. Catalytic and high temperature incinerators are available to prevent these emissions.

d) Economic aspects

The described plant with a flow of 2.5 m^3/h (comprising the two wastewater streams mentioned) needed investment of 180,000 euros. Operating cost, including external disposal of the concentrate (which is the major part) is about 4 euros/ m^3 .

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.10.5.

4.5.1.15 Ref. Datasheet 4.A.25: Treatment of selected and segregated, non-biodegradable wastewater stream by chemical oxidation

a) Description of the technique

Desizing baths with non-biodegradable sizing agents and exhausted dye baths can be treated by oxidation in a special reactor at 100–130°C and about 3 bars pressure (max. 5 bars). The main oxidising agent is molecular oxygen. Hydrogen peroxide only initiates the oxidation reaction and keeps it running (delivering 1/5 of the reactive oxygen). Iron(II)-salt is added as catalyst in acid medium. With COD of the feed of more than 2500 mg/l, the reaction is exothermic. The process is called Thermal Fenton Process.

b) Applicability, operational data and driving force for implementation

The oxidation technique is applicable to both new and existing installations.

Wastewater streams from different processes are treated in sequence to minimise running costs. The treatment is performed continuously and is fully automated. It needs low manpower for operation.

Typical dosage of chemicals for the oxidation process is (e.g. for COD = 8 500 mg/l):

- 13 l H_2O_2 -solution (35%)/ m^3 wastewater (1.53 l H_2O_2 -solution/ m^3 and 1 000 mg/l)
- 35 ml H_2SO_4 (30%)/ m^3 wastewater
- 120 g Fe^{2+} / m^3 wastewater.

The driving force for implementation is difficulty in complying with standards set by municipal wastewater treatment plant in terms of COD-load, biodegradability and toxicity.

c) Environmental benefit

COD removal efficiencies of 70–85% are achieved, depending on retention time, applied temperature and pressure and chemical properties of the compounds in the effluent to be treated.

Residual COD is largely biodegradable. Given that the effluent is in most cases submitted to subsequent biological treatment, high COD removal efficiencies (95% or higher) are achieved. De-colouration is more than 90% and treated exhaust dye baths are practically colourless.

d) Economic aspects

Investment cost for a reactor with a flow of 4–5 m³/h (including reactor, dosing system for hydrogen peroxide and catalyst, heat exchanger, catalyst preparation unit, automated control and pipe-work) is about 230,000 euros. Operation cost, including above-mentioned dosage of chemicals, maintenance, labour and electricity, is about 3 €/m³. It should be emphasized that this number is for the treatment of the selected high-loaded wastewater streams and not for the whole of the mixed wastewater.

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 –§ 4.10.7.

4.5.1.16 Ref. Datasheet 4.A.26: Wastewater treatment by flocculation/precipitation and incineration of the resulting sludge

a) Description of the technique

Today there are techniques that minimise the quantity of sludge produced and reduce negative effects associated with its disposal. Instead of landfill disposal, the sludge can be incinerated using state-of-the-art technology.

In modern plants the precipitate is separated from the aqueous phase not just by sedimentation but also by dissolved air flotation. Flocculation agents are specifically selected in order to maximise COD and colour removal, and to minimise sludge formation. In most cases, best performances are obtained with a combination of aluminium sulphate, cationic organic flocculant and very low amounts of an anionic polyelectrolyte.

The use of sulphate is preferred to chloride. Iron sulphate is equally effective for the removal of COD and can also be considered as coagulant.

b) Applicability, operational data and driving force for implementation

The technique is applicable to both new and existing installations.

The dosage of flocculants (e.g. for a mixed effluent with COD of ca. 1,000 mg/l) is about:

- Aluminium sulphate: 400–600 mg/l
- Cationic organic flocculent: 50–200 mg/l
- Anionic polyelectrolyte: 1–2 mg/l

The quantity of sludge produced is about 0.7–1 kg of dry matter/m³ treated wastewater. Usually, the sludge is dewatered in a chamber filter press to reach a dry matter content of about 35–40% (3 kg of sludge are therefore produced for 0.5 kg of COD removed).

c) Environmental benefit

Typically COD removal is only about 40–50%. When the effluent has a high content of water-insoluble compounds, COD-removal is higher. De-colouration is more than 90%.

The sludge is fully mineralized in an incineration plant.

d) Economic aspects

No data available.

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 –§ 4.10.8.

4.5.2 Air emissions abatement techniques

Among the end-of-pipe technologies, also air emissions abatement techniques are considered.

Here are described some off-gas abatement techniques, that in some cases can be used in integrated way.

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

a) Description of the technique

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

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

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

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

b) Applicability, operational data and driving force for implementation

Oxidation techniques

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

These techniques are used for large scale solid waste.

Condensation techniques

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

Absorption techniques

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

Electrostatic precipitation

Electrostatic precipitators can precipitate dusts and aerosols with a size between 0.01 and 20 µm even if the maximum efficiency will be attained at around 0.1 µm – 1.5 µm. For this reason manufacturers recommend installing a mechanical filter before the electrostatic filter, which precipitates most of the particles with size > 20 µm. The electrostatic

precipitators for particle-sized solid and liquid pollutants have efficiency between 90% and 95%. Gaseous pollutants and odorous substances cannot be precipitated. In order to improve efficiency, all condensable substances, emitted as aerosols, are removed before reaching the electrostatic precipitator. This can be achieved by heat exchangers or scrubbers. The combination of electrostatic precipitation and heat exchangers or scrubbers is applied successfully in the treatment of fumes emitted from the stenters where the fabric is submitted to thermo fixation and it is particularly advantageous when this operation is done as a first treatment step before washing. The off-gas derived from oils and preparation agents present in grey fabric can be treated in four steps:

- 1) Mechanical filtration
- 2) Cooling and condensation
- 3) Ionisation/electro filtration
- 4) Collection of the condensates and separation of the oily phase from the aqueous phase in a static decanter.

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

An adjustment of the appropriate operating conditions and an appropriate maintenance of the equipment must be made to achieve high operational reliability.

The environmental legislation for air pollution and better performance in terms of odour nuisances are the main driving forces for the implementation of these techniques.

c) Environmental benefit

A reduction of VOC (volatile organic compounds), particulates and special toxic substances in the off-gas is achieved. Moreover odour nuisances are reduced.

d) Economic aspects

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

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 – § 4.10.9.

4.5.3 Waste management

This paragraph describes two waste management techniques.

One refers to the management of dye liquor losses, the other one consists in the bacterial cellulose production from cotton-based waste textiles.

4.5.3.1 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. Loss 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 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 thanks to this technique.

d) Economic aspects

Investment costs for an automated dosage system are high, but it could be partially counterbalanced by annual savings. Moreover, advantages are derived from the fact that a smaller quantity of wastewater requires treatment.

e) Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.6.7.

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

a) Description of the technique

This technique consists in using [AMIM]Cl (1-Allyl-3-methyl-imidazolium chloride) to dissolve cotton-based waste textiles as a pretreatment prior to enzymatic hydrolysis.

The dissolution of cotton in [AMIM]Cl increased with temperature and time; however, the yield of regenerated cotton cloth obtained after the 130°C pretreatment was relatively low. After 4 hours, the yields of reducing sugar from pre-treated and untreated cotton cloth were 22.4% and 4.0%, respectively. After hydrolysis for 24 hours, the yield of reducing sugar from untreated cotton was only 12.1%, whereas that of pre-treated cotton was 81.6%. This indicates that pretreatment with [AMIM]Cl is a very efficient approach to increase the hydrolytic rate of cotton cloth so the enzymatic saccharification of cotton materials can be improved by pretreatment with [AMIM]Cl or [BMIM]Cl.

b) Applicability, operational data and driving force for implementation

The technique can be applied to new and existing installations.

The cotton-based materials employed in the study were old undyed 100% cotton T-shirts in a number of Chinese firms.

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

c) Environmental benefit

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

d) Economic aspects

The technique allows obtaining cost savings compared to traditional methods.

e) Reference literature

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

CHAPTER 5

SELECTION OF THE BEST AVAILABLE TECHNIQUES (BAT)

In this chapter, the environmentally friendly techniques of chapter 4, and general techniques included in ANNEX 3 of this report, 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 41 the available environmentally friendly techniques of chapter 4 and general techniques are tested according to a number of criteria. This multi-criteria analysis allows for judging whether or not a technique can be considered a Best Available Technique. The criteria are not only related to the environmental media (water, air, soil, energy, noise/vibrations), but also cover the technical viability and the economic aspects. In that way, an integrated assessment, consistent with the BAT definition (cf. Chapter 1) is allowed for.

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

Technical viability

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

Environmental benefit

- **water use:** reuse of 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, NO_x, SO_x, NH₃, VOC, other emissions to air);
- **waste:** prevention and control of waste flows
- **use of raw and auxiliary materials:** influence on the amount and the kind of raw/auxiliary materials (e.g. chemicals) used;
- **soil:** addition of polluting substances to soil and groundwater as a result of the operation of the facility
- **global:** estimated influence on the environment as a whole.
- **noise/vibrations**

Per technique, for each of the above criteria a qualitative assessment is carried out in which:

- "-": negative effect;
- "0": no/negligible impact;
- "+": positive effect;
- "+/-": sometimes positive, sometimes negative effect.

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

Economic viability

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

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

Important remarks for using Table 41:

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 those 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, for instance, the technique is technically viable in his/her specific situation, does not hamper safety, cause unacceptable environmental nuisance or entail 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 whether the environmental techniques discussed 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 41. Evaluation of the available environmentally friendly techniques and selection of the BAT

General good management practices

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.

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?	
G1	Management and good housekeeping	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+	Yes	
G2	Input/output streams evaluation/inventory	+	+	0	0	+	+	+	+	+	+	+	+	+	+	0	Yes	
G3	Automated preparation and dispensing of chemicals	+	+	+	+	+	+	+	0	+	0	0	0	+	+	0	Yes	
G4	Optimising water consumption in textile operations	+	+	0	0	+	+	+	+	0	0	0	0	0	+	- 16	Yes	
G5	Insulation of High Temperature (HT) machines	+	+	0	0	+	0	0	+	0	0	0	0	0	+	0	Yes	

¹⁶ Investment in new equipment and/or structural modifications are needed.

Energy efficiency measures

Techniques to reduce energy consumption

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.

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 groundwater	Noise and vibrations	Raw/auxiliary materials	Global	Cost feasibility and cost effectiveness	BAT?	
1.B.1	Minimisation of energy consumption of stenter frames	+	+	0	0	+	0	0	+	0	+	0	0	0	+	0/- ¹⁷	Yes	
1.B.2	pH-controlled dyeing techniques	+	-/+ ¹⁸	0	0	-/+	0	0	+	+	0	0	0	0	+	+	Yes ¹⁹	

¹⁷ The technique gives economic savings being oriented to the reduction of energy consumption, but the economic viability score depends on the use of wet fabrics.

¹⁸ Candidate BAT for all textile companies, but some techniques can only be applied if the goods and liquor are well mixed.

¹⁹ Restriction: some of these techniques could have a limited technical applicability due to the fact that they can be applied only if the goods and liquor are well mixed.

Resource efficiency measures

Efficient use of chemicals and raw materials (low add-on technique)

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.

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.A.1	Minimizing sizing agent add-on by pre-wetting the warp yarns	+	+	+	0	+	0	+	0	0	0	0	0	+	+	0	Yes	
2.A.2	Use of techniques that allow reduced load of sizing agents on the fibre (compact spinning)	+	+	+	+	+	0	+	0	0	0	0	0	+	+	0	Yes	
2.A.3	Minimizing consumption of complexing agents in hydrogen peroxide bleaching	+	+	+	0	+	0	+	0	0	0	0	0	+	+	+	Yes	
2.A.4	Omitting the use of detergents in after washing of cotton dyed with reactive dyes	+	+	+	0	+	0	+	-	0	0	0	0	+	+	0 ²⁰	Yes	
2.A.5	Alternative process for continuous (and semi-continuous) dyeing of cellulosic fabric with functional reactive dyes	+	+	+	+	+	0	+	+	0	0	0	0	+	+	0	Yes	

²⁰ Economic savings are linked to the reduction in chemicals consumption and wastewater treatment. Rinsing without detergents however requires high temperatures and thus energy. The energy costs could balance out the savings.

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.A.6	Avoiding batch softening: application of softeners by pad mangles or by spraying and foaming application systems	+	-/+ ²¹	+	0	-/+	+	0	+	0	0	0	0	+	+	-	Yes ²²	

²¹The applicability depends on the types of fabric processed and softening agents used, such as non-ionic, cationic, anionic amphoteric softeners.

²² Restriction: this technique is a BAT with technical applicability limitations depending by the kind of processed fabrics and softening agents used.

Resource 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.

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.B.2	After treatment in PES dyeing	+	-/+ ²³	+	0	-/+	+	0	+	0	+	0	0	+	+	+	Yes ²⁴	
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	+	-/+ ²⁵	+	0	-/+	+	0	+	0	0	0	0	+	+	-- ²⁶	No	
2.B.4	Reduction of water consumption in cleaning operations	+	+	0	0	+	+	0	0	0	0	0	0	0	+	0	Yes	
2.B.5	The drain and fill method and smart rinsing systems	+	+	0	+	+	+	0	+	0	0	0	0	0	+	+	Yes	
2.B.6	Increasing washing efficiency and water flow control	+	+	0	0	+	+	0	+	0	0	0	0	0	+	-	Yes	

²³For blends with elastane fibres the applicability is limited.

²⁴Restriction: the technique is a BAT with technical applicability limitations.

²⁵The technique cannot be used for dyeing linen fabric because the linen lint causes scaling of the machine.

²⁶According to the opinion of TWG Members in Egypt this technique is not economically viable.

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.B.7	Re-use rinse water from process baths in the production process	+	-/+ ²⁷	+	-/+ ²⁸	-/+	+	+	0	0	0	0	0	+	+	+	Yes ²⁹	
2.B.8	Dry bleaching using ozone instead of wet washing using chlorine or hydrogen peroxide	+	+	-	+	-	+	+	0	0	0	0	0	+	+	- ³⁰	No	

²⁷ In Egypt this technique can't be considered applicable for dyeing processes for quality reasons.

²⁸ Re-use of rinse water can in some cases decrease the quality of the final product.

²⁹ Restriction: this technique is a BAT with technical viability limitations.

³⁰ According to the TWG Members, in Egypt, this technique is not economically viable due to a high investment cost.

Resource 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.

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.C.1	Recovery of sizing agents by ultra-filtration	+	-/+ ³¹	0	0	-/+	0	+	+	0	0	0	0	0	+	- ³²	No	
2.C.2	Recovery of alkali from mercerizing	+	+	0	0	+	0	+	0	0	0	0	0	0	+	- ³³	Yes	
2.C.6	Direct re-use of dye baths and auto-control of the process online	+	-/+ ³⁴	+	0	-/+	+	+	+	0	0	0	0	+	+	- ³⁵	Yes ³⁶	

³¹ In Egypt this technique can only be applied if specific sizing agents are used, especially in cases using synthetic sizing agents such as polyvinyl alcohol, polyacrylate, carboxymethylcellulose (CMC).

³² According to the TWG Members, in Egypt, this technique is not economically viable as it requires high investment and operational (maintenance) costs.

³³ The investment costs depends on different factors: the plant size and the purification technique used. In Europe the investment costs can vary from 200,000 to 800,000 euros. The payback period can also vary on different factors as for example the market price of alkali.

³⁴ This technique is only applicable for certain types of dyestuffs, like acid dyestuff and disperse dyestuff. While for others types of dyestuff, like active dyestuffs, the technique is not applicable.

³⁵ The RAMAN spectroscopy unit used and others similar ones on the market are quite expensive.

³⁶ Restriction: this technique is a BAT with technical limitations depending by the kind of dyestuffs.

Resource 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.

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.D.1	One-step desizing, scouring and bleaching of cotton fabric	+	-/+ ³⁷	0	0	-/+	+	0	+	0	0	0	0	0	+	+	Yes ³⁸	
2.D.2	Optimization of cotton warp yarn pre-treatment	+	+	+	0	+	+	+	+	0	0	0	0	+	+	0	Yes	
2.D.3	Application of the oxidative route for efficient, universal size removal	+	+	+	0	+	+	+	+	+	0	0	0	+	+	0	Yes	

³⁷ Only companies with new machinery used in this process are able to apply this technique.

³⁸ Restriction: this technique is BAT only for companies with new machinery.

Resource efficiency measures

Reduction moth proofer and resist insect agent emissions

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.

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.E.2	Proportional overtreatment of loose fibre	+	+ ³⁹	0	+	+	0	+	0	0	0	0	0	0	+	- ⁴⁰	Yes	

³⁹The technique is not applicable to the majority of dye houses, because it needs specially constructed equipment.

⁴⁰On a self-build basis the cost of constructing a dedicated installation from available materials is said to be in excess of EUR 130000.

Selection/substitution of chemicals by other more environmentally friendly ones
Alternatives to mineral oils

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.

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?	
3.A.1	Mineral oils substitution in knitted fabric manufacturing	+	+	+	+	+	+	0	+	+	+	0	+	+	+	0	Yes	

Selection/substitution of chemicals with others more environmentally friendly
Use of enzymatic treatment/enzymes in processes 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.

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?	
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	+	-/+ ⁴¹	+	+	-/+	+	0	+	0	0	+	0	+	+	+	Yes ⁴²	

⁴¹This technique is only applicable when using not anionic dyestuffs.

⁴² Restriction: this technique is BAT only when using non-anionic 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.

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?	
3.C.1	Dispersing agents with higher bio eliminability in dye formulations	+	+	+	+	+	0	0	0	0	0	0	0	+	+	- ⁴³	Yes	
3.C.2	Dyeing with sulphur dyes	+	-/+ ⁴⁴	+	+	-/+	+	0	0	0	0	0	0	+	+	0	Yes ⁴⁵	
3.C.4	Silicate-free fixation method for cold pad batch dyeing	+	-/+ ⁴⁶	+	0	-/+	+	+	0	0	0	0	0	+	+	-	Yes ⁴⁷	
3.C.5	Exhaust dyeing of cellulosic fibres with high-fixation polyfunctional reactive dyestuffs	+	+	+	+	+	+	+	+	0	0	0	0	+	+	-	Yes	

⁴³ Dispersing agents with higher bioeliminability in dye formulations are more expensive than conventional ones.

⁴⁴ This technique is applicable only for dyeing into dark colours only.

⁴⁵ Restriction: this technique is BAT with technical applicability limitations.

⁴⁶ This technique is only applicable if the installation uses reactive dyestuffs.

⁴⁷ Restriction: this technique is BAT only when installation employs reactive dyestuffs.

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?	
3.C.6	Exhaust dyeing with low-salt reactive dyes	+	+	+	+	+	0	+	0	0	0	0	0	+	+	-/-- ⁴⁸	Yes ⁴⁹	
3.C.7	Dyeing without water and chemicals	+	-/+ ⁵⁰	0	0	0	+	+	-	0	+	0	+	+	+	-- ⁵¹	No	

⁴⁸ In Egypt the economic viability depends on the final destination of wastewater and the related cost of water treatment. The use of low-salt dyes reduces the load of TSS and salinity in the wastewater. If the installation is connected to the public sewer system, the owner pays only small amounts to treat wastewater. In this case the returns and savings achieved with the technique do not balance out the costs. If the installation is not connected to the public sewer system and the owner emits wastewater into surface water, than the owner has to treat it in a dedicated wastewater treatment plant. In this case the technique allows achieving low concentration of TSS in the effluent and the returns and savings balance out the costs of the technique and it is considered to be BAT.

⁴⁹ Restriction: this technique is BAT with economic limitations.

⁵⁰ This technique is applicable for synthetic fibres only.

⁵¹ According to TWG members, in Egypt, this technique is not economically viable.

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.

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?	
3.D.3	Substitution for sodium hypochlorite and chlorine-containing compounds in bleaching operations	+	+	+	0	+	0	+	0	0	0	0	0	+	+	+	Yes	
3.D.4	Selection of biodegradable/bioeliminable complexing agents in pretreatment and dyeing processes	+	+	+	0	+	0	+	+	0	0	0	0	+	+	0	Yes	
3.D.5	Selection of antifoaming agents with improved environmental performance	+	+	+	+	+	0	+	0	0	+	0	0	0	+	0	Yes	
3.D.9	Urea substitution and/or reduction in reactive printing and reactive two-step printing	+	+	+	0	+	0	+	0	+	0	0	0	+	+	- ⁵²	Yes	
3.D.12	Use environment-friendly alternative chemicals for finishing activities	+	+	+	+	+	0	+	0	0	0	0	0	+	+	-	Yes	

⁵² Economically viable only in plants of large capacity.

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?	
3.D.14	Use of nanomaterials in textile finishing	+	+	+	+	-	0	0	0	0	+	0	0	+	+	0	Yes	

End of pipe techniques**Wastewater load 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.

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?	
4.A.5	Purification of Industrial And Mixed Wastewater By Combined Membrane Filtration And Sonochemical Technologies	-	-	+	0	-	0	+	-	- ⁵³	0	0	-	-	-	-- ⁵⁴	No	
4.A.6	Appropriately treat industrial wastewater by implementing a combination of suitable waste purification techniques	+	+	0	0	+	0	+	- ⁵⁵	- ⁵⁶	0	+	0	-/0 ⁵⁷	0	-/-- ⁵⁸	Yes ⁵⁹	
4.A.8	Anaerobic degradation of textile dye bath effluent using Halomonas sp	- ⁶⁰	+/- ⁶¹	-	0	-	0	+	+	0	-	0	0	0	+	0	No	

⁵³ The UF will generate a concentrated reject that must be treated and safely disposed.

⁵⁴ This technique is very expensive due to both installation and membranes maintenance.

⁵⁵ Some of the water treatment techniques require additional energy.

⁵⁶ Some of the water treatment techniques create a residue (sludge) during the treatment process.

⁵⁷ Some of the water treatment techniques require the use of chemicals.

⁵⁸ Wastewater treatment will always require an additional cost. The costs depend on, amongst other things, the type, design and size of the system.

⁵⁹ Restriction: this technique is BAT with economic limitations.

⁶⁰ The technique has not yet been proven on a large industrial scale.

⁶¹ The technique can be applied to wastewater produced by azo-reactive dye used by a nearby textile industry.

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?	
4.A.9	Colour removal of dyes from synthetic and real textile wastewater in one- and two-stage anaerobic systems.	- ⁶²	+/- ⁶³	0	0	-	0	+	+	0	-	0	0	0	+	0	No	
4.A.10	Integrating photo biological hydrogen production with dye-metal bio removal from simulated textile wastewater	- ⁶⁴	-	-	0	-	0	+	0	-	0	0	0	0	0	-- ⁶⁵	No	
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	- ⁶⁶	-	0	0	-	0	+	0	0	0	0	0	+	+	+	No	

⁶² The technique has not yet been proven on an industrial scale.

⁶³ The technique can be applied in synthetic textile wastewater and in real textile wastewater.

⁶⁴ The technique has not yet been proven on an industrial scale (only on research scale).

⁶⁵ According to the TWG Members in Egypt this technique is not economically viable due to high investment costs.

⁶⁶ Technique has not yet been proven on an industrial scale (only on a research scale).

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?	
4.A.13	Bio sorption of reactive dye from textile wastewater by non-viable biomass of Aspergillus niger and Spirogyra sp	- ⁶⁷	+ ⁶⁸	+	0	-	0	+	0	- ⁶⁹	0	0	0	+	+	+	No	
4.A.14	Use of Chlorella vulgaris for bioremediation of textile wastewater	+	+ ⁷⁰	0	0	+	0	+	0	0	0	0	0	+	+	0	Yes	
4.A.15	Chemical coagulation/flocculation technologies for removal of colour from textile wastewaters	+	+	0	0	+	0	+	-/0	-	0	0	0	-	0	0	Yes	
4.A.17	Potential of combined fungal and bacterial treatment for colour removal in textile wastewater	- ⁷¹	- ⁷²	0	0	-	0	+	0	0	0	0	0	0	+	0	No	
4.A.20	Utilization of modified silk cotton hull waste as an adsorbent for the removal of textile dye (reactive blue MR) from aqueous solution	+	+	+	0	+	0	+	+	-	0	0	0	+	+	+	Yes	

⁶⁷ The technique has not yet been proven on an industrial scale (only on a pilot scale).

⁶⁸ The technique can be applied to new and existing installations.

⁶⁹ In Egypt, the non-recoverable biomass produced will be disposed of as hazardous waste as it will contain heavy metals.

⁷⁰ The technique can be applied to new and existing installations.

⁷¹ The technique has not yet been proven on an industrial scale (only on pilot scale).

⁷² This technique is difficult to apply in Egypt.

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?	
4.A.22	Bio sorption of anionic textile dyes by nonviable biomass of fungi and yeast	- ⁷³	+	+	0	-	0	+	0	0	0	0	0	+	+	+	No	
4.A.23	Combined biological physical and chemical treatment of mixed wastewater effluent	+	+	+	0	+	0	+	+	+	0	0	0	+	+	-	Yes	
4.A.24	Treatment and recovery of wastewater containing pigment paste	+	+	+	0	+	+	+	0	0	-/+	0	0	+	+	-/--	Yes ⁷⁴⁷⁵	
4.A.25	Treatment of selected and segregated, non-biodegradable wastewater stream by chemical oxidation	+	+	0	0	+	0	+	0	+	0	0	0	-	+	-/--	Yes ⁷⁶⁷⁷	

⁷³ The technique has not yet been proven on an industrial scale (only on pilot scale).

⁷⁴ In Egypt the economic viability depends on the final destination of wastewater and the related cost of water treatment. The use of low-salt dyes allows reducing the load of TSS and salinity in the wastewater. If the installation is connected to the public sewer system, the owner pays only small amounts to treat its wastewater. In this case the returns and savings achieved with the technique don't balance out the costs. If the installation is not connected to the public sewer system and the owner emits its wastewater into surface water, than the owner has to treat it in a dedicated wastewater treatment plant. In this case the technique allows achieving low concentration of TSS in the effluent and the returns and savings balance out the costs of the technique and it is considered to be BAT.

⁷⁵ Restriction: this technique is BAT with economic limitations.

⁷⁶ In Egypt the economic viability depends on the final destination of wastewater and the related cost of water treatment. The use of low-salt dyes allows reducing the load of TSS and salinity in the wastewater. If the installation is connected to the public sewer system, the owner pays only small amounts to treat its wastewater. In this case the returns and savings achieved with the technique don't balance out the costs. If the installation is not connected to the public sewer system and the owner emits its wastewater into surface water, than the owner has to treat it in a dedicated wastewater treatment plant. In this case, the technique achieves low concentration of TSS in the effluent, the return and savings balance out the costs, and it is considered to be BAT.

⁷⁷ Restriction: this technique is BAT with economic limitations.

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?	
4.A.26	Wastewater treatment by flocculation/precipitation and incineration of the resulting sludge	+	+	0	0	+	0	+	-	+	-/0	0	0	-	0	0	Yes	

End of pipe techniques**Air emissions 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.

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?
4.B.1.	Absorption techniques (e.g. wet scrubbers), particulates separation techniques (e.g. electrostatic precipitators, cyclones, fabric filters), adsorption techniques (e.g. activated carbon adsorption).	+	-/+ ⁷⁸	0	0	-/+	0	0	0	0	+	0	0	0	+	-		Yes ⁷⁹

⁷⁸ The applicability depends on the kind of technique used. The choice of the technique will depend on the pollutant to abate (dust, VOC, etc.).

⁷⁹ Restriction: these techniques are BAT with technical applicability limitations.

End of pipe techniques**Waste management**

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.

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.B.1	Minimization of dye liquor losses in pad dyeing techniques	+	-/+ ⁸⁰	0	0	-/+	+	+	0	0	0	0	0	+	+	+	Yes ⁸¹	
2.C.7	Bacterial cellulose production from cotton-based waste textiles: Enzymatic saccharification enhanced by ionic liquid pre-treatment	- ⁸²	+	0	0	-	0	0	0	+	0	0	0	+	+	+	No	

As can be observed in the table, some techniques have been proven at laboratory scale. According to the BAT classification included in the BREF these techniques can be considered 'emerging techniques'.

⁸⁰ This technique is not suitable for light fabrics (below 220 g/m) or fabric with good wettability. In addition, it can only be applied for certain types of reactive dyes in the dyeing of cotton.

⁸¹ Restriction: this technique is BAT with technical limitations due to the kind of fabric used and the type of reactive dyes.

⁸² The technique has not yet been proven on an industrial scale (only on pilot scale).

5.2 BAT conclusions

Based on Table 41, the following conclusions can be formulated for the textile sector.

Remarks:

Unless otherwise stated, the BAT conclusions presented in this section are generally applicable to the textile sector.

The techniques listed and described in these BAT conclusions are neither prescriptive nor exhaustive. Other techniques that ensure (at least) an equivalent level of environmental protection can be used.

Usually, in a BAT study, emission levels associated with the best available techniques (BAT AELs) are determined. These are the range of emission levels obtained under normal operating conditions using a BAT or a combination of BAT, expressed as an average over a given period of time, under specified reference conditions.

These BAT AELs are considered as the ultimate goal, whether it is by applying one or a combination of technique: as long as the environmental performance of an installation is in line with BAT AELs. In the present study however, the determination of BAT AELs was impossible due to lack of performance data. BAT are simply listed according to the textile process to which they apply. Depending on the environmental performance level one envisages, one or a combination of techniques might have to be applied. Combinations of techniques were not evaluated in this study.

5.2.1 General BAT for *all* textile companies

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

- *Management and good housekeeping (G1)*
- *Input/output streams evaluation/inventory (G2)*
- *Automated preparation and dispensing of chemicals (G3)*
- *Optimising water consumption in textile operations (G4)*
- *Insulation of High Temperature (HT) machines (G5)*

5.2.2 Energy efficiency measures

5.2.2.1 Techniques to reduce energy consumption

BAT is to reduce energy consumption by using the following technique:

- *Minimisation of energy consumption of stenter frames(1.B.1).*

This technique is identified as BAT, but only under certain circumstances:

- *pH-controlled dyeing techniques (1.B.2)*

This technique is a candidate BAT for all textile companies, but some underlying techniques can be applied only if the goods and liquor are well mixed. The technique (or techniques) is commonly applied in uni-dyeing processes, whereas it presents

some limitations when blends of fibres are dyed to obtain differential shades (differential dyeing).

5.2.3 Resource efficiency measures

5.2.3.1 *Efficient use of chemicals and raw materials (low add-on technique)*

BAT for an efficient use of chemicals and raw materials is to implement one or a combination of the following techniques:

- *Minimizing sizing agent add-on by pre-wetting the warp yarns (2.A.1)*
- *Use of techniques that allow reduced load of sizing agents on the fibre (compact spinning) (2.A.2)*
- *Minimizing consumption of complexing agents in hydrogen peroxide bleaching (2.A.3)*
- *Omitting the use of detergents in rinsing after washing of cotton dyed with reactive dyes (2.A.4)*
- *Alternative process for continuous (and semi-continuous) dyeing of cellulosic fabric with functional reactive dyes (2.A.5)*

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

- *Avoiding batch softening: application of softeners by pad mangles or by spraying and foaming application systems (2.A.6)*

This technique is only a BAT for certain kind of fabrics processes and softening agents used.

5.2.3.2 *Efficient use of water*

BAT for an efficient use of water is to implement one or a combination of the following techniques:

- *Reduction of water consumption in cleaning operations (2.B.4)*
- *The use of the drain and fill method and smart rinsing systems (2.B.5)*
- *Increasing washing efficiency and water flow control (2.B.6)*

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

- *After treatment in PES dyeing (2.B.2)*
For blends with elastane fibres, the applicability is limited.
- *Re-use rinse water from process baths in the production process (2.B.7)*
This technique is not a BAT for dyeing processes, for quality reasons.

5.2.3.3 *Resource recovery measures*

BAT is for resource recovery measures by using the following technique:

- *Recovery of alkali from mercerizing (2.C.2)*

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

- *Direct re-use of dye baths and auto-control of the process online (2.C.6)*
This technique is only BAT when it is used for some dyestuffs.

5.2.3.4 ***Integrated process measures***

BAT is for integrated process measures by using the following technique are:

- *Optimization of cotton warp yarn pretreatment (2.D.2)*
- *Application of the oxidative route for efficient, universal size removal (2.D.3)*

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

- *One-step desizing, scouring and bleaching of cotton fabric (2.D.1)*
This technique is only BAT for companies with new machinery used in this process.

5.2.3.5 ***Reduction moth proofing and insect agent emissions***

BAT is to reduce mothproofing and insect-resistance agent emissions by using the following technique:

- *Proportional overtreatment of loose fibre (2.E.2)*

5.2.4 ***Selection/substitution of chemicals with others more environmentally friendly***

5.2.4.1 ***Alternatives to mineral oils***

BAT is about alternatives to mineral oils by using the following technique:

- *Mineral oils substitution in knitted fabric manufacturing (3.A.1)*

5.2.4.2 ***Use of enzymatic treatment/enzymes in processes resources recovery measures***

This technique is identified as BAT, but only under certain circumstances:

- *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 only BAT when using non-anionic dyestuffs.

5.2.4.3 ***Less pollutant dyes***

BAT is for less pollutant dyes by using one or a combination of the following techniques:

- *Dispersing agents with higher bioeliminability in dye formulations (3.C.1)*
- *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 only a BAT for dark dyes.
- *Silicate-free fixation method for cold pad batch dyeing (3.C.4)*
This technique is only a BAT if the installation uses reactive dyestuffs.
- *Exhaust dyeing with low-salt reactive dyes (3.C.6)*

This technique is only a BAT if it is economically viable.

5.2.4.4 Other measures

BAT is about other measures by using one or a combination of the following techniques:

- *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)*
- *Urea substitution and/or reduction in reactive printing and reactive two-step printing (3.D.9)*
- *Use environment-friendly alternative chemicals for finishing activities (3.D.12)*
- *Use of nano materials in textile finishing (3.D.14)*

5.2.5 End of pipe techniques

5.2.5.1 Wastewater load abatement techniques

BAT is wastewater load abatement by using one or a combination of the following techniques:

- *Use of *Chlorella vulgaris* for bioremediation of textile wastewater (4.A.14)*
- *Chemical coagulation/flocculation technologies for removal of colour from textile wastewater (4.A.15)*
- *Utilization of modified silk cotton hull waste as an adsorbent for the removal of textile dye (reactive blue MR) from aqueous solution (4.A.20)*
- *Combined biological physical and chemical treatment of mixed wastewater effluent (4.A.23)*
- *Wastewater treatment by flocculation/precipitation and incineration of the resulting sludge (4.A.26)*

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

- *Appropriately treat industrial wastewater by implementing a combination of suitable waste purification techniques (4.A.6)*
- *Treatment and recovery of wastewater containing pigment paste (4.A.24)*
- *Treatment of selected and segregated, non-biodegradable wastewater stream by chemical oxidation (4.A.25).*

These techniques are only BAT when they are economically viable.

5.2.5.2 Air emissions abatement techniques

The following technique is identified as BAT, but only under certain circumstances:

- *Absorption techniques (e.g. wet scrubbers), particulates separation techniques (e.g. electrostatic precipitators, cyclones, fabric filters), adsorption techniques (e.g. activated carbon adsorption) (4.B.1).*

Only some of these techniques can be considered BAT.

5.2.5.3 **Waste management**

The following technique is identified as BAT, but only under certain circumstances:

- *Minimization of dye liquor losses in pad dyeing techniques (2.B.1)*

This technique is only a BAT when it is applied for certain types of reactive dyes in cotton dyeing. Moreover, it is not suitable for light fabrics (below 220 g/m) or fabric with good wettability.

CHAPTER 6

RECOMMENDATIONS

In this chapter a number of general conclusions are drawn related to the BAT conclusions. It also highlights a number of experiences and limitations encountered during the process of writing this study. Based on these elements, this chapter serves as a valuation of the report and its results.

The chapter contains a reflection on the quality of data, evaluation and general contents of the report by the author as well as the TWG members. Also, since the regulatory framework of the MPC currently does not include the use of BAT, members of the TWG reflected on the priorities in the outcome of the study, the BAT.

6.1 Priorities in BAT conclusions

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

A general priority, when it comes to BAT, is the need for implementation of monitoring systems. In order to determine BAT and BAT associated emission levels, and to translate those into emission limit values, monitoring data are needed. When implementing these emission limit values, it is only possible to have control on implementation and compliance of legislation when adequate monitoring systems are used. Since monitoring is a basis in order to implement the BAT-principle, it is important to mention that good monitoring systems often require significant investments as well.

With this report we not only want to provide a list of environmental friendly techniques, but also to provide an effective tool to improve the environmental impact of the textile industry in Egypt. With this report we want to support textile companies in the identification of the (best) available techniques to improve their environmental performance. As explained in the previous chapters the authors of this report have classified the BAT in the following categories:

- Energy efficiency measures
- Resources efficiency measures
- Selection/substitution of chemicals by other more environmental friendly ones
- End of pipe techniques

This choice has been made to allow companies to identify easily the technique they could implement to improve their environmental performance. In addition, in Egypt there is an urgent need for upgrading, development and modernization of the textile sector in order to:

- help SMEs keep up with the high pace of innovation and technological changes in the rapidly changing field;
- promote business, technological and research collaborations;
- create new jobs;
- expand textile exports;
- invest in new products and processes for its future survival and prosperity;
- ensure industrial growth while keeping the environmental and social impacts at a sustainable level;
- focus on higher market segments;
- recover market share in local market.

Another priority of the report is to provide a useful tool for Egyptian Policy Institutions to further develop their environmental legislation. In many countries on the southern 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 legislation in any of the Arab Countries 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 aforementioned 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 of 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 Egyptian situation and describe how these drivers could favour or not the adoption of environmentally friendly techniques in the future. In this paragraph the following driving forces are included: environmental legislation, market requests, cost of the environmental resources, economic incentives.

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 Egypt, the regulatory and legislative framework does not require companies to consider or to adopt the BAT. The environmental laws impose emission limits (e.g. for water emissions) and they are still oriented to promote the implementation of end-of-pipe techniques instead of the application of preventive measures. Furthermore, the legislation does not envisage limits for some environmental aspects (e.g. groundwater use).

The pressure of the local market on textile companies does not yet represent a driver to improve the environmental performance of textile processes. Companies that produce for foreign countries must follow environmental rules imposed by those countries (e.g. the REACH Regulation) and are more open to eco-innovation. In the local market, most products are low-quality products. Local consumer behaviour is still not oriented to select the products with highest environmental performance. In any case, future positive developments could be expected in this regard. Firstly, we can point out that Egypt is the largest cotton producer in Africa and a market leader. The cotton fabrics, compared to other products (e.g. synthetic fabrics), can be directed toward higher quality markets stimulating innovation. Secondly the competition of emerging Countries could convince the Egyptian producers to improve their products. With escalating international competition, the emphasis will be on continuous innovation and on providing products and services with a customized element and higher environmental quality.

The *cost of the environmental resources* represents another driving force to promote eco-innovation. In Egypt the costs for some resource are still too low to represent a driver to implement more environmentally friendly techniques. An example is the cost of water. The textile industry uses a huge amount of water. As described in chapter 4, there are many techniques aiming at reducing water use. Despite this, the low cost of water in Egypt could represent an obstacle to adopting these techniques. Another example could be given by the traditional process that uses pollutant chemicals (e.g. hydrogen peroxide). Several techniques aim to replace this product with other more environmentally friendly ones, but the low cost of that chemical impedes the adoption of substitutes.

Finally, in Egypt there are still no concrete public *incentives* and there is no access to finances to promote the adoption of environmental techniques. Policymakers could improve

this aspect by, for example, offering tax reductions or subsidies to companies adopting cleaner production measures.

6.2 Limitations to the BAT evaluation and report

There are two main limitations to the current report. These limitations can be taken into account for a possible future update of the report or future similar reports.

Both limitations are linked to the availability of quantitative data, data needed to assess the environmentally friendly techniques in chapter 5 (for example in some cases there are no data on the additional energy required by some of the water treatment techniques) and to determine BAT associated emission values (BAT-AEL). The lack of quantitative data prevented us from performing 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 that is mainly based on expert judgement by the TWG members.

The lack of environmental performance data also prevented us from determining BAT-AEL, the basis for emission limit values (ELV) for the Egyptian textile industry.

Value of the report to TWG members

According to the Egyptian TWG members, the information included in this report is sufficient, although it could be further developed considering especially other new and emerging techniques in textile industries, such as nanotechnology, biotechnology, plasma technology, information and communication technology. Despite this, bear in mind that the objective of the report was the identification of BAT and not the emerging techniques.

The report is considered a useful tool to use in the future, and in particular for selecting the proper candidate BAT which meets the textile facility requirements as well as in plant training courses. Moreover this report could be considered as guidance for eco-friendly processes and products, energy and cost savings, upgrading knowledge and practices, and compliance with legislation. Future users could be both textile companies that want to revise their processes, introducing eco-technologies or researchers and consultants as well.

Moreover, TWG members think that the BAT methodology used in the report could be valorised in the future in the Egyptian legislative framework. Currently the method is still difficult to apply in the legislative framework due to lack of facilities and experience.

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<http://purifast.tecnotex.it/project.asp>

LIST OF ABBREVIATIONS

Ag	Silver
AOX	Absorbable organo-halogen
As	Arsenic
BAT	Best Available Technique
BAT4MED	Boosting Best Available Techniques in the Mediterranean Partner Countries
BOD	Biochemical oxygen demand
BREF	BAT Reference Documents
CAS	Compressed Air Systems
Cd	Cadmium
CFD	Computational Fluid Dynamics
CMC	Carboxymethylcellulose
CO	Carbon monoxide
CO ₂	Carbon dioxide
COD	Chemical Oxygen Demand
CR	Congo Red
Cr	Chromium
Cr+6	Hexavalent chromium
Cs	Caesium
Cu	Copper
Deca-BDE	Decabromediphenyl ether
EEAA	Egyptian Environmental Affairs Agency
EBP	Environmental benefit potential
EDTA, DTPA and NTA	Amino carboxylic acids
EED	energy efficient design
ELS	Extra-long stable
ENEMS	Energy Efficiency Management System
ERFT	External Floating Roof Tanks
ETS	Emissions Trading System
EU	Europe/European
Fe	Iron
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
h	Hour
HBCD	Hexabromocyclododecane
Hg	Mercury
H ₂ O ₂	Hydrogen peroxide
HRAP	High rate algae ponds
H ₂ S	Hydrogen Sulphide
H ₂ SO ₄	Sulphuric acid
HT	High temperature
IDA	Industrial Development Authority
IED	Industrial Emissions Directive
IPPCD	Directive on Industrial Pollution Prevention and Control
JV	Joint Venture

LE	Egyptian Pounds
LS	Long stable
MAPP	Major Accident Prevention Policy
MENA	Middle East and North Africa
Min	Minute
Mn	Manganese
MPC	Mediterranean Partner Country
Na ₂ Cr ₂ O ₇	Sodium dichromate
Na ₂ S	Sodium sulphide
Na ₂ HSO ₃	Sodium hydrogen sulphite
NaOH	Sodium hydroxide
NH ₃	Ammonia
NH ₄ -N	Ammonium as Nitrogen
Ni	Nickel
NO ₂	Nitrogen dioxide
NO ₃	Nitrate
NO _x	Nitrogen Oxide
PACT	Powdered Activated Carbon treatment
Pb	Lead
PES	Polyester
PFBS	Perfluoro butane sulphonate
PFOA	Perfluoroactane acid or pentadecafluorooctane acid
PFOS	Perfluorooctanesulphonate or heptadecafluorooctane sulphonate
POY	Polyester
RBMR	Reactive blue MR
Rpm	Revolutions per minute
RRM	Risk and Reliability Based Maintenance
Sb ₂ O ₃	Antimony trioxide
SME	Small and medium enterprises
SO ₂	Sulphur dioxide
SSSUP	Scuola Superiore di Studi Universitari e di Perfezionamento Sant'Anna
SUK1, LBC2 and LBC3	Bacterial strains
TDS	Total dissolved solids
T&C	Textile and clothing
TOC	Total organic carbon
TSP	Trisodium phosphate
TSS	Total suspended solids
TW	Textile wastewater
TWG	Technical Working Group
UF	Ultrafiltration
US	Ultrafiltration (UF) combined with sonication (US)
USD	United States Dollar
UV-VIS	Ultraviolet-visible
VSD	Variable Speed Drives
VOC	Volatile Organic Compounds
Zn	Zinc

ANNEXES

LIST OF THE ANNEXES

- Annex 1: Participants to the BAT study
- Annex 2: Technical Data Sheets
- Annex 3: General and horizontal techniques for textile sector

ANNEX 1: Participants to the BAT study

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Plants visited during the course of this study

1. Seif eldeen for textile
2. Elnaggar for textile
3. Star Tex company
4. Eldabaa Tex

ANNEX 2: Technical data sheets

There are two ways to access the database to consult technical data sheets.

1:

1. Go to bat4med.org
2. Click on the quick access to the Bat4med database at the bottom of the page



Another tab opens that gives you access to the database.

Possibility 2: You can also access the database by clicking on the following link:
(<http://databases.bat4med.org/>)

On the database page

Once you are on the database web page, follow the steps to select the desired datasheet and download it.

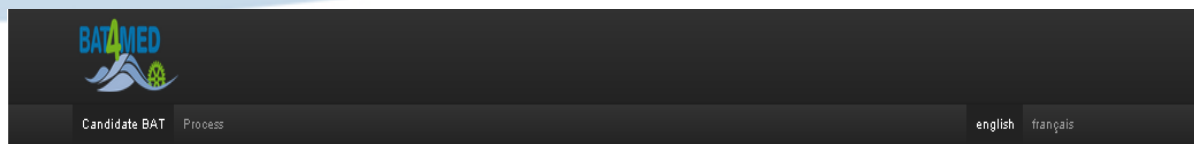
To select datasheets:

1. Choose the language you want to download the datasheet in (horizontal BAT are not translated into French). The language choice appears on the top of the page, on the right side (see 1)
2. Choose from which database you would like to download datasheets. The Candidate BAT database appears (with both sectors BAT, and horizontal BAT) and the process database. The database choice appears on the top of the page, on the left side (see 2)
3. Choose the sector for which you would like to download the datasheet. You can choose the textile sector, the dairy sector, both sectors, and any. (see 3)
4. Choose the criteria you want the datasheet (BAT or process datasheet) to comply with. The menu of criteria is in the centre of the page. You can also run a search with key words. (See 4)
5. Click on the search button. If you made a mistake in choosing one of the previous options, you can reset your search request by clicking on the reset button (see 5)

The screenshot shows the BAT4MED database search interface. The browser address bar displays 'databases.bat4med.org'. The page has a dark header with the BAT4MED logo and navigation tabs for 'Candidate BAT' and 'Process'. On the right side of the header, there are language selection buttons for 'english' and 'français'. Below the header, the main content area is titled 'Candidate BAT' with the instruction 'Please, select your criteria'. There are three main sections for selection: 'Sector' with radio buttons for '(any)', 'Dairy', 'Textile', and 'Both sectors'; 'Impact on environmental topic' with checkboxes for 'Air' (Dust, NO_x, SO_x, NH₃, VOC, Other emissions to air, Odour) and 'Water' (BOD, COD, Nutrients, Other emissions to water, Water consumption); and 'Other' with checkboxes for 'Use of raw & auxiliary materials (e.g. chemicals)', 'Waste production', 'Energy consumption', 'Noise & vibrations', 'Emissions to soil & ground water', and 'General'. At the bottom, there is a 'By text' search input field and two buttons: 'Search' and 'Reset'. Numbered arrows indicate the following steps: 1 points to the language selection buttons; 2 points to the 'Candidate BAT' database selection; 3 points to the 'Sector' selection; 4 points to the 'Impact on environmental topic' and 'Other' criteria checkboxes; and 5 points to the 'Search' button.

To download the datasheets:

Once the search is run, the following list appears with the result of the search (see A):



Candidate BAT

Please, select your criteria

Sector: ☒ (any) ☐ Dairy ☐ Textile ☐ Both sectors

Impact on environmental topic:

Air

☐ Dust

☒ NO_x, SO_x, NH₃

☐ VOC

☐ Other emissions to air

☐ Odour

Water

☐ BOD, COD

☐ Nutrients

☐ Other emissions to water

☐ Water consumption

Other

☐ Use of raw & auxiliary materials (e.g. chemicals)

☐ Waste production

☐ Energy consumption

☐ Noise & vibrations

☐ Emissions to soil & ground water

☐ General

By text:

Found 17 rows

A

B

1. [bat-dairy-25_en.pdf](#) - Two-stage drying in milk powder production
2. [bat-dairy-26_en.pdf](#) - Use of combined heat and power generation (CHP)
3. [bat-dairy-39_en.pdf](#) - Air emissions control strategy
4. [bat-dairy-40_en.pdf](#) - End-of-pipe air treatment
5. [bat-dairy-41_en.pdf](#) - Cyclones
6. [bat-dairy-42_en.pdf](#) - Bag filters
7. [bat-dairy-43_en.pdf](#) - Tubular filters
8. [bat-dairy-44_en.pdf](#) - Absorption
9. [bat-dairy-45_en.pdf](#) - Biofilter
10. [bat-dairy-46_en.pdf](#) - Bioscrubber
11. [bat-dairy-48_en.pdf](#) - Oxidation of waste gases in an existing boiler
12. [bat-dairy-50_en.pdf](#) - Use of UV/ozone in absorption for odour abatement
13. [bat-textile-1_en.pdf](#) - "Fitting of covers on scour bowls to prevent heat loss by convection or evaporation, Optimizing the performance of the final squeeze press in order to improve mechanical removal of water from the wool before it enters the evaporative dryer, Running the last bowl at relatively high temperature, Retrofitting heat recovery units to dryers, Direct gas firing of scour bowls and driers"
14. [bat-textile-6_en.pdf](#) - Use of techniques that allow reduced load of sizing agents on the fibre (compact spinning)
15. [bat-horizontal-07_en.pdf](#) - Reduction of noise emissions
16. [bat-horizontal-08_en.pdf](#) - Techniques to minimise dust from treated raw wool - General approach

To choose and download the datasheets:

1. To choose the datasheet, each search result have a title, and a link, where you can find the type of datasheet answers your request, and the sector it refers to.
2. Once chosen the datasheet, you have to click on the related link (in blue see B)
3. A new tab opens with the chosen datasheet, in a pdf format. In order to download it, you just have to save the pdf document (procedure depending on the navigator you use, and the pdf version installed on the computer)

ANNEX 3: General and horizontal techniques for textile sector

I. General Techniques

I.1 General good management practices for textile sector

- *Ref. Datasheet G.1: Management and good housekeeping*

Description

Some principles of this practice.

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

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

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

Moreover, chemicals storage, handling, dosing and dispensing should be guaranteed.

Improved knowledge of chemicals and raw materials used is also important.

Ensure minimization and optimisation of the chemicals used.

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 is essential.

Some measures concern management of waste streams.

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 alterations. 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.

Environmental benefit

The 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.

Economic aspects

F. These measures are economically 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.

Reference literature

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

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

Description

In order to consider options and priorities for improving environmental and economic performance, it is important to ascertain the quality and quantity of input/output streams. Input/output stream inventories can be drawn up on different levels. The most general level is 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 of textiles processed).

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

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 facilitate the implementation of some kind of environmental management systems.

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.

Economic aspects

These measures have short pay-back periods.

Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.1.2.-.

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

Description

Automated chemical 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 preparation 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 greater saving of chemicals, water and time.

Applicability, operational data and driving force for implementation

Typical automated dosing and dispensing techniques can be applied to new and existing installations. Exception is made for sophisticated techniques which are expensive and for this reason can be apply for large installations.

Qualified personnel are 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.

Environmental benefit

Many environmental benefits are achieved: reduction of wastewater pollution and waste chemicals. Positive aspects also for the working environment.

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 230,000 to 310,000 euros. For powder dyes, the investment is between 250,000 and 700,000 euros. Cost savings (about 30%) can be derived from a reduction in consumption of chemicals and water, increase in reproducibility and decrease in staff costs.

Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.1.3-.

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

Description

Many techniques allow a reduction of water consumption.

Controlling water consumption in plants 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 can be achieved by improving working practices, reducing liquor ratio, improving washing efficiency and by combining processes.

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

Applicability, operational data and driving force for implementation

The principles above are applicable at general level.

The following specific water consumption level is considered achievable:

- Finishing of yarn: 70/120 l/kg
- finishing of knitted fabric: 70/120 l/kg
- pigment printing of knitted fabric: 0.5-3 l/kg
- finishing of woven fabric consisting mainly of cellulosic fibres: 50-100 l/kg
- finishing of woven fabric consisting mainly of cellulosic fibres (including vat and/or reactive printing): < 200 l/kg
- finishing of woven fabric consisting mainly of wool: < 200 l/kg
- finishing of woven fabric consisting mainly of wool (for processes that require high liquor ratio): < 250 l/kg

Environmental benefit

Savings in energy and water consumptions.

Economic aspects

Investment in new equipment and/or structural modifications is requested.

Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.1.4.

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

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.

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- or water- resistant outer layer.

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

Environmental benefit

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

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: 0.25 €/m³
- loss through 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

	Dyeing unit 1	Dyeing unit 2	Dyeing unit 3
Material costs - insulation (EUR)	3,838	5,263	6,500
Labour costs - installation (EUR)	2,000	2,000	2,000
Annual losses due to thermal radiation (MWh/yr)	45.4	60.9	81.9
Annual gas savings (€/yr)	1,434	1,926	2,590
Payback period (yr)	4.9	4.6	3.8

Reference literature

Reference Document on Best Available Techniques for the Textile Industry, July 2003 -§ 4.1.5.

II. Horizontal techniques

Some environmental issues are common for many industries. For these issues, standard 'horizontal' candidate BAT is selected. The techniques presented here, are gathered by screening the European horizontal BREF documents.

Important to notice is that some of the horizontal techniques are mentioned more specifically for the textile sector in the paragraphs above. Therefore, in this paragraph, only the *additional* candidates BAT 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 applicability, environmental benefit, economic viability, etc. we again refer to the candidate BAT database.

II.I Best Available Techniques for Industrial Cooling Systems

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.

Techniques for reduction of energy consumption

Database references: technique CV2

In the design phase of a cooling system, energy consumption can be reduced when:

- Resistance to water and airflow is reduced;
- High efficiency/low energy equipment is applied;
- The amount of energy demanding equipment is reduced;

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

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.

Techniques for the reduction of entrainment of organisms

Database references: technique CV4

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

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.

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, ...

Reduction of noise emissions

Database references: technique CV7

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

Reduction of risk of leakage

Database references: technique CV8

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

II.II Best Available Techniques on Energy Efficiency

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.

Techniques to optimise the energy efficiency of combustion by relevant techniques

Database references: technique ENE2

The combustion installations discussed here are heating devices or installations using the combustion of a fuel (including wastes) to generate and transfer heat to a given 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;
- **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;
- **Reducing the mass flow of the flue-gases by reducing excess air:** excess air can be minimised by adjusting the air flow rate in proportion to the fuel flow rate. Depending on how fast the heat demand of the process fluctuates, excess air can be manually set or automatically controlled;
- **Burner regulation 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;
- **Fuel choice:** the type of fuel chosen for the combustion process affects the amount of heat energy supplied per unit of fuel used. The required excess air ratio is dependent on the fuel used and this dependence increases for solids. The choice of fuel is therefore an option for reducing excess air and increasing energy efficiency.
- **Oxy-firing (oxyfuel):** oxygen is used instead of ambient air is either extracted from air on the site, or more usually, bought in bulk. Energy requirement to concentrate the air is considerable, and should be taken into account in any energy calculations;
- **Reducing heat losses by insulation:** the heat losses through the walls of the combustion system are determined by the diameter of the pipe and the thickness of the insulation. An optimum insulation thickness which relates energy consumption with economics should be found in every particular case;

Reducing losses through furnace openings: heat losses by radiation can occur via furnace openings for loading/unloading. Openings include furnace flues and stacks, peepholes used to visually check the process,

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**

Techniques to optimise the energy efficiency of electric motor-driven sub-systems

Database references: technique ENE4

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

The following measures may be taken:

- **Energy efficient motors:** energy efficient motors and high efficiency motors offer greater energy efficiency. Additional purchase costs may be up to 20-30% higher, however the energy savings of about 2-8% can be achieved.
- **Proper motor sizing:** often motors are oversized for the real load they have to run. The maximum efficiency however is obtained for the motors of between 60-100% of full load. Therefore proper sizing improves energy efficiency, may reduce line losses due to low power factors and may slightly reduce the operating speed and thus power consumption of fans and pumps.

- **Variable speed drives:** the adjustment of the motor speed through the use of variable speed drives can lead to significant energy savings associated to better process control, less wear in the mechanical equipment and less acoustical noise.
- **Reduce transmission losses**
- **Motor repair**
- **Rewinding**

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,...

Energy efficiency management

Database references: technique ENE1

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

- All industrial companies can save energy by applying the same sound management principles and techniques they use elsewhere in the business for key resources such as finance for example. These management practices include full managerial accountability for energy use. The management of energy consumption and costs eliminates waste and brings cumulative savings over time. Some important features for a successful **energy efficiency management system (ENEMS)** are:
 - Commitment of top management;
 - Definition of an energy efficiency policy;
 - Planning and establishing objectives and targets;
 - Implementation and operation of procedures;
 - ...
- **Planning and establishing objectives and targets.** An important element of an environmental management system is **maintaining overall environmental improvement**, including energy efficiency. Additionally, it was shown that, while there are savings to be gained by optimising individual components (e.g. pumps), the biggest energy efficiency gains are to be made by taking a **systems approach**, starting with the installation, considering the component units and systems and optimising how these interact, and optimising the system. Only then any remaining devices should be optimised.
- Experience shows that, if energy efficiency is considered during the planning and design phase of a new plant, saving potentials are higher and the necessary

investments to achieve the savings are much lower, compared with optimising a plant in commercial operation. **Energy efficient design** should therefore be performed.

- Intensifying the use of energy and raw materials by optimising their use between more than one process or system is called **process integration**. This is site- and process-specific.
- **Maintaining the impetus of energy efficiency initiatives** often creates problems. It is important that savings in energy efficiency due to adoption of a new technology or technique are sustained over time.
- **Other:** communication, effective control of processes, maintenance, monitoring and measurement, energy audits and energy diagnosis, pinch methodology, enthalpy and exergy analysis, thermo economics, energy models, benchmarking, ...

Energy efficient design (EED)

Database references: technique ENE7

In the planning phase of a new plant or installation the 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. energy efficient design (EED) should be initiated at the early stages of the conceptual design/basic design phase, 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.

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).

Techniques to improve energy efficiency in space heating and cooling

Database references: technique ENE9

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

- **Space heating and cooling:** energy savings can be achieved e.g. by reducing the heating/cooling needs or improving the efficiency of the system (by 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;
- **Free cooling:** can be used for cooling in order to increase energy efficiency. It takes place when the external ambient air enthalpy is less than the indoor air enthalpy.

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.

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.

Techniques to optimise the energy efficiency of Pumping Systems

Database references: technique ENE12

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

- **Inventory and assessment of pumping systems:** the first step is to establish an inventory of the pumping systems in the installations with the key operating characteristics.

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

II.III Best Available Techniques on Emissions from Storage

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.

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.

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.

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.

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.

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*)

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 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.

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-of-service inspections

Inspections can be categorized as regular in-service inspections or as regular out-of-service inspections.

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-wall valves

Double-wall 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.

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 tier 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 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 at 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 wall (or single wall 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.