Pollution prevention in the

Textile industry

within the Mediterranean region

Regional Activity Centre for Cleaner Production (RAC/CP)
Mediterranean Action Plan

UNEP

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for Cleaner Production

Ministry of the Environment
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Government of Catalonia
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If you consider that some part of this study could be improved or there is any lack of precision, we would appreciate very much receiving notification of it.

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1. INTRODUCTION AND BACKGROUND

In response to the recommendations made by the National Focal Points of the Regional Activity Centre for Cleaner Production (RAC/CP), the RAC/CP has carried out a Study on prevention and reduction of pollution at source in the textiles industry of the countries of the Mediterranean Action Plan (MAP).

The textiles sector encompasses a wide diversity of activities. Below we present one such possible group by subsectors:

• Washing and combing of wool and hair
• Preparation and spinning of textile fibres
• Manufacture of woven fabrics
• Manufacture of knitted fabrics
• Textile dyeing
• Textile printing
• Textile finishing
• Apparel manufacture (garments)
• Rug and carpet manufacture
• Manufacture of rope, twine, netting, etc.
• Manufacture of non-woven fabrics

This variety of activities, together with the diversity of existing fibres and combinations of fibres, the handling requirements of each of them and the constant change in the market demand, subject to the dictates of fashion, make the textiles sector dynamic and of great interest, but at the same time a highly complex sector which is constantly evolving.

In addition, in the Mediterranean framework which is considered for this study, we should add to the previously mentioned diversity, the peculiarities that derive from the different geographical, cultural, social and economic areas.

Thus, we have considered that essential to clearly delimit the scope of the study, which has been restricted to the dyeing, printing and finishing subsectors as they are considered the most relevant in the Mediterranean basin and, also, since these are activities that have significant effects on the environment, both in regard to the consumption of resources, especially water, and due to the generation of pollution, especially wastewater.

For these subsectors, cotton, wool, cellulosic and synthetic fibres have been considered, as well as blends thereof, either in yarn, fabric or knitwear form.

To carry out the study, we have had the collaboration of and received information from the National Focal Points of the MAP countries. Specifically, for the elaboration of the chapter concerning the description of the textiles subsectors being studied in the MAP countries, a questionnaire overseen by the staff of the RAC/CP, was sent to the focal points to be duly filled out.

The questionnaire was sent to: Albania, Algeria, Bosnia and Herzegovina Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Lebanon, Libya, Malta, Monaco, Morocco, Spain, Syria, Tunisia and Turkey. It was not possible to send it to Slovenia given that there is no National Focal Point which could take charge of filling out the questionnaire.

No data have been included on either Monaco or Cyprus given that they do not have a textiles industry.

Nor have any data been included on Greece or Lebanon, given that these countries have not answered the questionnaire that was sent.

The data quoted in the case of Italy refer exclusively to the Prato region and not the country as a whole. However, an important part of the textiles industry, specifically the most technologically advanced, is concentrated in this region.

Based on the questionnaire and supplementary information as well as comments presented by each of the countries, a description of the situation of the textiles subsectors being studied in each of the countries and a comparison between them was drawn up. These texts were later sent by the RAC/CP to each of the countries participating in the project for their revision.

In the following chapters, a brief description is presented concerning the textiles subsectors studied in the different MAP countries, a description of the main processes of each of the subsectors, a description of the main waste flows generated and the opportunities for pollution prevention identified, as well as some case studies of companies that have successfully implemented practices, equipment or technology that make pollution prevention possible.

2. EXECUTIVE SUMMARY

The textiles sector can be considered an important input to the economy of most of the countries of the Mediterranean basin, as may be seen from the data received on their contribution to the GDP, which varies between 1%, in the case of Israel, and 23%, in the case of Syria. Nevertheless, the textiles sector presents differentiated structures in then MAP countries. This, together with the heterogeneity of the information received with regard to the subsectors that are the object of this study —dyeing, finishing and printing— makes comparison among countries difficult. In some countries, these subsectors are not dealt with separately, and so it has not been possible to obtain data that refer to them exclusively.

Based on the information received, it can be seen that most companies in the dyeing, finishing and printing subsectors may be considered as being SMEs, although large companies also exist, sometimes in the public sector, in countries such as Egypt and Libya.

Regarding types of raw materials, the great importance of the cotton industry in countries such as Egypt, Turkey and Syria should be highlighted; and for wool, in countries such as Libya, Syria, Tunisia and Turkey.

The situation of the textiles sector concerning environmental management is diverse, specifically in the dyeing, finishing and printing subsectors, given that both legal obligations and the infrastructures available in the different countries are also diverse. With regard to costs relating to environmental management, it can be concluded that the main costs concern the supply of water, the cost of treating wastewater and the taxes applicable as well as the cost of waste management. Other costs, such as taxes on water consumption, waste generation or emissions into the atmosphere, or the cost of treating these emissions are of less importance or are non-existent.

As far as the description of the dyeing, printing and finishing subsectors are concerned, this has been limited to:

- Dyeing of cotton, wool, cellulosics and synthetic fibres and yarn, and blends of each of these with other fibres.
- Dyeing and finishing of cotton and wool fibres, and blends of both with other fibres.
- Dyeing and finishing of cotton, wool and cellulosic knitwear, and blends of each of these with other fibres.
- Printing of cotton, wool, cellulosics and synthetics, and blends of each of these with other fibres.

2.1. DYEING AND FINISHING PROCESSES

Prior to the dyeing process, the fibre or the fabric must be prepared. There are several preparation processes depending on the type of fibre in question. Below there is a table showing the most common as well as the reagents used and the waste flows generated:

Table 1

RAW MATERIALS	PRE-TREATMENT STAGES	AUXILIARIES/ REACTIVE AGENTS	WASTEWATER	WASTE	EMISSIONS INTO ATMOSPHERE
FIBRES					
Cotton and blends	Scouring	• NaOH • Detergents • Sodium hydrosulphite • Chelating agents	• DQO • Alkalinity • Dirt from fibres	—	• Alkaline vapours
	Mercerising	• NaOH • Anionic wetting agents • HCl / H_2SO_4	• Alkalinity	—	—
	Optical and chemical bleaching	• H_2O_2 / $NaClO_4$ • pH buffer • Optical bleachers	• Oxidising agents • AOX • COD	—	• Vapours • Aerosols
Wool and blends	Special anti-felt treatment	• Chlorine gas	• Acidity • AOX • Oxidising agents	—	• Vapours • Aerosols • Chlorine
		• Sodium hypochlorite • Formic acid			
		• Sodium sulphate • Potassium permanganate • Sodium bisulphite	• Acidity • Oxidising / reductive agents • COD		• Vapours • Aerosols
		• Permono-sulphuric acid • Sodium sulphite			
	Degreasing	• Sodium carbonate • Detergents • Non-ionic surfactants	• Basicity • COD • Conductivity	—	• Vapours • Aerosols
	Optical and chemical bleaching	• Liquid or gas SO_2 / sulphuric acid • Optical bleaching ag.	• Reductive agents • COD	—	• Vapours • Aerosols • SO_2
		• Hydrogen peroxide • Sodium perborate • Optical bleaching agents	• Oxidising agents • COD	—	• Vapours • Aerosols
Cellulosic	Scouring	• Anionic surfactants • Sodium carbonate • Acetic / formic acid	• COD • Alkalinity (if not neutralised)	—	• Alkaline vapours
	Optical and chemical bleaching	• Hydrogen peroxide (Alkaline medium)	• Oxidising agent • COD	—	• Vapours • Aerosols
		• Sodium chloride • Optical bleaching agent (Acid medium)			

RAW MATERIALS	PRE-TREATMENT STAGES	AUXILIARIES/ REACTIVE AGENTS	WASTEWATER	WASTE	EMISSIONS INTO ATMOSPHERE
Synthetic	Scouring	• Anionic surfactants • Sodium carbonate • Acetic / formic acid	• COD • Alkalinity (if not neutralised)	—	• Alkaline vapours
	Steaming	—	—	—	• Water vapour • VOCs
FABRICS					
Cotton and blends	Singeing	—	—	—	• Combustion gases
	Desizing (quenching)	• Amylases • Cellulases • Sodium persulphate • Detergents (Acid or basic medium)	• COD • BOD • Alkalinity (generally)	—	• Vapours
	Scouring	• NaOH • Detergents • Sodium hydrosulphite • Chelating agents	• COD • Alkalinity • Dirt from fibres	—	• Alkaline vapours
	Mercerising	• NaOH • Anionic wetting agents • HCl / H_2SO_4	• COD • Alkalinity	—	—
	Optical and chemical bleaching	• $NaClO_4$ / H_2O_2 • pH buffer • Optical bleaching agents	• Oxidising agents • AOX (if hypo-chlorite is used) • COD	—	• Vapours • Aerosols
Wool and blends	Carbonisation	• Detergents • Wetting agents • Inorganic acid (HCl / H_2SO_4) • Electrolyte (NaCl / Na_2SO_4)	• Acidity / basicily • COD	• Carboni-sed vegetable particles	• Acid vapours • Combustion gases
	Chemical washing	• Detergents • Electrolytes	• Alkalinity • COD • Conductivity	—	—
	Solvent washing	• Perchloroethylene • Trichloroethylene	• Fatty emulsions • AOX (PER and TRI) • Toxicity	• Exhausted PER & TRI • PER and TRI distillation pastes	• PER and TRI vapours
	Heat setting	—	—	—	• Water vapour • VOCs
	Fulling	• HCl / H_2SO_4	• Acidity • COD	• Lint (short fibres)	—
		• Detergent	• Basicity • COD		
	Fixing	• Vapour	—	—	• Water vapour

RAW MATERIALS	PRE-TREATMENT STAGES	AUXILIARIES/ REACTIVE AGENTS	WASTEWATER	WASTE	EMISSIONS INTO ATMOSPHERE
	Optical and chemical bleaching	• Liquid or gas SO_2 / sulphuric acid • Optical bleaching ag.	• Reductive agents • COD	—	• Vapours • Aerosols • SO_2
		• Hydrogen peroxide • Sodium perborate • Optical bleaching agents	• Oxidising agents • COD		• Vapours • Aerosols
KNITWEAR					
Cotton and blends	Scouring	• NaOH • Detergents • Sodium hydrosulphite • Chelating agents	• COD • Alkalinity • Dirt from fibres	—	• Alkaline vapours
	Mercerising	• NaOH • Anionic wetting agents • HCl / H_2SO_4	• COD • Alkalinity	—	—
	Optical and chemical bleaching	• H_2O_2 • pH buffer • Optical bleaching agents	• Oxidising agents • AOX (if hypo-chlorite is used) • COD	—	• Vapours • Aerosols
Wool and blends	Washing/degreasing	• Detergents • Electrolytes	• Alkalinity • COD • Conductivity	—	—
	Solvent washing	• Perchloroethylene • Trichloroethylene	• Fatty emulsions • AOX (PER and TRI) • Toxicity	• Exhausted PER & TRI • PER & TRI distilaation pastes	• PER and TRI vapours
	Optical and chemical bleaching	• Liquid or gas SO_2 / sulphuric acid • Optical bleaching ag.	• Reductive agents • COD	—	• Vapours • Aerosols • SO_2
		• Hydrogen peroxide • Sodium perborate • Optical bleaching agents	• Oxidising agents • COD		• Vapours • Aerosols
Cellulosics and blends	Scouring	• NaOH • Detergents	• COD • Alkalinity	—	• Alkaline vapours
	Optical and chemical bleaching	• H_2O_2 / $NaClO_4$ • pH buffer • Optical bleaching agents	• Oxidising agents • AOX (if hypo-chlorite is used) • COD	—	• Vapours • Aerosols

As far as the dyeing process is concerned, there is a wide variety of dyes, auxiliaries and chemicals used, depending on the desired fibre and colour. The following table summarises the influence of the dyeing operation on the environment:

Table 2

RAW MATERIALS	DYES	AUXILIARIES/ REACTIVE AGENTS	WASTEWATER	WASTE	EMISSIONS INTO ATMOSPHERE
FIBRES					
Cotton and blends	Direct	• Neutral electrolyte • Wetting agents • Levelling agents	• COD • Colour • Specific pollutants according to the dyes used	—	• Vapours
	Insoluble azo dyes	• Wetting agents or detergents • Acids			
	Sulphurs	• Reductive agent • Neutral electrolyte • Wetting agent • Oxidising agent • Detergent • Sodium acetate			
	Vat	• NaOH • Sodium hydrosulphite • Neutral electrolyte • Wetting agents • Levelling agents • Oxiding agents • Detergent			
	Reactive	• Neutral electrolyte ($NaCl$ or Na_2SO_4) • Wetting agents • Alkali ($NaOH$, $NaHCO_3$ or Na_2CO_3)			
Wool and blends	Acids	• Levelling agents • Acetic / formic acid • Ammonium sulphate • Sodium sulphate	• COD • Colour • Specific pollutants according to the dyes used (metals, for example)	—	• Vapours
	Premetallised	• Detergents • Acetic acid • Levelling agents			
	Chromium acids	• Chromium salts			
	Reactive	• Neutral electrolyte • Wetting agents • Alkali ($NaOH$, $NaHCO_3$ or Na_2CO_3)			
Cellulosic	Reactive	• Neutral electrolyte • Wetting agents • Alkali ($NaOH$, $NaHCO_3$ or Na_2CO_3)	• COD • Colour • Specific pollutants according to the dyes used (conductivity for example)	—	• Vapours • Aerosols
	Sulphur	• Reductive agent • Neutral electrolyte • Wetting agent • Oxidising agent • Detergents • Sodium acetate			

RAW MATERIALS	DYES	AUXILIARIES/ REACTIVE AGENTS	WASTEWATER	WASTE	EMISSIONS INTO ATMOSPHERE
Synthetic	Acids	• Levelling agents • Acetic / formic acid • Ammonium sulphate • Sodium sulphate	• COD • Colour • Specific pollutants according to the dyes used	—	• Vapours • Aerosols
	Disperse	• Dispersing agents • Reductive agent			
	Cationic	• Acetic / formic acid • Cationic or anionic retarders • Levelling agents			
FABRICS					
Cotton and blends	Direct	• Neutral electrolyte • Wetting agents • Levelling agents	• COD • Colour • Specific pollutants according to the dyes used	—	• Vapours
	Insoluble azo dyes	• Wetting agents or detergents • Acids			
	Sulphur	• Reductive agent • Neutral electrolyte • Wetting agents • Oxidising agent • Detergent • Sodium acetate			
	Vat	• NaOH • Reductive agent • Neutral electrolyte • Wetting agents • Levelling agents • Oxidising agents • Detergent			
	Reactive	• Neutral electrolyte • Wetting agents • Alkali (NaOH, $NaHCO_3$, Na_2CO_3)			
	Cationic	• Acetic / formic acid • Cationic or anionic retarders • Levelling agents			
	Disperse	• Dispersing agents			
	Acid	• Levelling agents • Acetic / formic acid • Ammonium sulphate • Sodium sulphate			
	Premetallised	• Detergents • Acetic acid • Levelling agents • Ammonic salts			

RAW MATERIALS	DYES	AUXILIARIES/ REACTIVE AGENTS	WASTEWATER	WASTE	EMISSIONS INTO ATMOSPHERE
Wool and blends	Acids	• Levelling agents • Acetic / formic acid • Ammonium sulphate • Sodium sulphate	• COD • Colour • Specific pollutants according to the dyes used (eg metals)	—	• Vapours
	Premetallised	• Detergents • Acetic acid • Levelling agents • Ammonic salts			
	Chrome	• Chromium salts			
	Cationic	• Acetic / formic acid •Cationic or anionic retarders • Levelling agents			
	Reactive	• Neutral electrolyte • Wetting agents • Alkali (NaOH, $NaHCO_3$ or Na_2CO_3)			
KNITWEAR					
Cotton and blends	Direct	• Neutral electrolyte • Wetting agents • Levelling agents	• COD • Colour • Specific pollutants according to the dyes used	—	• Vapours
	Insoluble azo dyes	• Wetting agents or detergents • Acids			
	Sulphur	• Reductive agent • Neutral electrolyte • Wetting agents • Oxidising agents • Detergent • Sodium acetate			
	Vat	• NaOH • Reductive agent • Neutral electrolyte • Wetting agents • Levelling agents • Oxidising agents • Detergent			
	Reactive	• Neutral electrolyte • Wetting agents • Alkali (NaOH, $NaHCO_3$ or Na_2CO_3)			
	Cationic	• Acetic / formic acid • Cationic or anionic retarders • Levelling agents			
	Disperse	• Dispersing agents			
	Acid	• Levelling agents • Acetic / formic acid • Ammonium sulphate • Sodium sulphate			

RAW MATERIALS	DYES	AUXILIARIES/ REACTIVE AGENTS	WASTEWATER	WASTE	EMISSIONS INTO ATMOSPHERE
	Premetallised	• Detergents • Acetic acid • Levelling agents • Ammonic salts			
Wool and blends	Acid	• Levelling agents • Acetic / formic acid • Ammonium sulphate • Sodium sulphate	• COD • Colour • Specific pollutants according to the dyes used (eg metals)	—	• Vapours
	Premetallised	• Detergents • Acetic acid • Levelling agents • Ammonic salts			
	Chrome	• Chromium salts • Levelling agents			
	Cationic	• Acetic / formic acid • Cationic or anionic retarders • Levelling agents			
	Reactive	• Neutral electrolyte • Wetting agents • Alkali (NaOH, $NaHCO_3$ or Na_2CO_3)			
Cellulosics and blends	Direct	• Neutral electrolyte • Wetting agents • Levelling agents	• COD • Colour • Specific pollutants according to the dyes used (metals, for example)	—	• Vapours
	Sulphur	• Reductive agent • Neutral electrolyte • Wetting agents • Oxidising agent • Surfactants • Sodium acetate			
	Vat	• NaOH • Reductive agent • Neutral electrolyte • Wetting agents • Levelling agents • Oxidising agent • Detergents			
	Soluble-type sulphur	• Reductive agent • Neutral electrolyte • Wetting agents • Oxidising agent • Cationising agent • Sodium acetate			
	Reactive	• Neutral electrolyte • Wetting agents • Alkali (NaOH, $NaHCO_3$ or Na_2CO_3)			

2.2. PRINTING PROCESSES

As in the case of dyeing, the fabric must also be prepared prior to the printing process. There are several types of printing. The table below shows the most common, as well as the stages that follow printing, the most commonly used chemicals and their influence on the environment (both for fabrics and knitwear).

Table 3

PROCESS STAGES		AUXILIARIES/ REACTIVE AGENTS	WASTEWATER	WASTE	EMISSIONS INTO ATMOSPHERE
Printing	Spray printing	• Dyes / pigments • Organic solvent • Resins • Emulsifier	—	—	• Aerosols • VOCs (solvents)
	Corrosion	• Dye • Thickeners • Auxiliaries • Corrosives	• Thickeners and products not fixed in the fibre	• Paste remains	• VOCs
	Direct	• Dye • Thickeners • Auxiliaries	• Thickeners and products not fixed in the fibre	• Paste remains	• VOCs
	Pigment printing	• Pigments • Resins • Thickeners • Additives	—	• Paste remains	• VOCs
Drying		—	—	—	• VOCs
Steaming		• Steam	—	—	• Vapours • VOCs
Washing		• Detergents	• COD • Colour • Metals (printing by corrosion)	—	• Vapours • Aerosols • VOCs
Polymerisation		—	—	—	• Water vapour • VOCs

2.3. FINISHING PROCESSES

As far as finishing is concerned, both for dyed and printed fabrics, a distinction should be made between mechanical and chemical finishing. The chemicals used, as well as the waste flows that are generated, depend on the type of finish desired, and so it is not possible to generalise. Below is a table showing the waste flows that are considered as being the most common:

Table 4

TYPE OF FINISHING	WASTEWATER	WASTE	EMISSIONS INTO THE ATMOSPHERE
MechanicaL	—	• FibrEs • Lint	• Fibre particles and dust • VOCs
Chemical	• COD • Specific pollutants according to finishes used (AOX, surfactants, fats, etc.)	• Finishing bath remains	• VOCs

2.4. POLLUTION PREVENTION OPPORTUNITIES

Below, in the form of a table, we present the most relevant opportunities for preventing pollution, which are classified according to the following breakdown:

OPPORTUNITIES FOR REDUCTION AT SOURCE
- Redesigning of products
- Redesigning of processes
  - Substitution of raw materials
  - New technologies
  - Good housekeeping practices

OPPORTUNITIES FOR RECYCLING AT SOURCE

OPPORTUNITIES FOR WASTE RECOVERY
- External recycling
- Energy recovery

Table 5

	REDUCTION AT SOURCE			RECYCLING AT SOURCE
	SUBSTITUTION OF RAW MATERIALS	NEW TECHNOLOGIES	SUBSTITUTION OF RAW MATERIALS	
REDUCTION IN WATER CONSUMPTION	6.1.1.2 6.1.1.5 6.1.1.7	6.1.2.1 6.1.2.2 6.1.2.3 6.1.2.4 6.1.2.5 6.1.2.7 6.1.2.9 6.1.2.11 6.1.2.12 6.1.2.13	6.1.3.1 6.1.3.2 6.1.3.3 6.1.3.4 6.1.3.5 6.1.3.6	6.2.1.1 6.2.1.2 6.1.2.3
REDUCTION IN ENERGY CONSUMPTION	6.1.1.1 6.1.1.2	6.1.2.1 6.1.2.2 6.1.2.3 6.1.2.4 6.1.2.5 6.1.2.6 6.1.2.8 6.1.2.9 6.1.2.13	6.1.3.1 6.1.3.2 6.1.3.3 6.1.3.4 6.1.3.5 6.1.3.6	6.1.2.3
REDUCTION IN THE CONSUMPTION OF RAW MATERIALS	6.1.1.1 6.1.1.5 6.2.1.1	6.1.2.1 6.1.2.2 6.1.2.3 6.1.2.6 6.1.2.10	6.1.3.1 6.1.3.4	6.2.1.1 6.1.2.3
REDUCTION IN WASTEWATER POLLUTANT LOAD	6.1.1.1 6.1.1.3 6.1.1.4 6.1.1.5 6.1.1.6 6.1.1.7 6.2.1.1	6.1.2.1 6.1.2.2 6.1.2.3 6.1.2.4 6.1.2.6 6.1.2.9 6.1.2.10 6.1.2.11 6.1.2.12 6.1.2.13	6.1.3.1 6.1.3.2 6.1.3.4 6.1.3.5 6.1.3.6	6.2.1.1 6.2.1.2 6.1.2.3
REDUCTION IN EMSISSIONS INTO THE ATMOSPHERE	6.1.1.5	6.1.2.2 6.1.2.7 6.1.2.8	6.1.3.5 6.1.3.6	—
REDUCTION IN THE AMOUNT OF WASTE GENERATED	—	6.1.2.2 6.1.2.3 6.1.2.11	6.1.3.6	6.1.2.3
IMPROVEMENTS FOR THE TREATMENT SYSTEM	6.1.1.1 6.1.1.3	6.1.2.2 6.1.2.3	—	6.1.2.3
INCREASE IN PRODUCTIVITY	6.1.1.1 6.1.1.2 6.1.1.4	6.1.2.1 6.1.2.2 6.1.2.4 6.1.2.6 6.1.2.7 6.1.2.9	6.1.3.3 6.1.3.4	—
OTHER BENEFITS	—	6.1.2.8	—	—

2.5. CONCLUSIONS AND RECOMMENDATIONS

Given the characteristics of the subsectors studied, it is considered that their main effects on the environment are the following:

- High water and energy consumption.

- Greater or lesser consumption of colouring agents, auxiliary and chemicals depending on the available technology.

- Large volume of wastewater with a significant pollutant load. (Although the pollutant load of wastewater generated depends on the processes carried out, the parameters that are usually most significant are COD, BOD, total solids, AOX, toxicity, and sometimes nitrogen).

- Generation of colouring agents, auxiliary and out-of-date chemicals due to the great variety that an establishment must handle and the changes in their level of consumption from one season to another.

- Generation of a large number of empty containers, corresponding to colouring agents, auxiliary and chemicals used in the process.

- Emission into the atmosphere of volatile organic compounds, if colouring agents and/or auxiliary products that contain such compounds have been used in formulating them.

However, this situation allows for the implementation of a great number of improvements in order to achieve pollution prevention and savings in natural resources. Broadly speaking, bearing in mind the diversity of the sector, and in order to maintain competitiveness among companies, the solution lies in the introduction, in each particular case, of the improvement or improvements that are considered as being most suitable from among all those possible. A brief list of such improvements would be:

- The insulation of all pipes and equipment that use steam or hot water, in order to minimise energy loss.

- Assessing possibilities for heat recovery, whether by means of hot gases, steam or hot water.

- Identifying the possibility of reducing the number of stages carried out wet, by carrying out two or more stages in the same bath. In this way, usually, water and energy consumption as well as auxiliary and chemical product consumption is reduced.

- The optimisation of processes and equipment in order to reduce the number of baths used and thus minimise water consumption.

- To implement the automatic control of the critical variables of the process in order to minimise the indices of “re-operation” and “additions”, with which not only are water, energy, colouring agents, auxiliary and chemicals saved, but also the establishment’s productivity can be increased.

- The automation of the preparation of dye baths, pastes for printing and additives, by means of automatic colour laboratories and the automatic dosage of auxiliaries in order to minimise potential errors which would have repercussions on a higher incidence of “re-operation” and “additions”.

- Identifying the possibilities of wastewater reuse in specific processes such as preliminary rinsing.

- Assessing the possibility of recycling at source some of the baths, some sizing agents and remains of printing pastes.

- The optimisation of machine and utensil cleaning operations.

- A progressive increase in the use of dyes and processes that lead to high exhaustion onto fibres.

- The reduction, as far as possible, of the variety of colouring agents, auxiliary and chemicals that are used; and the correct storage and control of stocks of all of these in order to reduce the generation of out-of-date products or products that are in a bad state that need to be managed as waste.

- The adaptation of the volume of the containers in which colouring agents, auxiliary and chemicals are acquired, to the degree of consumption of each product. In the cases in which consumption is high, it would be interesting to have facilities for the bulk reception of the product, given that in this way, the generation of empty containers would be avoided.

However, in order to carry out some of these measures, it is necessary to substitute certain raw materials, acquire certain facilities and/or introduce certain new technology (as indicated in chapter 6). Analysis of the economic feasibility of the different alternatives should be made in each particular case, given that the investments that are required will depend on each company’s pre-existing technology.

In any case, the introduction of any of the aforementioned cleaner production options and, especially when dealing with the substitution of raw materials or modifications in the processes, should be accompanied by information and the training of employees so that the desired environmental benefits may be obtained and maintained without affecting either the quality of the product or the establishment’s productivity.

3. SITUATION OF THE TEXTILES INDUSTRY IN THE MAP COUNTRIES

This chapter has been drawn up with information supplied by the different countries that belong to the MAP. When compiling this information, we used a questionnaire, which was overseen by the personnel of the RAC/CP, and was sent out in July 2001 to the focal points on which we are focussing our attention, to be duly filled in.

The questionnaires were sent to the following countries: Albania, Algeria, Bosnia and Herzegovina, Croatia, Cyprus[1], Egypt, France, Greece[2], Israel, Italy[3], Lebanon[2], Libya, Malta, Monaco[1], Morocco, Spain, Syria, Tunisia and Turkey[4].

Based on the questionnaire and supplementary information as well as comments presented by each of the countries, a description of the situation of the textiles subsectors being studied in each of the countries and a comparison between them was drawn up. These texts were later sent by the RAC/CP to each of the countries participating in the project for their revision and final approval.

Data supplied in US dollars have been converted into € at the following exchange rate:
1 € = 0.93 US$.

3.1. DESCRIPTION OF THE TEXTILES SECTOR IN THE MAP COUNTRIES

3.1.1. Albania

The information contained in this document was supplied by the Environmental Pollution Control and Prevention Directorate of the National Environmental Office (today Ministry of Environment), with the collaboration of M. Sc. Mirela Kamberi.

The main sources of data related to environmental practices in the textiles industry of Albania come from:

- National Environmental Agency
- INSTAT: Albanian National Statistics Institute
- Municipal Offices; Statistical Offices;
- National Energy Agency
- Ministry of Public Economy and Privatisation

[1] No data have been included on either Monaco or Cyprus given that they do not have a textiles industry.

[2] No data have been included on Greece and Lebanon since neither from the country filled in the questionnaire.

[3] The data quoted in the case of Italy correspond, exclusively, to the Prato region and not the country as a whole. This region hosts an important part of the textiles industry, specifically, the most technologically advanced.

[4] The questionnaire was not sent to Slovenia since there was no national focal point that could fill in the questionnaires.

3.1.1.1. General data concerning the country's textiles industry

Main geographical areas with textiles industry

The textiles industry in Albania is located mainly in the following areas:

- Tirana
- Korca
- Gjirokastra
- Durres
- Shkoder

Main textiles subsectors which are present in the country

According to INSTAT sources, from the municipal offices and the Yearly Statistical Book for the year 2000, the subsectors of dyeing and finishing use the following as raw materials: wool, producing 4,960,024.7 €/year, cotton, producing 13,226,731.2 €/year, artificial fibres, with a production of 6,613,365.5 €/year, synthetic fibres, with a production of 992,005.38 €/year and blends, with a production of 7,274,702.1 €/year.

As far as printing is concerned, according to the same sources, the printing subsector uses the same raw materials, with the following yearly production: wool with 2,670,782.8 €/year, cotton with 7,122,086.02 €/year, artificial fibres with 3,561,043.0 €/year, synthetic fibres with 534,156.99 €/year and blends with 3,917,147.3 €/year.

Total number of textiles companies and workforce in the country

According to data from the year 2000, supplied by INSTAT, the following figures are provided:

- 138 is the total number of companies that correspond to the dyeing and finishing sectors, with a total of 2,539 workers; and 113 the number of companies that deal with printing, employing 1,223 workers.

- 251 is the total number of companies from the group of dyeing, finishing and printing sectors, with a total of 3,762 workers.

- 123,643 the overall number of industries in the country, with a total of 970,020 workers.

% contribution to GDP

According to data from INSTAT concerning the year 2000, the set of all activities corresponding to the textiles sector contributed 3.74% to the total of the country's GDP which is 2,473,120,000 €.

According to the same sources, the dyeing and finishing sectors correspond to 65% of the textiles industry and the printing subsector corresponds to the remaining 35%.

3.1.1.2. Environmental aspects

National infrastructures of environmental management

The existence of only urban solid waste landfills is recognised and it is specified that industrial waste is taken to these landfills. No further environmental infrastructures exist. The information dates from the year 2000 and comes from the National Environmental Agency.

Annual energy consumption in the dyeing, finishing and printing subsectors

All data in this section correspond to the year 2000 and come from the National Energy Agency.

The annual consumption of electrical energy is 124,200 MW/year, with a unit cost of 90.87 €/MW.

The annual consumption of diesel oil is 14,400 t/year, with a unit cost of 530.06 €/t.

The annual consumption of fuel oil ascends to 16,000 t/year, with a unit cost of 189.31 €/t.

It must be stated that the consumption of natural gas was negligible and that other energy sources were used in addition to those mentioned above.

Annual water consumption in the dyeing, finishing and printing subsectors

According to data from water supply companies corresponding to the year 2000, most of the water for consumption by the studied subsectors is supplied by the public supply network, with a total of 49,640,000 m^3/year and a cost of 0.45 €/m^3. Also, 28,000,000 m^3 of water are used that come from superficial catchment, with a cost of 0.13 €/m^3.

Annual consumption of chemical products in the dyeing, finishing and printing subsectors

According to information corresponding to the year 2000, supplied by the INSTAT, the studied subsectors in Albania consumed:

- 500 t of pigments and colouring agents
- 301 t of auxiliary chemical products
- 12,000 t of inorganic salts
- 2,993 t of halogenated solvents
- 1,212 t of non-halogenated solvents
- 1,000 t of other unspecified products

Annual generation of wastewater and fate in the dyeing, finishing and printing subsectors

According to data supplied by municipal offices, 10% of the industries corresponding to the textiles subsectors of dyeing, finishing and printing, possess a wastewater treatment plant, treating a total of 7,764,000 m^3/year. The remaining 90% do not perform any sort of water treatment and discharge 5,124,000 m^3/year.

Annual generation of waste and fate in the dyeing, finishing and printing subsectors

According to information supplied by municipal offices, Albania produces yearly:

- 120 t of waste corresponding to traces of solid pigments and colouring agents
- 220 t of remains of liquid pigments and colouring agents
- 90 t of remains of solid auxiliary chemical products
- 150 t of remains of liquid auxiliary chemical products
- 4,000 t of inorganic salts
- 1,600 t of used halogenated solvents
- 680 t of used non-halogenated solvents
- 200 t of used oils

It should be noted that information regarding other waste such as packaging or leftover fabric is not available.

As far as the fate of the different types of waste is concerned, the same sources indicate that the solids (remains of pigments and colouring agents, remains of auxiliary chemical products, containers, packaging and left-over fabric) are sent to landfills while liquids (remains of pigments and colouring agents, remains of auxiliary chemical products, solvents and oils) and inorganic salts are usually discharged in wastewater.

Environmental management costs of the dyeing, finishing and printing subsectors

According to data for 2000, supplied by statistics offices, the annual cost of environmental management for the companies in the studied subsectors would correspond to the cost of the taxes on the dumping of wastewater 1,182,795.6 €/year, and the cost of the taxes on the generation of waste 1,612,903.2 €/year.

The data supplied consider that other factors, such as external treatment of waste, treatment of atmospheric emissions, taxes on the consumption of water and taxes on the generation of emissions into the atmosphere did not represent any cost.

No data are available on the cost of wastewater treatment at source for those companies that have their own water treatment plant.

State aid for the textiles sector

Environmental projects have not received any state aid up to now.

Common environmental practices in the dyeing, finishing and printing industries

Concerning the degree of establishment of environmental practices aimed at the prevention of pollution, the information received was supplied by audits performed in textiles industries. The data refer to the percentage of companies that are considered to carry out a specific practice, over the total number of companies pertaining to the studied subsectors.

Based on these audits, it can be concluded that 10% of medium-sized companies treat their wastewater at source.

Information regarding the existence of automatic colour laboratories, preventive maintenance of the facilities, automatic dosage of auxiliary products and “on-line” control systems of the processes is not available.

Other environmental practices, such as reuse of wastewater or of finishing baths, recycling of solvents at source, recovery of printing pastes, optimisation of the size of the containers on the scale of the consumption of each product and the application of systems of prevention aimed at avoiding the generation of products that have expired, as well as ISO 14001 certification and/or EMAS verification are not carried out by the companies in the textiles subsectors that are the object of this study.

Environmental legislation

According to the Ministry of the Environment, Albania has legislation on collection of waste and atmospheric emissions.

Concerning the legislation on wastewater treatment and soil pollution, Albania is in the stage of preparation of their draft laws.

3.1.2. Algeria

The information contained in this document has been supplied by the “Ministère de l’Aménagement du Territoire et de l’Environnement” with the collaboration of Ms Dalila Boudjemaa. The main sources of data related with environmental practices in the textiles industry in Algeria come from:

- MATE: Ministère de l’Aménagement du Territoire et de l’Environnement

3.1.2.1. General data concerning the country’s textiles industry

Main geographical areas with textiles industry

It should be noted that Algeria’s textiles industry is located in the East, the West, the Central-Northern area and the Southeast of the country.

Main textiles subsectors in the country

The data supplied by the MATE correspond to the years 1998-1999 and refer to the dyeing and finishing subsector.

Regarding the raw materials used, annual production totalled 540 t of wool (corresponding to 1,020,000 metres), 428,815 t of cotton (corresponding to 18,000,000 metres and 5,320,020 articles), 3,560 t of blends (corresponding to 14,972,444 metres), 7 t of artificial fibres and 390 t of synthetic fibres (corresponding to 629,922 metres and 1,765,000 articles).

Total number of textiles companies and workforce in the country

In the information supplied, according to data for 1998-1999 from MATE, the following figures are presented:

- 4 is the total number of companies corresponding to the dyeing and finishing sectors, with a total of 1,570 workers.

- 39 is the total number of companies in the textiles sector as a whole, with a total of 9,589 workers.

3.1.2.2. Environmental aspects

National infrastructures of environmental management

The information refers to the years 1998-1999 and comes from the MATE.

It is specified that there are 11 wastewater treatment plants, 8 used oil treatment plants, 1 container recycling unit, 10 for the valorisation of fabric leftovers, 5 non-polluted container valorisation facilities and 2 plastics valorisation plants. No indication is made as to the existence of hazardous waste landfills or of urban solid waste landfills or of solvent valorisation plants.

Annual water consumption in the dyeing, finishing and printing subsectors

The greatest amount of water consumed by the companies in the textiles sector comes from the public water supply network, with a total of 16,029 m^3/day (4,808,700 m^3/year). Also, 2,543 m^3/day (763,000 m^3/year) of well water are used.

The information refers to the years 1998-1999 and comes from the MATE.

Annual consumption of chemical products in the dyeing, finishing and printing subsectors

Annually, the Algerian textiles industry consumes:

- 40.12 t of pigments and colouring agents
- 16,356 t of solid auxiliary chemical products
- 156,584 litres of liquid auxiliary chemical products
- 4,381 t of inorganic salts
- 7,850 t of other unspecified products

Annual generation of wastewater and fate in the dyeing, finishing and printing sub-sectors

According to data supplied by the MATE, 30% of the industries corresponding to the dyeing, finishing and printing textiles subsectors possess a wastewater treatment plant, while 70% dumps with no previous treatment.

Annual generation of waste and fate in the dyeing, finishing and printing subsectors

According to MATE sources, the following quantities of waste are produced annually:

- 632.15 t of liquid auxiliary chemical products waste, which are discharged together with the wastewater
- 11,000 t of used oils, which are recovered by NAFTEL
- 208 t of container remains, which are valorised by means of sale
- 430.5 t of fabric leftovers, which are recovered
- 68.3 t of packaging leftovers that are partially reused or disposed of at landfills
- 74.9 t of wastewater treatment plant sludge
- 13 t of other products that are recycled

Common environmental practices in the dyeing, finishing and printing industries

Concerning implementation of good housekeeping practices, it is only indicated that no company in the textiles industry has ISO/EMAS certification.

Environmental legislation

According to the MATE, Algeria possesses environmental legislation on waste, wastewater and soil pollution. Nevertheless, there is no legislation on atmospheric emissions.

3.1.3. Bosnia-Herzegovina

The information contained in this document has been supplied by the Hydro-Engineering Institute, the Center for Environmentally Sustainable Development, with the collaboration of Ms Irem San.

The main sources of data related to environmental practice in the textiles industry in Bosnia-Herzegovina are:

- B&H in numbers, 2000
- Statistical Yearbook of FB&H, 1999
- Statistical Yearbook of RS, 1998
- BiH Economic Update 2000-Third Quarter, USAID report
- Hydro-Engineering Institute

It is explained that the majority of data are only available for the Federation of Bosnia-Herzegovina.

Unfortunately, in Bosnia-Herzegovina, the general state of industry is very poor. Most industries were destroyed or damaged during the war between 1992 and 1995 and so today, they are functioning at 30% of the capacity that they had prior to the conflict. 99% of industry is in the process of being privatised and does not perform any kind of investment in improvements, be they technological or environmental, and so work with outdated technology.

3.1.3.1. General data concerning the country's textiles industry

Bosnia-Herzegovina consists of two entities that correspond to different geographical areas and are highly autonomous. Both have their own Statistics Offices and produce their own data separately:

- The Federation of Bosnia-Herzegovina (FB&H): a decentralised entity, divided into ten cantons, each being a separate governmental entity with high legislative and executive capacity.

- The Republic of Srpska (RS): a centralised entity divided into seven regions. The local administration in each of the regions exists only on the municipal scale. The Republic is responsible for environmental protection, and the municipalities, in accordance with the law, are in charge of satisfying the specific needs of the population concerning the protection of the environment.

Main geographical areas with textiles industry

The most relevant geographical regions or areas in which textiles activities take place are:

- Northern Bosnia-Herzegovina
- Central Bosnia-Herzegovina

Main textiles subsectors in the country

The information available divides the textiles industry into subsectors that are different from the ones proposed, i.e.: the manufacturing of fabrics and the making of clothing. The fabric manufacturing sector includes the processes of cotton and wool yarns, the manufacture of cotton and mixed fabric sheets, the manufacturing of woollen and synthetic fibre blankets; while the manufacturing sector includes the manufacturing of cotton garments, knitwear, lingerie and "prêt à porter". Thus, the information refers to these two subsectors.

According to data for 1999 supplied by "FB&H in numbers, 2000", in Bosnia-Herzegovina, the textiles industries corresponding to the subsectors of manufacturing use wool, cotton and artificial fibres as raw materials.

Annual production in 1999 for the subsector of the manufacturing of fabric was: 29 t/year of cotton yarns, 216 t/year of wool yarns, 81 t/year of cotton fabric and 105 t/year of woollen fabric. It should be noted that annually 1,803,000 pairs of socks and 302,000 m^2 of household cloths are produced.

Concerning the clothing subsector, 109 t/year of knitwear, 58,000 m^2 of household cloths and 5,897,000 m^2 of garments are produced annually.

Data supplied by FB&H refer to 2000.

Total number of textiles companies and workforce in the country

According to the "Statistical Yearbook of FB&H, 1999", the "Statistical Yearbook of RS, 1998" and the "BiH Economic Update 2000-Third Quarter, USAID report", which use data from 1998, 1997 and 2000 respectively, there are 701 industries in the country employing 633,540 workers. Of these, 91 companies operate in the textiles sector, providing jobs for 12,750 workers. Of the latter, 16 belong to the subsector of fabric manufacturing (1,832 workers) and 75 to clothing manufacturing (10,918 workers).

% Contribution to GDP

No data concerning the textiles sector's contribution to the country's GDP is available.

The industry's total contributes 20% in FB&H, and 27% in RS to the country's total GDP, which is 3,554,700 €.

This information was obtained from the "Statistical yearbook of FB&H, 1998", the "Statistical yearbook of RS, 1998" and the "BiH Economic Update 2000-Third Quarter, USAID report".

3.1.3.2. Environmental aspects

National infrastructures of environmental management

The only existing environmental infrastructures are landfills for urban solid waste. Almost all factories have a landfill nearby, but only three of them are controlled, one is currently operating and the other two have yet to open. The rest correspond to non-controlled dumps.

These data have been obtained from the Hydro-Engineering Institute, and correspond to 2001.

Annual energy consumption in the textiles sector

The data supplied refer only to the consumption of electricity in the Federation of Bosnia and Herzegovina, which amounts to 21,627 MW/year (5,331 MW in the fabric manufacturing subsector and 16,296 MW in clothing manufacturing). The unit cost is 0.13 €/kW.

This information is taken from the "Statistical Yearbook of FB&H, 1999".

Annual water consumption in the textiles sector

This information, which has been provided by the Hydro-Engineering Institute, is an estimate based on consumption prior to the war (1992). The information that refers to prices is up-to-date (2001) and is an average, since the price varies from municipality to municipality.

The water used comes from the public network and it is estimated that the textiles sector consumes approximately 1,620,000 m^3/year, at cost of 0.97 €/m^3.

Annual consumption of chemical products in the textiles sector

This information is not available.

Annual generation of wastewater and fate in the textiles sector

It is specified that 26% of companies have their own wastewater treatment systems, today annually processing 1,296,000 m^3. Nevertheless, these plants either do not work or yield poorly due to the damage suffered during the war. The volume of treated wastewater has been estimated by considering only 80% of the water consumed. It is considered that the remaining 74% of the enterprises, do not treat their wastewater.

This information is approximate and has been provided by the Hydro-Engineering Institute.

Annual generation of waste and fate in the textiles sector

Information on the quantity of different types of waste generated by the studied subsectors has not been provided, as it is not available.

According to data (the year they refer to is not stated) provided by the Hydro-Engineering Institute, waste such as remains of pigments and colouring agents, solids and liquids, auxiliary chemical products, solids and liquids, inorganic salts and solvents, halogenated or non-halogenated, are discharged by means of the wastewater, given that no infrastructures are available for their adequate treatment and management.

On the other hand, used oils, remains of containers and packaging, leftover fabric and sludge from the wastewater treatment plant are usually taken to a landfill with no valorization or recycling being performed.

Environmental management costs of the textiles sector

The costs of environmental management that must be assumed by the companies in the textiles sector are limited, according to the information received, to the taxes on the consumption of water and on the dumping of wastewater, and the cost involved in treating wastewater and the waste generated.

Nevertheless, what the latter two may involve is not known.

As far as the previously mentioned taxes are concerned, according to data from the Water Law of B&H referring to 2001, the following taxes are applied:

Tax on the consumption of water: 0.023 €/m^3

Tax on the dumping of wastewater: 0.97 €/IE*

In Bosnia-Herzegovina, there are no environmental taxes either on industrial waste or on atmospheric emissions.

State aid for companies in the textiles sector

A total of 10.8 M€ have been assigned as economic aid for the textiles sector as a whole, which were distributed equally (2.7 M€) for each of the following activities:

- Environmental Protection. No information concerning the amount awarded has been provided
- New facilities (1.2 M€ granted)
- Reconstruction, modernisation and expansion (1.2 M€ granted)
- Maintenance of the facilities (0.027 M€ granted)

These data have been obtained from BiH Economic Update 2000-Third Quarter, USAID report.

Common environmental practices in the textiles sector

Concerning the degree of establishment of environmental practices aimed at preventing pollution, the information received comes from the Hydro-Engineering Institute and no information concerning the year it refers to has been facilitated.

According to data referring to the textiles sector as a whole, only one large company performs automatic dosage of auxiliary products, while 26% of industries treat wastewater at source.

Environmental legislation

By means of the “EC Environment program for B&H” the European Commission has provided technical and financial support to FB&H and RS for the drafting of laws on environmental protection. Specifically, they are at the final phase of the drafting of an Environmental Framework Law, a law that establishes the framework for granting environmental licences both in FB&H and RS, and laws on the protection of water, waste, polluted soils, protection of the air and of nature.

* IE: Inhabitant Equivalent, unit used to determine the organic load of wastewater. Its calculation is based on a procedure established by the law on water.

3.1.4. Croatia

The information contained in this document has been supplied by the Croatian Cleaner Production Centre, with the collaboration of Dijana Baksa B.Sc. (Econ).

The main sources of data related to environmental practice in the textiles industry in Croatia are:

- CBS: Central Bureau of Statistics
- CCE: Croatian Chamber of Economy
- MZOPU: Ministry of Environmental Protection

For the filling in of the questionnaire sent, all members of the Association of Textiles Industries and Clothing, belonging to the Department of Industry of the Croatian Chamber of Economy (CCE), were contacted and asked for case studies of the introduction of pollution prevention measures in 80 companies belonging to the Association of Textiles Industries and Clothing of the CCE.

Some companies do not wish to participate in the study because they think that the information requested is confidential.

3.1.4.1. General data concerning the country's textiles industry

Main geographical areas with textiles industry

According to the CCE, the most relevant geographical regions or areas in which textiles activities take place are the counties of:

- Cakovec
- Karlovac
- Varazdin
- Osijek
- Zagreb

Main textiles subsectors in the country

In Croatia, the subsectors of the textiles industry are: the manufacturing of fabric (cotton yarns, wool yarns, fabric, etc.), the manufacturing of clothes, and the dyeing and making of leather go-ods. Based on the information supplied, it is considered that the dyeing, finishing and printing subsectors would be included in the sector of fabric manufacturing, however, the information is unclear.

According to data from the year 2000, from the CCE, in Croatia the textiles industries correspon-ding to the subsectors of dyeing and finishing use wool, cotton, artificial fibres, synthetic fibres and blends as raw materials. No information has been provided on the printing sector.

As for annual production, for the dyeing and finishing subsector, which uses wool as a raw material, the total is 375 t/year, for cotton, 6,074 t/year, for blends, 55,786,000 m^2/year, for artificial fibres, 2,589 t/year, and 823 t/year for synthetic fibres (data form the CBS).

Total number of textiles companies and workforce in the country

No data are available on the number of companies by subsectors.

As for the total of the textiles sector, data supplied by the CBS and the CCE corresponding to the year 2001 are as follows:

- The total number of companies in the sector as a whole is 720, with a total of 39,200 workers (data from the year 2000). In the dyeing and finishing sector there is a total of 11,192 workers and 28,008 in printing (data from the year 2001).

- The overall number of the country's industries is 84,394, with a total of 1,008,415 workers (data from the year 2001).

% Contribution to GDP

According to the information supplied by the CBS corresponding to the year 1998, the textiles sector contributed with 1.3% of the total GDP. Based on data provided, this contribution could be attributable, solely, to the dyeing and finishing subsector.

3.1.4.2. Environmental aspects

National infrastructures of environmental management

There are no data concerning this point.

Annual energy consumption in the dyeing, finishing and printing subsectors

All data in this section correspond to the year 1999, and come from the CBS. No information is supplied on the unit cost of different types of energy sources.

The consumption known of the different types of energy is as follows:

Electrical energy: 150 MW/year
Natural gas: 9,000 m^3/year
Petroleum products: 7,000 t/year

Annual water consumption in the dyeing, finishing and printing subsectors

According to data from the CBS referring to 1998, most water consumed by studied companies comes from the public supply network, with a total of 1,846,000 m^3/year, followed by surface water from rivers with a total of 1,295,000 m^3/year. It is estimated that water from wells provides a total of 5,000 m^3/year and other types of ground water, 971,000 m^3/year.

Annual consumption of chemical products in the dyeing, finishing and printing subsectors

No data exist on this point.

Annual generation of wastewater and fate in the dyeing, finishing and printing subsectors

No data exist on this point.

Annual generation of waste and fate in the dyeing, finishing and printing subsectors

The only information on this point, facilitated by the CCE, consists of the generation of 21 t/year of leftover fabric.

Environmental management costs

No information exists on this point.

State aid for companies in the textiles sector

No information exists on this point.

Common environmental practices in the dyeing, finishing and printing industries

According to the Croatian Society for Quality, today, 18 of the country's companies have ISO 14001 Certification, and none belong to the textiles sector.

It should be noted that the companies in this sector carry out, above all, subcontracted work, and so they do not have the resources to improve equipment or for new technology.

Environmental legislation

Croatia possesses environmental legislation concerning dumping of wastewater, disposal and management of waste, control of atmospheric emissions and on polluted soils, according to data obtained from the MZOPU.

Companies are obliged by law to produce with respect for nature. Those that do no comply with this requirement may be fined and even shut down.

3.1.5. Egypt

The information contained in this document has been supplied by the Ministry of State for Environment Affairs, with the collaboration of Dr Ahmed Hamza (Senior Technical Advisor).

The main sources of data concerning environmental practice in the textiles industry in Egypt are:

- EMTF: Egyptian Manufacturing Textiles Federation (Year book 2000)
- National Statistics Yearbook
- Ministry of the Environment
- Ministry of Housing

3.1.5.1. General data concerning the country's textiles industry

Main geographical areas with textiles industry

The most relevant geographical areas or regions in which the textiles activity takes place are, in accordance with the EMTF:

- Cairo
- Alexandria
- Shoubra (Kaliobia)
- Mehalla (Gharbia)
- Mansoura (Dakhlia)

Main textiles subsectors in the country

The textiles sector is the country's number two industrial sector, after food, representing 25% of the industrial product, excluding petroleum products. Within the textiles sector, cotton crops, yarns and fabric are worthy of mention. Egypt produces 25-30% of the world's top quality cotton.

According to data for 1999 supplied by the EMTF, the textiles industries corresponding to the dyeing and finishing subsectors use wool, cotton, artificial fibres, synthetic fibres and blends as raw materials. The chemical products that are necessary for the production of artificial and synthetic fibres are mainly imported. The printing subsector, with the exception of wool, uses the same raw materials cited.

As for annual production, for the dyeing and finishing sector that uses wool as a raw material, there is a total of 19,000 t/year, for the remaining raw materials, production is 659.5 M€/year. Of this, 426.9 M€/year correspond to the production of cotton, 32.8 M€/year to the production of mixed fibres, 110.2 M€/year to artificial fibres and 79.5 M€/year to synthetic fibres.

These data correspond to 1999 and were supplied by the National Statistics Yearbook.

The main products manufactured are T-shirts, beach towels, sports clothes and casual clothes aimed at the European and American markets.

No information regarding annual production has been supplied for the printing subsector.

Total number of textiles companies and workforce in the country

The “Arab Economic Report” of the year 1999, includes the following data for 1998:

- 10,444 as being the total number of companies in the textiles sector as a whole, with a total of 213,103 workers
- the total number of the country’s industrial establishments is about 25,500, with a total of 25,000,000 workers.

No separate information exists for each of the subsectors in the study.

About 31% of the Egyptian textiles industry corresponds to large public companies. These large public companies constitute 100% of the country’s yarns, 70% of weaving, 40% of knitwear manufacture and 30% of the finishing industry. The largest company has 34,000 workers and manufactures approximately 25% of the country’s textiles production.

The distribution of the workforce in Egypt is as follows:

- 40% agriculture
- 38% services
- 22% industry

% Contribution to GDP

Egypt’s total GDP in 1999 was 81,308 M€, and the contribution by the textiles sector was 2,488 M€.

According to the “Arab Economic Report” of the year 1999, the textiles sector contributed approximately with 3% of the total GDP.

3.1.5.2. Environmental aspects

National infrastructures of environmental management

The information below on infrastructures for environmental management refers to the whole country. In each case, the source of information is mentioned although in most of them, no information regarding the year to which they refer is given.

The country has:

- 185 municipal wastewater treatment plants. (Source: Ministry of Housing)

• 150 controlled urban solid waste landfills. (Source: Ministry of the Environment)
• 25 solvent recycling plants. (Source: Ministry of the Environment)
• Approximately 200 container and packaging recycling plants. (Source: Ministry of Industry)

No hazardous waste landfills or treatment plants exist now in Egypt, though there are plans for the construction of facilities for treatment and safe disposal of hazardous waste in several locations in the country.

No information has been supplied on the existence of valorization companies of leftover fabric.

It is indicated that there are currently secondary water treatment plants being built. For 2010, it is forecast to have a further 500 plants in addition to the existing ones.

Annual energy consumption in the dyeing, finishing and printing subsectors

All data in this section correspond to the year 1999, and are obtained from the National Energy report published in 2000. No information has been supplied on the unit cost of the different energy forms.

The consumption known of the different types of energy is as follows:

• Electrical energy: 1,100,000 MW/year
• Natural gas: 550,000,000 m^3/year
• Gas-oil: the equivalent of 680,000,000 Mcal/year

A programme is being implemented to substitute liquid fuels with natural gas in 2010.

Annual water consumption in the dyeing, finishing and printing subsectors

According to estimates by the Ministry of Housing, most water consumed by the companies studied comes from the public supply network with a total of 400,000,000 m^3/year, at a cost of 0.21 €/m^3. It is estimated that water from wells provides some 100,000,000 m^3/year, with a cost ranging between 0.16 and 0.32 €/m^3.

It is estimated that the industry of the subsectors in this study recycles a total of 35,000,000 m^3/year, according to data supplied by the Ministry of the Environment.

No data have been supplied on the consumption of surface water.

All data supplied are estimates since no exact measurements of volume are available.

Annual consumption of chemical products in the dyeing, finishing and printing subsectors

Data available from the Ministry of Industry for the year 2000 refer solely to auxiliary chemical products. They have been obtained from audits carried out in the thirty principal establishments and estimates of consumption of small and medium-sized companies, are calculated by extrapolation.

Consumption is presented in t/year:

• NaOH	7,000
• H_2O_2	1,600
• Wetting agents	750
• Sodium silicate	1,400
• H_2SO_4	300
• Others	≈ 2,000

Annual generation of wastewater and fate in the dyeing, finishing and printing subsectors

The data, although they come from two different sources, have been obtained from audits carried out at the main establishments and estimates of the volume of wastewater generated by small and medium-sized companies.

There is no information regarding the year that the data supplied refer to.

According to the Ministry of the Environment:

- About 20% of the companies in the subsectors in question possess wastewater treatment plants, treating a total of approximately 90,000,000 m^3/year.

- Approximately 35% dump their wastewater untreated, reaching a value of approximately 100,000,000 m^3/year.

According to the Ministry of Housing:

- About 45% of the companies in the subsectors in question dump their wastewater at municipal wastewater treatment plants, which treat a total of approximately 2.4 Mm^3/year.

Annual generation of waste and fate in the dyeing, finishing and printing subsectors

According to data (the year they refer to is not stated) from the Ministry of the Environment, the fate of the different types of waste is as follows:

Controlled landfills:

- Remains of solid and liquid pigments
- Solid auxiliary chemical products
- Sludge from wastewater treatment plants

Discharged together with wastewater:

- Liquid auxiliary chemical products
- Inorganic salts

Recycling:

- Halogenated and non-halogenated solvents
- Used oils

Valorization (sale):

- Empty containers
- Packaging
- Remains of fabrics

Environmental management costs in the dyeing, finishing and printing subsectors

Data concerning environmental management come from the "Industrial Pollution Control Fund of the Ministry of the Environment" and are estimates. The year referred to is specified in each case whenever it is available.

In Egypt, no environmental taxes exist for any of the following activities:

- Dumping of wastewater in waterways. In a few instances, there are fees imposed on the dumping of industrial effluents in municipal sewage networks.
- Disposal of industrial waste.
- Generation of atmospheric emissions.

According to data from the year 2000, the estimated annual cost for:

- The treatment of wastewater at the different industries' own water treatment plants is variable
- External management of industrial waste: 215 M€
- Treatment of atmospheric emissions: 26.8 M€
- Fees for the consumption of water: around 5.4 M€

State aid for companies in the textiles sector

There is economic aid for industry in different fields within the framework of the Ministry of the Environment's Programme for Industrial Pollution Control.

For investment in the treatment of wastewater, the programme's budget totals 16 M€. The amount awarded was 5.7 M€, for a total of 30 companies.

For investment in systems for end-of-pipe treatment of pollution, the programme's budget totalled 5.4 M€. The amount awarded was 2.25 M€, for a total of 12 companies.

For investment in recycling equipment at the source of pollution, the programme's budget was 21.5 M€. The amount awarded was 9.1 M€.

For investment in equipment aimed at reducing pollution, the programme's budget was 10.75 M€. The amount awarded was 3.76 M€.

For the introduction of good practices, the programme's budget was 2.15 M€. The amount awarded was 1.6 M€.

The total given over to environmental education was 0.54 M€, of which 0.28 M€ have been awarded.

No help is foreseen in the field of research and development.

Common environmental practices in the dyeing, finishing and printing industries

Concerning the degree of establishment of environmental practices aimed at pollution prevention, the information received comes from the Ministry of the Environment and refers to the percentage of companies that carry them out, compared to the total number of companies from the subsectors in the study.

• ISO 14001 and/or EMAS Certification: 2%
• Reuse of wastewater in the production process: 60%
• Reuse of finishing baths: 15%
• Recycling of solvents at source: 25%
• Laboratories for the automatic preparation of colours: 10%
• Automatic dosage of auxiliary products: 5%
• Optimisation of the size of containers compared with consumption: 3%
• Preventive maintenance of the facilities: 25%
• "On-line" process control systems: 10%
• Wastewater treatment at source: 20%

No information is available on the predominant type of company that has applied each of the abovementioned practices.

Environmental legislation

Egypt possesses environmental legislation related to dumping of industrial wastewater, disposal and management of waste, control of atmospheric emissions and polluted soils. It must be noted that although legislation exists, enforcement must be increased.

3.1.6. France

The information contained in this document has been supplied by the Agence de l'Environnement et de la Maîtrise de l'Énergie (délégation régionale - Midi-Pyrénées et Direction de l'Industrie).

The main sources of data relating to environmental practice in the textiles industry in France come from:

- ADEME: Agence de l'environnement et de la maîtrise de l'énergie
- IUT: Institut universitaire de technologie
- UIT: Union des industries textiles
- FET: Fédération de l'ennoblissement textile
- ITFH: Institut textile français de l'habillement
- Service des statistiques du Ministère de l'industrie

3.1.6.1. General data concerning the country's textiles industry

Main geographical areas with textiles industry

The main areas with a textiles industry in France, according to data supplied by the IUT, ADEME and the Ministry of Industry correspond to:

- Nord-Pas de Calais
- Rhône-Alpes
- Champagne Ardennes Picardie
- Alsace-Lorraine
- Midi-Pyrénées

Main textiles subsectors in the country

According to data supplied by the ADEME, the French textiles industries for the dyeing, finishing and printing subsectors use wool, cotton, artificial fibres, synthetic fibres and blends.

Overall production corresponding to the dyeing and finishing subsectors is 300,000 t/year and production corresponding to the sector of printing rose to 370,000 million m^2/year.

These data are from the UIT and the FET and refer to the year 2000.

Total number of textiles companies and workforce in the country

The information, supplied by the UIT and the FET referring to the year 2000 is as follows:

- 240, the total number of companies corresponding to the dyeing, finishing and printing subsectors, with a total of 14,000 workers. The printing subsector is not dealt with separately from the finishing and dyeing subsector.

- 1,300 is the total number of companies that make up the textiles sector, with a total of 122,000 workers.

3.1.6.2. Environmental aspects

National infrastructure of environmental management

Information has only been facilitated concerning the valorisation of leftover fabrics. They refer to the year 2000 and were supplied by the ADEME. There are 15 companies (garnetting and companies that perform the collection of leftover fabric).

Annual energy consumption in the dyeing, finishing and printing subsectors

All data in this section correspond to the year 1998 and come from the Service des statistiques of the Ministère de l'industrie.

Annual electrical energy consumption totals 495.5 GWh, for natural gas, 959.5 GWh and for oil-bearing products as a whole 252.2 GWh.

The consumption of steam is quoted at 13.5 GWh.

Annual water consumption in the dyeing, finishing and printing subsectors

ADEME, based on the survey and study called "TRIVALOR" which was carried out in the year 2000, estimates the total consumption of water by the subsectors that are the object of this study at 31 million m^3/year, without specifying whether the water comes from the public water supply network, wells or surface collection.

Annual generation of wastewater and fate in the dyeing, finishing and printing subsectors

According to data estimated by ADEME, based on the "TRIVALOR" study and survey of the year 2000, 12% of companies possess their own wastewater treatment plant, 53% dump their waters at other types of wastewater treatment plants and 35% do not treat their wastewater.

Annual generation of waste and fate in the dyeing, finishing and printing subsectors

According to data supplied by the ADEME and the ITFH, the studied subsectors produce a yearly total of 9 t of waste corresponding to remains of colouring agents and solid and liquid pigments, remains of auxiliary chemical products, inorganic salts, remains of halogenated and non-halogenated solvents, used oils and empty containers. Nevertheless, it is considered that this figure may be wrong given that it is so low.

Likewise, it is indicated that 7,650 t/year of packaging leftovers are produced, 8,500 t/year of fabric leftovers and between 7,000 and 9,000 t/year of sludge (dry matter). 75% of this sludge is used to produce compost and to be used in agriculture soil, 25% is taken to controlled landfills and 5% is incinerated.

In addition, 765 t/year of other waste are produced.

Environmental management costs in the dyeing, finishing and printing subsectors

The only data supplied concerning this section was provided by the ADEME and the ITFH, and correspond to the cost of industrial waste disposal by means of specialised waste managers. In the year 1992, this totalled from between 54 and 93 €/t.

Common environmental practices in the dyeing, finishing and printing industries

Concerning the degree of establishment of environmental practices aimed at prevention pollution, the only data that has been facilitated are the following:

- Laboratories for the automatic preparation of colours: more than 50% of companies have them. The type of company is not specified.
- Automatic dosage of auxiliary products: more than 50% of companies have them. The type of company is not specified.

Neither the source nor the year that the data refer to have been supplied.

Environmental legislation

France possesses environmental legislation related to dumping of wastewater, disposal and management of waste, control of atmospheric emissions and polluted soils.

3.1.7. Israel

The information contained in this document was supplied by the Industry and Business Licensing Division of the Ministry of the Environment, with the collaboration of Dr Mordechai Sela.

The main sources of data concerning environmental practices in the textiles industry in Israel are:

- MAI: Manufacturer's Association of Israel
- CBSI: Central Bureau Statistics-Israel

3.1.7.1. General data concerning the country's textiles industry

Main geographical areas with textiles industry

The textiles industry in Israel is spread throughout the country.

Main textiles subsectors in the country

According to MAI sources, in Israel, the textiles industries for the sectors of dyeing, finishing and printing use cotton, artificial fibres, synthetic fibres and blends as raw materials.

It should be noted that, for these subsectors, no industries use wool as a raw material. No information on the year the data refer to is available.

It is explicitly to be noted that the information concerning annual production is not available.

Total number of textiles companies and workforce in the country

In the information supplied, according to data from 2000 supplied by the MAI and/or the CBSI, the following is to be observed:

- 22 is the total number of companies corresponding to the sectors of dyeing, finishing and printing, with a total of 1,300 workers. The printing subsector is not dealt with separately from those of dyeing and finishing.

- 300 is the total number of companies of the textiles sector as a whole, with a total of 36,000 workers.

- 18,000 is the overall number of the country's industries, with a total of 360,000 workers.

% Contribution to GDP

The set of all activities corresponding to the textiles sector contribute 0.9% to the country's total GDP, while dyeing, finishing and printing subsectors contribute 0.5%, and the total for the industry contributes 19%.

These data refer to the year 2000 and are supplied by the MAI.

3.1.7.2. Environmental aspects

National infrastructures of environmental management

It is stated explicitly that the information supplied, which is given below, refers to the whole country.

According to data from the year 2000, supplied by the MAI, there is a total of:

- 50 wastewater treatment plants
- 8 important urban solid waste landfills
- 1 controlled hazardous waste landfill
- 4 solvent recycling plants
- 3 container and packaging recycling plants
- 1 hazardous waste treatment plant

Annual energy consumption in the dyeing, finishing and printing subsectors

All data in this section correspond to the year 2000, and are supplied by the MAI, except those that refer to electrical energy, which have been supplied by the CBSI.

The annual consumption of electrical energy ascends to 458,300 MW/year, with a unit cost of 0.075 €/kW.

Regarding the annual consumption of diesel oil or fuel oil, data are not available, although data corresponding to unit cost is available, which are 0.21 €/kg and 0.15 €/kg respectively.

It should be noted that Israel still does not have natural gas.

Annual water consumption in the dyeing, finishing and printing subsectors

According to data supplied by the MAI, most water for consumption by the studied companies, is supplied by the public water supply network, with a total of 7,000,000 m^3/year and a cost of between 0.54-1.07 €/m^3. No data or information concerning the volume of water consumed from another source is available.

Annual consumption of chemical products in the dyeing, finishing and printing subsectors

It should be noted that no information concerning this section is available.

Annual generation of wastewater and fate in the dyeing, finishing and printing subsectors

According to data supplied by the MAI, 100% of the industries corresponding to the textiles subsectors of dyeing, finishing and printing, possess a wastewater treatment plant, treating a total of 5,500,000 m^3/year.

Annual generation of waste and fate in the dyeing, finishing and printing subsectors

Every year, Israel produces a total of 130,000 t of waste corresponding to mineral salts, of which 3,202 undergo some kind of treatment, while the remaining 126,798 t have another, unspecified fate (data supplied by the MAI). The mineral salts and brine constitute the country's biggest pollutant and its dumping into the public sewerage system is forbidden, and so it is separated and transported to authorised dumping areas.

Likewise, it is noted that information is not available for the other types of waste (chemical products, solvents, oils, recipients, packaging, treatment plant sludge,…) that may have been generated by the textiles subsectors that are the object of this study.

It is explicitly stated that containers and packaging waste are partially recycled.

Environmental management costs in the dyeing, finishing and printing subsectors

According to data from the year 2000, supplied by the MAI, the annual cost of wastewater treatment, at the industries' own wastewater treatment plants, was a total of 10.5 to 17.1 M€/year, while the environmental taxes applied to the dumping of wastewater were 4.3 M€/year).

According to the same source, and for the same period, the management of industrial waste by specialised managers was 9.8 M€/year.

State aid for the textiles sector

Environmental projects do not receive any state aid.

Common environmental practices in the dyeing, finishing and printing industries

Concerning the degree of establishment of environmental practices aimed at pollution prevention, the information received is from the MAI and refers to the percentage of companies that carry them out over the total number of companies in the studied subsectors.

- Reuse of wastewater in the production process: 30% (large national companies)
- Reuse of finishing baths: 20% (large national companies)
- Automatic colour laboratories: 100% (large and medium-sized national companies)
- Automatic dosage of auxiliary products: 100% (large and medium-sized national companies)
- Recovery of printing pastes: 100% (large and medium-sized national companies)
- Optimisation of the size of containers compared to consumption: 100% (large and medium-sized national companies)
- Preventive maintenance of the facilities: 50% (large and medium-sized national companies)
- "On-line" process control systems: 100% (large, medium-sized and small national companies)
- Treatment at source of wastewater: 100% (large, medium-sized and small national companies)
- Currently, no company in the sector object of this study holds ISO 14001 and/or EMAS Certification, nor are there any that recycle solvents at source, or have systems to prevent the generation of products that have expired.

Environmental legislation

Israel possesses environmental legislation related to dumping of wastewater, disposal and management of waste, and control of atmospheric emissions. On the other hand, Israel does not have legislation concerning polluted soils.

The main industries have signed the Reduction of Atmospheric Emissions Agreement.

3.1.8. Italy

The data supplied in reply to the questionnaire sent out only correspond to the Italian province of Prato. Data have not been facilitated on the national scale. Nevertheless, Prato constitutes a very important industrial area in Italy, in which the most modern, technologically advanced textiles industry in the country is located.

The information contained in this document has been supplied by the Italian National Environmental Agency (ANPA) with the collaboration of:

Dr Maria Dalla Costa
Dr Luca Manuta
Dr Paola Lucchesi (Studio Biosfera)

The main sources of data related to environmental practices in the textiles industry of the province of Prato, are:

- CCIAA: Camera di Commercio di Prato
- UIP: Unione Industriale Pratese
- IRPET: Instituto Regionale per la Programmazione Economica Toscana
- ARPAT: Agenzia Regionale per la Protezione Ambientale Toscana

3.1.8.1. General data concerning the textiles industry (Province of Prato

Main geographical areas with textiles industry (Province of Prato)

Prato textile industrial area:

- Province of Prato
  1. Prato
  2. Montemurlo
  3. Vaiano
  4. Cantagallo
  5. Vernio
  6. Poggio a Caiano
  7. Carmignano
- Agliana (PT)
- Montale (PT)
- Quarrata (PT)
- Calenzano (FI)
- Campi Bisenzio (FI)

These data are from the CCIAA, 2000.

Total number of textiles companies and workforce in the country (Province of Prato)

According to data from the year 2000 from the CCIAA, the number of workers in the textiles area of the District of Prato in the manufacturing industry is 58,648, of which 37,169 correspond to the textiles sector and 5,512 to the finishing subsector.

% Contribution to GDP (Province of Prato)

No data is available on the national scale. In the year 2000, the industrial sector contributed 37.4% to the added value generated in the province of Prato, which for that year was estimated at 4,990,000 €. The most specific datum concerning the dyeing, finishing and printing subsectors indicates that the added value from sales is 46%.

3.1.8.2. Environmental aspects (Province of Prato)

National infrastructures of environmental management (Province of Prato)

On the scale of the Prato Commune, there are 2 wastewater treatment plants, and 5 on the provincial scale. The opening of a new plant is foreseen in the provincial scale.

Also on a provincial scale, there is an urban solid waste landfill.

No data concerning other types of environmental infrastructures is available.

The above information mentioned is from the ARPAT and refers to the year 2001.

Annual energy consumption in the dyeing, finishing and printing subsectors (Province of Prato)

According to data supplied by IRPET, in 1999, the Prato province's textiles industry consumed 822,000 kWh of electricity. On the other hand, it is mentioned that the consumption of electrical energy in the area of the 1st Macrolotto (industrial area located in the area to the south of the Prato Commune) was approximately 82,000 kWh, a figure which, given the slight presence of other types of industry in that area, may be considered as being the equivalent to consumption by the textiles sector.

As for the consumption of natural gas, the only data available corresponds to the industry in the area of the 1st Macrolotto, which reaches 30.000 Nm^3/year (data supplied by Policarbo SpA Milano). The consumption of other energy sources has not been indicated.

Annual water consumption in the dyeing, finishing and printing subsectors (Province of Prato)

According to data supplied by CONSER for 1999, the greatest amount of water for consumption by the companies that are the object of this study came from the public water supply network (the urban industrial aqueduct of the city of Prato), with a total of 3,060,060 m^3/year. This consumption refers to the water distributed, among others, to the 32 industries located in the 1st Macrolotto and to a limited number of industries located in the urban area which are connected to the same aqueduct. Water from wells supplied a total of 998,467 m^3/year to the 32 previously mentioned companies.

No information concerning the cost resulting from with water consumption is available.

Annual consumption of chemical products in the dyeing, finishing and printing subsectors (Province of Prato)

Data are only available on the consumption of the different chemical products in the industrial area of Prato and they correspond to the following quantities expressed as t/year:

Surfactants: 850
Oils: 1,175
Acids: 9,266
Alkaline products: 5,773
Salts: 23,592.6

Annual generation of wastewater and fate in the dyeing, finishing and printing subsectors (Province of Prato)

Since companies do not have water meters, it is not possible to precisely quantify hydric discharge, but by carrying out an estimation based on the initial phase of environmental analysis, a reduction of approximately 5% of the quantity of incoming water can be estimated.

Environmental management costs in the dyeing, finishing and printing subsectors

For the industries object of this study, the tariffs are different according to the activity.

Common environmental practices in the dyeing, finishing and printing industries (Province of Prato)

According to data supplied by UIP for the dyeing and finishing subsectors, it is indicated that, on a scale of the Prato Commune, there are 4 companies having ISO 14001 and/or EMAS certification.

The same source of data indicates that, on the provincial scale, 5 companies in this subsector has one of these types of certification. There is one company that makes yarns that has an Ecolabel.

Environmental legislation

Italy has environmental legislation related to dumping of wastewater, disposal and management of waste, control of atmospheric emissions and polluted soils.

3.1.9. Libya

The information contained in this document was supplied by the Environment General Authority (EGA) with the collaboration of Mr Jalal Ibrahim Eltreki.

The main sources of data concerning environmental practice in the textiles industry in Libya are:

- The General National Company for Spinning & Weaving (GNC S&W)
- Regional study for textiles industry in Libya

3.1.9.1. General data concerning the country's textiles industry

Main geographical areas with textiles industry

According to data supplied by GNC S&W, the Libyan textiles industry is mainly found in the following areas:

- Tripoli (cotton weaving, dyeing and finishing industry)
- Benghazi (cotton weaving, dyeing and finishing industry)
- Musratta (cotton weaving, dyeing and finishing industry)
- Bani-Walid (yarns, finishing and weaving of wool)
- El-Marg (yarns, finishing and weaving of wool)
- Additionally, there are 3,681 small factories making clothes and other textile-related products dotted around the territory.

Main textiles subsectors in the country

Based on information supplied, it seems that the subsectors into which the Libyan textiles industry is divided are those of the modern textiles sector and the traditional textiles sector, as well as the wool subsector, producing rugs and blankets, and the cotton and blends subsector, producing fabrics and garments.

It is indicated that the dyeing, finishing and printing subsectors are not considered as being specific subsectors of the Libyan textiles industry, rather they are included as sections within the complex of the wool and cotton industry.

According to sources of the Regional study for the textiles industry and the GNC S&W in 2000, the dyeing and finishing subsectors use different raw materials with the following annual production: wool (900 t/year, that correspond to 13,367,414 m), cotton (14,829,750 kg/year) and blends (unknown quantity). On the other hand, for the printing subsector, the corresponding data are: wool (884 t/year), cotton (unknown quantity) and blends (annual production unknown).

Synthetic and artificial fibres are imported as dyed yarns. This is the only supply source for the studied subsectors.

Total number of textiles companies and workforce in the country

According to the information supplied by the Regional study for the textiles industry in 2001, there are 8,035 workers employed in the Libyan textiles industry.

There are three large companies in the textiles sector, corresponding to the public sector and employing 5,014 workers:

• The General National Company for Spinning & Weaving (3,194 workers)
• The Garments National Company, in Tripoli (1,120 workers)
• The General Garments Company in Benghazi (700 workers)

In addition, there are 672 small companies operating in the private sector employing 3,021 workers.

% Contribution to GDP

The set of all activities corresponding to the textiles sector (both production and trade) contribute 10% to the country's total GDP, although it is indicated that this information is approximate because trade is susceptible to profits and losses.

These data refer to the year 2000 and are supplied by the Regional study for the textiles industry in Libya.

3.1.9.2. Environmental aspects

National infrastructures of environmental management

According to the GNC S&W, Libya possesses 3 wastewater treatment plants, 1 urban solid waste landfill, 1 solvent recycling plant and 1 container and packaging recycling plant. In the comments, it is indicated that the three wastewater treatment plants belong to the GNC S&W, and are located in Janzur, Bani-Walid and El-Marg.

This information corresponds to the year 2000.

Annual energy consumption in the dyeing, finishing and printing subsectors

All data in this section correspond to the year 2000 and are from the GNC S&W.

The annual consumption of electrical energy ascends to 18.5 MW/year, with a unit cost of 0.27 €/MW.

Annual consumption of fuel oil is 1,180 t/year, with a unit cost of 0.13 €/t.

Also, 361.8 t/year of kerosene are consumed at a cost of 0.09 €/t.

It should be noted that the consumption of natural gas and diesel oil was negligible.

The consumption at the three major complexes working in the textiles industry in Libya was:

- Janzur Complex: 1,700,000 kW of electricity and 580 m^3 of fuel oil
- Bani-Walid Complex: 15,850,000 kW of electricity and 560 m^3 of fuel oil
- El-Marg Complex: 600,000 kW of electricity and 40 m^3 of fuel oil

Annual water consumption in the dyeing, finishing and printing subsectors

According to data supplied by the GNC S&W corresponding to the year 2000, the water consumed by the companies that are the object of this study comes from both wells, with annual consumption of 344,850 m^3, and the public water supply network, with a total of 180,000 m^3/year and a cost of 0.17 €/m^3.

For the different complexes of the textiles industry, water consumption is as follows:

- Janzur: 180,000 m^3 from the water treatment plant at Tripoli west
- Bani-Walid: 182,425 m^3 from wells
- El-Marg: 162,425 m^3 of water from wells

Annual consumption of chemical products in the dyeing, finishing and printing subsectors

The information concerning this section is unknown.

Annual generation of wastewater and fate in the dyeing, finishing and printing subsectors

According to the data supplied, the volume of wastewater generated by the sector is 524,850 m^3/year. This figure coincides with the water consumed.

Nevertheless, this information does not coincide with the data on the generation of wastewater supplied for the three main industrial complexes:

- Janzur: 45,000 m^3/year
- Bani-Walid: 45,606 m^3/year
- El-Marg: 40,606 m^3/year

Additionally, according to data on the El-Marg Complex, a third (one in three companies) possess a wastewater treatment plant.

Annual generation of waste and fate in dyeing, finishing and printing subsectors

No information is available regarding the types of waste produced or its final destination. The information that is available corresponds to the total amount of waste generated by the textiles industry:

- Janzur: 135 t/year
- Bani-Walid: 137 t/year
- El-Marg: 122 t/year

Information comes from the GNC S&W.

Environmental management costs in the dyeing, finishing and printing subsectors

The total cost for the three major complexes is around 949,725 €, (GNC S&W). No detailed information exists on the concepts that make up this cost. This information corresponds to the year 2000.

The environmental taxes related to wastewater are around 8%.

State aid for the textiles sector

Since the textiles industry largely belongs to the State, it is not applicable to talk about state aid.

Common environmental practices in the dyeing, finishing and printing industries

The information received indicates that no independent dyeing, finishing or printing companies exist; rather there are production lines that carry out these processes within the large wool and cotton textiles complexes.

The only improvements implemented seem to be wastewater treatment plants and automatic colour laboratories (the latter on the printing production lines).

Environmental legislation

Libya possesses legislation on solid waste and wastewater (General Environmental form). Nevertheless, no legislation exists on atmospheric emissions or on the pollution of soils.

3.1.10. Malta

The information contained in this document has been supplied by the Cleaner Technology Centre, with the collaboration of Mr Anton Pizzuto.

It should be noted that Malta does not possess a textiles industry that operates in the studied subsectors and fabrics are imported from other countries (Turkey, Tunisia, Spain,...) and garments, principally jeans and garments, are made. Therefore, the description of the sector given below refers to the garment making sector.

The main sources of data related to environmental practices in Malta's textiles industry are:

- Cleaner Technology Centre (CTC)
- Central Office of Statistics (COS)
- Industry (VF): the name of a large jeans industry, with access to data from the Federation of Industry

3.1.10.1. General data concerning the country's textiles industry

Main geographical areas with textiles industry

The most relevant geographical regions or areas in which textiles activities take place are:

- The south of Malta
- Central Malta
- Gozo

Main textiles subsectors in the country

As we have already commented in the introduction, there are no companies in Malta operating in the dyeing, finishing and printing subsectors.

Nevertheless, fabrics are imported from other countries (Turkey, Tunisia, Spain,...) and they are used to make garments, principally jeans and garments. Therefore, the main textiles subsector is that of garment making.

The sector uses 8,000,000 m of fabric per year, mainly DENIM-type cotton.

Total number of textiles companies and workforce in the country

According to data supplied by the COS, referring to 1999, there are 188 industries in the country with a total of 3,752 workers.

No data are available concerning the sector textiles.

% Contribution to GDP

Industry as a whole contributes 4% to Malta's total GDP, according to data of the COS for 1999.

3.1.10.2. Environmental aspects

National infrastructures of environmental management

According to data supplied by the CTC corresponding to 2001, very little infrastructure exists relating to environmental management. Specifically, Malta has a wastewater treatment plant and a urban solid waste landfill.

Annual energy consumption in the textiles sector (garment making)

With regard to energy consumption in the textiles sector, the data available corresponding to the year 2001 are as follows:

- Electricity: 10,950 MW/year (with a unit cost of 0.06 €/kWh)
- Fuel oil: 1,248 m^3/year

Annual water consumption in the textiles sector (garment making)

With regard to water consumption in the textiles sector, data is only available concerning consumption by the company VF, corresponding to the year 2001. They are as follows:

- Water from the public network: 8,000 m^3/year (with a unit cost of 1.6 €/m^3)

- Recycled water: 8,650 m^3/year (with a unit cost of 0.26 €/m^3)

Annual generation of waste and fate in the garment-making sector

According to data available, a total of 1,200 t/year of leftover fabric are produced, which are all recycled or recovered, as well as 52 t/year of treatment plant sludge, which is disposed of at landfills.

No information is available on other waste products.

Environmental management costs

According to data available, referring to the year 2001, the environmental costs that must be borne by the textiles companies are limited to the cost of the external management of waste generated, reaching an annual total of 21,505 €.

There are no taxes on the consumption of water, the landfilling of wastewater, the generation of waste or emissions into the atmosphere.

Environmental legislation

According to data supplied by the CTC, Malta possesses environmental legislation relating to dumping of wastewater, disposal and management of waste, control of atmospheric emissions and concerning polluted soils.

3.1.11. Morocco

The information contained in this document has been supplied by Ms Asmâa Tazi, Assistant General Director of the Centre Marocain de Production Propre.

The main sources of information relating to the good housekeeping practices of the Moroccan textiles industry are:

- MICEM: Ministère de l'Industrie, du Commerce, de l'Énergie et des Mines du Maroc
- AMITH: Association Marocaine du Textile et Habillement
- CMPP: Centre Marocain de Production Propre
- KOMPASS for the textiles and leather sector

3.1.11.1. General data concerning the country's textiles industry

Main geographical areas with textiles industry

The geographical areas or regions in which the textiles activity is carried out are, in order of decreasing relevance, located in:

- Casablanca-Mohammedia (two-thirds of the companies in the textiles sector are located in this area, representing 75% of the total textile production)
- Rabat-Salé
- Fès-Meknès
- Marrakech
- Tangiers
- Agadir

Main textiles subsectors in the country

Ever since Morocco decided to progressively open up its borders to trade, competitiveness has become one of the main issues of the strategic business sectors of Morocco, among these the textiles sector.

This integration into the world economy offers many opportunities to the textiles sector, but it also calls for a serious effort in modernising the production facilities, as well as adapting production facilities to the new rules and demands of the export markets, both with regard to the quality of the products, as well as in their compliance with international standards.

The year 2000 was a difficult year for the textiles sector, especially for the clothing subsector, due to the unfavourable evolution of the exchange rate of the Dirham with respect to the Euro since 1999, and also to the increase in wage costs. In the year 2000 itself, the textiles sector lost 30,000 jobs and 100 companies closed. Ironically, exports from the sector in the year 2000 grew by 4% compared to the previous year, reaching € 21,000 M. In the year 2000, the textiles sector represented 44% of the national exports of Morocco.

Nevertheless, not all the textiles subsectors contributed to the same extent to these exports. Manufactured clothing products represented 81% of these exports. 70% of the exports were to Europe.

According to data supplied by the MICEM, the textiles sector in Morocco includes the following activities:

- Spinning of wool, cotton, silk and other vegetable fibres
- Finishing and sizing of cloth
- Manufacturing of simple textile products, other than clothing
- Manufacturing of carpets, doormats and mats
- Hats
- Manufacturing of lingerie and shirts
- Manufacturing of clothing

In turn, these activities include subsectors of interest in this study, such as dyeing, finishing and printing. According to the data supplied by the AMITH, these subsectors use all types of raw materials: wool, cotton, artificial fibres and blends.

The subsector for denim washing is worth a special mention, and is included in the dyeing and finishing subsectors. The washing is normally carried out with either pumice stone, or by using enzyme baths, or by a combination of both methods.

The data supplied by AMITH shows an annual production figure of 24,600 t/yr for the dyeing, finishing and printing subsectors.

Total number of textiles companies and workforce in the country

The information on the total number of companies in the dyeing, finishing and printing subsectors is supplied by KOMPASS for the textiles and leather sector, and refers to the year 2000. In accordance with this data, there are:

- 1,440 companies in the textiles sector (the textiles sector include: spinning, weaving, finishing and garment manufacturing)

- 6,800 companies in the whole industrial sector of the country

The studied subsectors only represent 10% of the total companies in the textiles sector. The dyeing and finishing subsector comprises 93 companies that employ between 7,800 and 8,200 workers, whereas the printing subsector comprises 45 companies and employs 3,200 workers. The information is supplied by AMITH, relating to the year 2000 and is based on data obtained by surveys carried out on the companies in the sector. In accordance with this data, the companies in the dyeing, finishing and printing subsectors have the following geographical distribution:

- Casablanca-Mohammedia: 75%
- Tangiers: 6%
- Fès-Meknès: 5%
- Rabat-Salé: 4%
- Other: 10%

% Contribution to GDP

The textiles and leather industry as a whole comes in third place in the ranking of Moroccan industry, following the agricultural-food industries and the chemicals and related products industries.

In the year 2000, at the national level it contributed 15% to the total production and 17% to the total industrial GDP of the country and provided employment for 42% of the total working population.

3.1.11.2. Environmental aspects

National infrastructures of environmental management

According to data supplied by AMITH and CMPP there are:

- Approximately 50 municipal wastewater treatment plants. (Data corresponding to the year 2001)
- 2 controlled landfills for urban solid waste (Tifelt and Essaouira). (Data corresponding to the year 2000)
- 7 solvent recycling plants. (Data corresponding to the year 2001)
- 20-23 plants for recycling containers and other packaging. (Data corresponding to the year 2000)
- 6 plants for valorizing textile waste. (Data corresponding to the year 2000 supplied by KOMPASS for the textiles and leather sector). Mention is made of the fact that if all the industries that use textile waste in their activities or processes were taken into consideration, there would at least be 30 of them.

In accordance with the data supplied, there are no controlled landfills or treatment plants for hazardous waste. For this reason certain sectors, such as the pharmaceutical industry, have built their own management infrastructure facilities.

Annual energy consumption in the dyeing, finishing and printing subsectors

The energy types used by the dyeing, finishing and printing subsectors are basically electricity and thermal energy generated by the combustion of petroleum products.

In accordance with the data supplied by AMITH and CMPP, the known consumption of the different types of energy, is as follows:

- Electricity: reached 30,500 MWh/yr with a unit cost of € 118.28/MWh
- Fuel oil: 112,000 t/yr with a unit cost of € 258.06/t
- For liquid petroleum gases (LPG), basically butane and propane, and diesel fuel, no information is available relating to the annual consumption. The unit costs are € 322.58/t for LPGs and € 559.14/m^3 for diesel fuel.

The values relating to consumption have been estimated by using the data obtained from carrying out surveys of the industries in the sector and based on environmental audits carried out by the CMPP.

Annual water consumption in the dyeing, finishing and printing subsectors

In accordance with the data for the year 2000, supplied by AMITH and CMPP, water consumed by the companies belonging to the studied subsectors comes on the one hand from the public supply network, with a total of 5,680,000 m^3/yr and a cost of € 0.87/m^3, and on the other from wells and own supplies with a total of 4,420,000 m^3/yr and a cost of € 0.08/m^3.

The cost of water coming from own supplies corresponds to the costs of drilling and installing the wells, and it is estimated that they are payed back in less than 3 years.

The catchment of surface waters is minimal and it is estimated that 30% of the wastewater is reused.

Annual consumption of chemical products in the dyeing, finishing and printing subsectors

The available information is supplied by AMITH and CMPP and relates to the year 2001. Annual consumption in t/yr for each of the families of products is:

- Dyes and pigments: 2,250-2,500 t/yr
- Auxiliary chemical products (wetting agents and surfactants): 2,300 t/yr
- Inorganic salts: 20,000 t/yr
- Halogenated solvents: small amounts

It should be mentioned that the quantity of halogenated solvents used is being reduced as the industries are replacing them with biodegradable products.

With regard to the use of non-halogenated solvents, such as toluene, xylene, acetone or ether, the industries surveyed have not provided specific information.

Annual generation of wastewater and fate in the dyeing, finishing and printing subsectors

The data from the reports on the textiles sector prepared by the CMPP in the period between June 2000 and September 2001 were:

- Around 5% of the companies in the subsectors of interest have their own wastewater treatment plants, treating approximately a total of 825,000 m^3/yr
- Around 35% (2,340,000 m^3/yr) have some type of pre-treatment plant that allows for decantation of the wastewater before discharge.
- Around 60% (5,500,000 m^3/yr) dump their wastewater without any type of treatment.

Annual generation of waste and fate, in the dyeing, finishing and printing subsectors

In accordance with the data supplied by CMPP and MICEM, there is an annual production of:

- 194 t of remains of colouring agents and solid pigments
- 85 t of remains of colouring agents and liquid pigments, which is destined for uncontrolled dumping
- An indefinite but small amount of solid auxiliary chemical products, destined for uncontrolled dumping
- 360 t of inorganic salts, which is destined for uncontrolled dumping
- 345 t of empty containers, destined for valorization and/or recycling
- 258 t of other packaging waste, which is destined for valorization and/or recycling
- 12,500-13,200 t of textile waste, destined for valorization and/or recycling
- 3,750 t of sludge from washing baths, which is destined for valorization/incineration in the ovens of cement factories.

It is estimated that 90% of the companies recycle and/or valorize their leftover fibres and textile waste.

Environmental management costs of the dyeing, finishing and printing subsectors

Very few companies in the studied subsectors have a waste management policy. 85% of these companies are affiliated companies of multinational corporations and the aforementioned costs are directly absorbed by the group within their general policies.

In accordance with the data supplied by CMPP, relating to the period from June 2000 to September 2001, the costs due to the treatment of wastewater by using the companies' own treatment plants, are between € 26,800 and 43,000 per year.

State aid for companies in the textiles sector

In December 1997, through its Ministry of the Environment together with the German Agency for Financial Cooperation (KfW), the government of Morocco set up the industrial pollution management funds (FODEP1 and FODEP2). These are instruments for offering incentives to invest in industrial pollution management and the saving of natural resources.

The FODEP1 programme finances two types of projects:

- Integrated projects, which in addition to industrial pollution management also contemplate a reduction in the consumption of natural resources (water, energy,...)
- Projects leading to the reduction of pollution by implementing treatment facilities or through eliminating pollution.

54 industries have joined this programme, of which 10 (19%) belong to industries in the textiles and leather sector.

As at December 31, 2001, the Technical Committee of FODEP had examined 30 projects, of which 15 have been considered eligible. Of these 15 projects, 8 are related to the dumping of liquids, 5 to gaseous emissions and 2 to solid waste. The 15 projects involve an overall investment of € 7,820,000, of which € 4,077,000 will be in the form of subsidies and € 3,743,000 will be in the form of soft loans.

The FODEP2 programme is different from the previous one, in that it is a financial aid package in the order of €10 M, granted by the German government. Eight companies in the textiles sector have expressed their interest in requesting financing through this programme, for projects relating to the treatment and optimisation of the use of water.

The Moroccan Government has set other additional initiatives in motion, in order to foster the improvement of the textiles sector. Of these, those considered most significant are the “Contrat Branche” presented by the AMITH to the government in August 1999, and the creation of CMPP in June 2000, thanks to the financial support given by the Government of Switzerland, with a duration of 5 years.

The CMPP offers technical assistance to the industries of the textiles sector and constitutes a reference body on environmental matters.

Common environmental practices in the dyeing, finishing and printing industries

With regard to the degree of establishment of the environmental practices aimed at pollution prevention, the information received has been supplied by the AMITH and CMPP and refers to the percentage of companies that carry them out, compared to the total number of companies in the subsectors being studied.

- ISO 14001 Certification and/or EMAS: 1%. (As at March 2002, only one company in the sector has obtained ISO 14001 certification and five more are in the process of being certified. The companies in this sector prefer the O-Ktex Standard 100, as it specifically pertains to the sector).

- Reuse of wastewater in the production process: 1%

- Reuse of rinsing baths: 60%

- Although the recycling of solvents at source is a common practice, there is no percentage available for the industries that carry it out.

- Very few industries have prevention systems for the generation of obsolete products.

- Laboratories for the automatic preparation of colours: 2% (Nevertheless, it is estimated that 85% have laboratories for the non-automatic preparation of colours).

- Automatic dosage of auxiliary products: 30% (100% of the companies have systems for the dosage of auxiliary products, in 70% of the cases this is not considered automatic).

- Preventive maintenance of the facilities: 85%

• “Online” process control systems: 99%

• On-site treatment of wastewater: 5%

Environmental legislation

Morocco has a great number of legal texts that were passed more than half a century ago. The services of the General Board of Urbanism have prepared an inventory of almost 356 texts passed between 1913 and 1985.

Nevertheless, these texts are not adapted to current needs as on the one hand, their main objective was to protect private and State property, preserving the wellbeing of the population, and on the other, the preservation by the State of the products “on loan”, such as water and air, which are considered resources in the public domain.

In order to remedy this situation, the Ministry of the Environment has prepared a strategy to provide the country with a legal and institutional framework, with the following objectives:

• To establish a legal and regulatory framework for the protection and assessment of the environment, simultaneously taking into account the needs for preservation, and sustainable socio-economic development.

• To ensure the legal coherence of all existing or future texts as well as their adaptation to the assessment of new technologies and to the status of the receiving entities.

• To bring the national legislation into harmony with the commitments subscribed by Morocco at a regional and international level.

Currently there is the Law 10-95 on water, which provides for the principle of an environmental levy on water. There is presently a pilot programme in progress, on the environmental levy, in the Oum Errabii river basin (Khouribga region).

The final touches are being put to the draft of a law relating to the discharge of wastewater, gas emissions and the generation of waste by several industrial sectors.

Moreover, the General Secretariat of the Government, SGG, is working on the draft of a law relating to waste management and disposal.

3.1.12. Spain

The main sources of information used in drafting this document were:

• The National Statistics Institute (INE)
• The Centre for Information on Textiles and Garment Making (CITYC)
• The Spanish Intertextiles Council
• The Ministry of the Environment of the Government of Catalonia

3.1.12.1. General data concerning the country's textiles industry

Main geographical areas with textiles industry

According to data supplied by the INE and the Spanish Intertextiles Council, the geographical areas or Autonomous Communities where the textiles activity is located in Spain correspond to:

- Catalonia, with 65% of the total
- The Community of Valencia, with 25% of the total

The remaining 10% is shared among other Autonomous Communities. The dyeing, finishing and printing subsector is highly relevant both in Catalonia and the Community of Valencia.

Main textiles subsectors in the country

According to data from the year 1999 supplied by the CITYC, the textiles industries corresponding to the dyeing and finishing subsectors use wool and cotton, artificial fibres, synthetic fibres and blends as raw materials, producing overall 550,300 t/year for 1999.

According to the same source, in the printing subsector, the same raw materials as those mentioned above are used with the exception of wool, which is not often used. Overall production for 1999 was 58,500 t/year.

Total number of textiles companies and number of workers in the country

The information below refers to the year 2000 and was supplied by the INE and the CITYC.

It is estimated that the number of companies in the dyeing, finishing and printing subsectors is approximately 490, with 17,880 workers. The total for the textiles sector, including the garment making subsector is comprised of 7,615 companies, which employ 278,200 workers.

The country's industrial sector includes 163,265 industries which provide a total of 2,628,008 jobs.

% Contribution to GDP

According to data from the year 1999, supplied by the INE, the textiles sector as a whole contributed 1.8% to the country's total GDP, while the dyeing, finishing and printing subsectors contributed 0.08%.

3.1.12.2. Environmental aspects

National infrastructure of environmental management

No information on this section has been facilitated, since global data on the national scale are not available. However, it may be said that facilities of all the types mentioned do exist: wastewater treatment plants, urban solid waste landfills, industrial waste landfills, hazardous waste landfills, plants for the recycling of containers and packaging, facilities that valorise fabric leftovers and waste treatment plants.

Annual energy consumption in the dyeing, finishing and printing subsectors

According to data supplied by the Spanish Intertextiles Council, in the year 1998 the subsectors in this study consumed:

- Electrical energy: 1,014,775 MW/year, with a unit cost of 66 €/MW (0.066 €/kW)
- Thermal energy: 13,270,070,000 MJ/year

Data concerning the consumption of natural gas, diesel oil and fuel oil have been estimated based on the consumption declared for the year 2000 by the companies in the subsectors in this study in Catalonia, bearing in mind that 65% of Spanish textiles are located in this Community. According to this estimate, consumption was as follows:

- Natural gas: 7,872,000 m^3/year, with a unit cost of 0.45 €/m^3
- Diesel oil: 2,300 t/year
- Fuel oil: 9,400 t/year

No information on the unit price of diesel oil, fuel oil or thermal energy has been facilitated.

Annual water consumption in the dyeing, finishing and printing subsectors

According to data supplied by the Spanish Intertextiles Council, total water consumption for the subsectors in this study was 55,397,340 m^3 for the year 1998.

Although no data are available on the sources of the water consumed for the whole of Spain, they are available for Catalonia, corresponding to the year 2001. These data, supplied by the Catalan Water Agency, have been taken from the document “Declaraciones de Uso y Consumo del Agua”, —Declarations concerning the Use and Consumption of Water— which companies must provide every year for fiscal purposes.

According to these data, in Catalonia, 71% of the water consumed by the subsectors studied comes from their own sources, such as wells and surface catchment, while the remaining 29% comes from a supply company. The consumption of water in Catalonia for the subsectors in this study was approximately 25,475,768 m^3.

It is specifically stated that the price of water varies greatly from one Autonomous Community to the next.

Annual consumption of chemical products in the dyeing, finishing and printing subsectors

No overall data are available on the whole of Spain and, consequently, estimates have been ma- de for the different consumptions based on the data declared by the companies in the subsectors in this study in the “Declaración de Residuos” —Declaration of Waste Products— for the year 2000 in Catalonia, bearing in mind that 65% of the country’s textiles industry is located in Catalonia.

The quantity of different chemical products used can be broken down as follows:

• Colouring agents and pigments: 9,850 t/year

• Auxiliary chemical products: 13,900 t/year (including soaps, surfactants, detergents, waxes, glues, gelatines, adhesives, sizing products, dye accelerators, fixatives for colouring agents, fire-proof preparations, water repellent preparations, etc.)

• Inorganic salts (common salt): 23,100 t/year (only data concerning the consumption of common salt have been included. The remaining salts consumed are included in the section on chemical products)

• Halogenated solvents: 27 t/year

• Non-halogenated solvents: 276 t/year

• Other chemical products: 63,000 t/year (both organic and inorganic products have been considered (oxides, hydroxides, peroxides, organic and inorganic acids, enzymes, urea, silicone, etc.)

Annual generation of wastewater and fate in the dyeing, finishing and printing subsectors

No data are available concerning the whole of Spain. Nevertheless, data corresponding to Catalonia are available, corresponding to the year 2001. These data, supplied by the Catalan Water Agency, have been taken from the document “Declaraciones de Uso y Consumo del Agua” —Declarations concerning the Use and Consumption of Water— which companies must provide every year for fiscal purposes.

According to these data, approximately 30% of the texiles companies in the sectors in this study, which dump 60% of the wastewater generated by these subsectors, have their own treatment facilities of one type or another. The remaining 70%, which generates 36% of all wastewater, do not have any treatment system. However, of the companies that do not have treatment systems, the great majority (60% of the total) dump into a treatment system and the water is treated by a municipal wastewater treatment plant. Therefore, only 10% of companies dump into public riverbeds, either directly or indirectly, without any type of treatment of their water. The dumping by this 10% of companies corresponds to 18% of wastewater generated by the subsectors in this study.

The volume of wastewater dumped by the companies of the subsectors in this study in Catalonia in the year 2001, is, according to the same source, 16,998,227 m^3, that is to say, 67% of the volume consumed.

The treatment carried out by the companies themselves on their wastewater is more or less complex in accordance with whether it is poured into public riverbeds or a drainage system. In the former case, the most common treatment is a physical-chemical one followed by a biological one. In the latter case, the most common treatment is a primary one with an homogenisation tank with aeration and neutralisation filtration systems.

Annual generation of waste and fate in the dyeing, finishing and printing subsectors

No data are available concerning the whole of Spain and so the different consumption has been estimated based on data declared in the "Declaración de Residuos" —Declaration of Waste Products— for the year 2000 by the companies of the subsectors in this study in Catalonia, bearing in mind that 65% of the textiles industry is located in this Community.

According to these estimates, the amount and fate of the different types of waste generated annually would be as follows:

- 1.6 t of waste from colouring agents and solid pigments. 96.6% initially end up at a collection and transfer centre although it may be considered that in most cases, their final destination are the controlled landfills. The remaining 3.4% is directly disposed of at controlled landfills.
- 31 t of waste from colouring agents and liquid pigments. 97.9% is treated at specific treatment plants, while the remaining 2.10% ends up initially at a collection and transfer centre.
- 1.7 t of halogenated solvents, 98 t of non-halogenated solvents and 107 t of used oils. 100% of this waste ends up being valorised and/or recycled.
- 619 t of empty chemical product containers. 83.20% of them are valorised and/or recycled, 12% end up being disposed of at controlled landfills and the remaining 4.8% initially go to a collection and transfer centre.
- 95 t of leftovers of packaging materials. 83.30% of this is disposed of at controlled landfills and the remaining 16.6% is valorised and/or recycled.
- 6,047 t of leftover fabric. 74.6% is disposed of at controlled landfills, 22.40% is valorised and/or recycled and the remaining 3% ends up initially at a collection and transfer centre.
- 31,760 t of treatment plant sludge. 59.90% is valorised and/or recycled, 39.8% is disposed of at controlled landfills and 0.10% is treated at a treatment plant.
- 17,466 t of other waste products. 62.50% is disposed of at controlled landfills, 27.80% ends up initially at a collection and transfer centre, 8.30% is valorised and/or recycled and 1.40% is treated at a treatment plant.

No information has been supplied concerning auxiliary solid and liquid chemical waste.

Environmental management costs in the dyeing, finishing and printing subsectors

No overall data is available concerning the whole of Spain and so the costs have been estimated based on data supplied in Catalonia for the year 2000. It should be borne in mind that the levies on the consumption and dumping of water vary greatly from one Autonomous Community to the next.

According to an estimate, the annual cost of environmental management for companies in the dyeing, finishing and printing subsectors would be:

- External waste product management: 2.5 M€/year.
- Environmental taxes for the dumping of wastewater: 7.9 M€/year (in order to estimate this cost, the data for the volume of water have been taken for 1998).
- Environmental taxes for the consumption of water: 3.0 M€/year (in order to estimate this cost, the data for the volume of water have been taken for 1998).

No information is available on the cost of treating wastewater at the companies' own treatment plants.

In Spain, taxes are not applicable to the generation of waste or to the generation of emissions into the atmosphere.

State aid for companies in the textiles sector

Economic aid, as shown below, corresponds to calls for application for aid, which are open at present for the industrial sector in general. Such aid can come from the state, and cover the whole country, or may be of a regional nature, thus only applicable to the industries of the Autonomous Communities that make such calls.

The information has been obtained from the different Autonomous Communities.

Aid recently awarded was for the following lines of action:

- Investments for the treatment of wastewater: valid, for the period between 1999 and 2001, in the communities of Catalonia and Castilla León. In Catalonia, the total amount assigned for 1999 was 2,386,018.05 €. The total assigned in Castilla León is mentioned in the chapter dealing with subsidies for the introduction of certified environmental management systems.
- Investments for other systems for the end-of-pipe treatment of pollution: these are valid in the communities of Navarra and Castilla León for the year 2001. In Navarra, the total assigned for the year 2001, which also includes action for the prevention of pollution, was 601,012 €. The total assigned in Castilla León is mentioned in the chapter dealing with subsidies for the introduction of certified environmental management systems.
- Research and development (R+D): there is a programme on the state scale for the period spanning 2000-2003 within the programme for the promotion of technical research (Programa del Fomento de la Investigación Técnica or PROFIT). No information is available on the budget that the programme disposes of.
- Investment in equipment for “in situ” recycling of pollutants: this was valid in the Community of Valencia for the year 2001, with a total assigned of 1,803,036 €. This also includes action to minimise waste products.

- Investments in equipment aimed at reducing pollution at source: these were valid in Catalonia, Navarra, the Basque Country and the Community of Valencia for the year 2001. In Catalonia, the total assigned was 721,214 €. In Navarra, the total assigned was mentioned when referring to the subsidies for the investment in systems for end-of-pipe pollution treatment. In the Basque Country, the total assigned was 3,066,359 €. In the Community of Valencia, the total assigned was mentioned when referring to the subsidies for the investment in equipment for recycling of pollution "in situ".

- Investments targeting the introduction of certified environmental management systems: these were valid in Catalonia and Castilla León for the year 2001. In Catalonia, the total assigned was 743,451 €. In Castilla León, the total assigned was 1,111,872 €, also including other action such as investments in corrective and preventive measures for pollution or in instruments to measure and control pollution, or the carrying out of audits and studies.

- To obtain the European Union's Eco-label: valid in Catalonia for the year 2001, with a total of 48,081 € assigned.

It should be noted that no information is available on previous calls which are now closed.

No information is available concerning aid targeted exclusively at environmental training, although this may be included in some of the calls that have already been mentioned.

In addition to the previously mentioned subsidies, the companies that can accredit investment in environmental facilities before the Administration can deduct 10% of these investments from their corporate tax dues.

Common environmental practices in the dyeing, finishing and printing industries

Concerning the degree of establishment of environmental practices aimed at pollution prevention, an estimate has been made that was contrasted, at a later date, with the Spanish Intertextiles Council.

Data refer to the percentage of companies that are considered to carry out a certain practice over the total number of companies of the sectors in this study.

- ISO 14001 and/or EMAS Certification: 2% (principally large companies and multinationals)
- Reuse of wastewater in the production process: 50% (it is considered that all sorts of companies reuse water, regardless of their size or whether they are national or multinational companies)
- Reuse of finishing baths: 50%
- Recycling of solvents at source: 10%
- Systems for the prevention of the generation of out-of-date products: 70%
- Laboratories for the automatic preparation of colours: 70%
- Automatic dosage of auxiliary products: 50%
- Reuse of leftovers of printing pastes: 30%
- Optimisation of the size of containers in relation with consumption: 70% (it is considered that all sorts of companies carry out this measure, regardless of their size or whether they are national or multinational companies)

• Preventive maintenance of the facilities: 75%
• “On-line” process control systems: 70%
• Treatment at source of wastewater: 30% (it is considered that all sorts of companies reuse water, regardless of their size or whether they are national or multinational companies).

Environmental legislation

Spain possesses environmental legislation on the state, autonomic region and local scale related to dumping of wastewater, disposal and management of waste, control of atmospheric emissions and concerning polluted soils.

3.1.13. Syria

The information contained in this document has been supplied by the Ministry of State for Environmental Affairs with the collaboration of Ms Abir Zeno.

The main sources of data concerning environmental practice in the textiles industry in Syria are:

• The Ministry of Industry
• The Textiles Industry Association
• The Central Bureau of Statistics
• The Chamber of Industry
• The Ministry of the Environment
• The Ministry of Housing

3.1.13.1. General data concerning the country’s textiles industry

Main geographical areas with textiles industry

According to data supplied by the Ministry of Industry, the Syrian textiles industry is located mainly in the following areas:

• Alleppo
• Damascus
• Homs
• Hama

The textiles industry is located around the big cities, Alleppo being the most important, followed by Damascus and Hama. Fabrics are made fundamentally in Alleppo and Damascus. 75% of the dyeing industry is found in Alleppo.

Main textiles subsectors in the country

According to the Ministry of Industry and the Association of the Textiles Industry, the dyeing, finishing and printing subsectors mainly use wool, cotton and blends as raw materials, with natural cotton being the most commonly used raw material. No information has been supplied concerning the use of synthetic and artificial fibres.

A survey carried out in 1999 by the "Syrian Cotton Sector", quotes annual production for the dyeing and finishing subsectors at 120,000 t/year.

Total number of textiles companies and workforce in the country

In the information supplied, according to data from the year 2000, supplied by the Ministry of Industry and the Association of the Textiles Industry, the total number of companies in the textiles sector as a whole is quoted at 8,893 with a total of 77,886 workers. Of the total number of companies, 8,867 are private and 26 are public. The former give work to 49,535 workers while the latter employ 28,351 workers. Furthermore, it is explicitly stated that there are 11,460 artisan textiles centres in the public sector.

The main large companies are public, although private initiative has come onto the market also in the form of large companies.

No separate information has been supplied concerning the dyeing, finishing and printing subsectors, or on the country's overall status.

% Contribution to GDP

The set of all activities corresponding to the textiles sector contributes 23% to the country's total GDP, according to the Central Bureau of Statistics.

3.1.13.2. Environmental aspects

National infrastructures of environmental management

On the national scale, mention is made of the existence of an urban solid waste landfill and two publicly managed wastewater treatment plants, although there are a further four being built. No mention is made of other types of environmental infrastructures.

The information dates from the year 2000-2001, and is supplied by the Ministry of Housing and municipal authorities.

Annual energy consumption in the dyeing, finishing and printing subsectors

No data have been supplied concerning the overall consumption of the different energy sources. However, by means of audits carried out in the textiles sector in the year 1998, it has been estimated that the consumption of electrical energy is 0.37-4.8 kWh/kg of finished product.

The Ministry of Industry is setting up a database that shall allow the collation of statistics on energy consumption within the next two years.

Annual water consumption in the dyeing, finishing and printing subsectors

It should be noted that this information is not available, since no statistics concerning this section are available.

Annual consumption of chemical products in the dyeing, finishing and printing subsectors

It should be noted that this information is not available since no statistics or exhaustive records of the consumption of chemical products are available.

Annual generation of wastewater and fate in the dyeing, finishing and printing subsectors

According to approximate data supplied by the Ministry of Industry, 30% of the industries corresponding to the textiles subsectors of dyeing, finishing and printing possess their own wastewater treatment plants, while the remaining 70% do not carry out any treatment whatsoever.

Annual generation of waste and fate in the dyeing, finishing and printing subsectors

According to the Ministry of Industry, waste generated by the subsectors in question is usually disposed of at public landfills. Nonetheless, the quantities that are generated on an annual basis are unknown for each kind of waste.

Environmental management costs in the dyeing, finishing and printing subsectors

There is no indication that environmental management involves any cost for the companies operating in the subsectors being studied.

State aid for the textiles sector

According to the Ministry of the Environment, only two companies have received grants for the introduction of good housekeeping practices.

It is stated that although at present companies do not receive economic aid from the State, a joint programme has been started by the Ministries of the Environment and Industry in order to achieve financial support with a view to setting up a Cleaner Production centre the aim of which will be to help companies to get economic aid either by means of “soft loans” or tax relief.

Common environmental practices in the dyeing, finishing and printing industries

Concerning the degree of establishment of environmental practices aimed at pollution prevention, the information received is supplied by the Chamber of Industry and refers to the percentage of companies over the total that are estimated to apply each of the practices below:

- ISO 14001 and/or EMAS Certification: 1% in dyeing and finishing, 1% in printing (it is considered that mainly medium-sized companies are dealt with here)

- Reuse of wastewater in the production process: 1% in dyeing and finishing, 1% in printing
- Reuse of finishing baths: 1% in the printing subsector
- Automatic dosage of auxiliary products: 10% in dyeing and finishing
- Preventive maintenance of the facilities: 55% in dyeing and finishing, 50% in printing
- Treatment at source of wastewater: 15% in dyeing and finishing, 1% in printing

No information is available concerning the application of other good housekeeping practices given that the country does not have the corresponding statistics available.

Environmental legislation

According to the Ministry of the Environment, Syria possesses legislation on wastewater and atmospheric emissions, but has none on solid waste or on soil pollution. It is indicated that Syria's legal requirements are quite lenient and incomplete, given that there is still no framework legislation on the Environment.

3.1.14. Tunisia

The information contained in this document has been supplied by the Tunis International Centre for Environmental Technologies, with the collaboration of:

- Ms Amel Benzarti, Director
- Mr Rachid Nafti, Expert on cleaner production

The main sources of data relating to environmental practice in the textiles industry in Tunisia are:

- FENATEX: National Textiles Federation
- CETTEX: Technical Centre for Textiles
- ATPNE: The Tunisian Association for the Protection of Nature and the Environment

Other data have been supplied by:

- The Ministry of Economic Development
- ANPE: The National Agency for the Protection of the Environment/statisdistics of FODEP: Fonds de Dépollution Industrielle
- Strategic study on textile sector garments, Gherzi Organisation, Zurich 1999.

3.1.14.1. General data concerning the country's textiles industry

Main geographical areas with textiles industry

The main geographical areas that possess a textiles industry in Tunisia are:

- Ben Arous
- Monastir
- Ariana

Main textiles subsectors in the country

In Tunisia, the textiles sector is classified in two categories: one is dyeing, finishing and printing, comprising a total of 41 companies, and the other is the washing of jeans, with a total of 48 companies.

Referring to the nature of raw materials used, it should be noted that it is most varied. More than half of the industries in the dyeing, finishing and printing sector are able to use wool, cotton, synthetic fibres or even blends of these raw materials.

According to data from the year 1992, supplied by the Ministry of Economic development, the production in the dyeing, finishing and printing sector is quoted at 1,800 t/year for the companies that use wool and 800 t/year for those that use cotton. No data have been supplied for the other raw materials or for the jeans-washing sector.

On the other hand, it should be noted that Tunisia is not a producer of raw materials, which implies that the industries in this sector depend on imports.

Total number of textiles companies and workforce in the country

According to data from the year 1999, the overall number of companies in the textiles sector is 1,806, with a total of 240,000 workers.

Data from the year 1995 quote 41 as being the number of companies in the dyeing, finishing and printing sector and 48 performing the washing of jeans, with a total of 5,119 workers.

On the other hand, according to other data supplied by the FENATEX, in 1999 there were 10,000 companies in Tunisia providing employment for a total of 406,000 workers.

It is also commented that 40% of the dyeing and finishing industries perform the wet ennoblement of fabrics, whether they are weaved or knitted. The machinery that is used in the dyeing process is also very varied and may consist of: winches (33.9%), jiggers (25%), autoclaves (4.6%), jets (15.6%) and overflows (20.8%).

% Contribution to GDP

The total of the textiles sector contributes 8% to the country's total GDP, according to data from the year 1995 supplied by the Ministry of Economic Development.

Explicit mention is made of the fact that information is only available for the textiles industry as a whole and not for the different sectors.

3.1.14.2. Environmental aspects

National infrastructure of environmental management

According to data from the year 2000 supplied by the ANPE, there are a total of 60 wastewater treatment plants. The same source quotes as being 4 the total number of controlled landfills and 1 the number of controlled landfills for hazardous waste.

No information has been supplied concerning the existence of infrastructures for the reuse and/or valorisation of containers, solvents and leftover fabrics, and neither is there any information concerning the existence of treatment plants for hazardous waste.

On the other hand, it is stated that a new controlled landfill for hazardous waste is being built.

Annual water consumption in the textiles sector

The consumption of water is calculated on the basis of 300 working days a year.

Most water consumption comes from the public water supply network with a total of 3,434,100 m^3/year and a unit cost of 0.93 €/m^3. Less considerable is the consumption of water from wells, which totals 105,000 m^3/year.

No data or information concerning any other type of water supply is provided, although it is commented that the ennoblement sector consumes 11,418 m^3/day while the sector dealing with the washing of jeans consumes 10,029 m^3/day.

Annual consumption of chemical products in the textiles sector

The consumption of colouring agents and pigments is 2,646 t/year while that of auxiliary chemical products is 1,622 t/year. These data are supplied by the ATPNE although it is not specified to which year they correspond.

No information is supplied concerning the consumption of inorganic salts, halogenated or non-halogenated solvents, or others.

Annual generation of wastewater and fate in the textiles sector

90% of the industries in the dyeing, finishing and printing sectors possess their own wastewater treatment plants, treating a total of 2,250,600 m^3/year while 10% have another type of water treatment plant though the volume of water treated by them is not mentioned. It should be pointed out that neither the date nor the source of these data have been provided.

On the other hand, information is provided on the following points:

- The treatment process for water effluents is, essentially, physical-chemical (homogenisation, regulation of the pH, coagulation, flocculation and decantation). Only 11% of the industries carry out biological treatment.

- 50% of the industries in the finishing subsector possess industrial pre-treatment plants for water, with estimated volumes of water dumped by this subsector at 7,502 m^3/day.
- 31% of industries that deal with the washing of jeans also possess industrial pre-treatment plants for water.

It is commented within this chapter that the concentration of chlorides in wastewater varies between 500 and 5,500 mg/l according to the nature of the fibre treated.

Annual generation of waste and fate in the textiles sector

An overall estimate of the waste generated is made, classified in two categories: one represented by the finishing subsector, which generates a total of waste coming from auxiliary chemical products (solids and liquids) of some 11,175 t/year and the other, represented by the companies that wash jeans, which generates 17,103 t/year of pumice stone waste. This information comes from the INS and does not include the year referred to.

State aid for the textiles sector

According to data supplied by the ANPE (FODEP department), during the period from 1994-2000, 260 companies have received aid from FODEP and 37 were from the textile sector. The amount granted (20% of the investment) was 9,384,976 €[5].

It is noted that there was little investment in equipment for the reduction of waste at source or for the introduction of good housekeeping practices (only some cases outside the textile sector).

Common environmental practices for companies in the textiles sector

Concerning the degree of establishment of environmental practices aimed at preventing pollution, the information received refers to the dyeing, finishing and printing subsector which, as we have already seen, are grouped in the same category.

10% of companies reuse finishing baths, 5% possess automatic colour laboratories, 40% apply systems for the prevention of the generation of out-of-date products, and 50% carry out preventive maintenance of their facilities.

Environmental legislation

Tunisia possesses standard (NT 106,022) for the disposal of wastewater and a law for management of solid waste (Law 96-41, of 10th June 1996). Tunisia possesses no legislation either for emissions into the atmosphere or for polluted soils.

[5] 1 dinar = 0,764 €

3.1.15. Turkey

The information contained in this document has been supplied by the Bogazici University, with the collaboration of Dr Nilgün Kiran Ciliz from the Institute of Environmental Sciences.

3.1.15.1. General data concerning the country's textiles industry

Main geographical areas with textiles industry

The cotton sector of the textiles industry is located in the following areas:

- The south east of Anatolia
- The Aegean Sea (Izmir, Manisa)
- Cukurova
- The Mediterranean Sea (Antalya)

Main textiles subsectors in the country

The information received concerning the main subsectors of the Turkish textiles industry classifies them according to the raw material used.

According to data referring to the period 1999-2000, Turkey is the world's sixth largest producer of cotton, and the fifth largest consumer. On the other hand, its cotton crops represent 6% of world production.

With regard to woollen products, Turkey is the world's fifth largest producer.

Concerning synthetic fibres, the main ones are polyester, polyamide and acrylic-type. Turkey is among the top 10 producers of synthetic yarns (representing 15% of the capacity of the countries of Western Europe).

According to data for 1997, the weight of each of the raw materials in the textiles sector was:

- Cotton (46%) (865,000 t in 1999-2000)
- Synthetic fibres: (16%)
- Wool (12%)
- Others (26%)

Total number of textiles companies and workforce in the country

In the information supplied, according to data from the year 1998, 20% of employment, 400,000 workers, is provided by 650 companies that operate in the textiles sector. This information excludes small family businesses.

Of Turkey's largest textiles companies, 15 belong to the cotton subsector, 5 to the wool subsector, 5 to the synthetic fibres subsector and 4 to that of garment making.

% Contribution to GDP

Turkey's largest industrial sector is that of textiles and garment making which, in the year 1998, contributed 8.4% to the country's GDP and constituted 11.5% of industrial products.

3.1.15.2. Environmental aspects

National infrastructure of environmental management

Development and enforcement of environmental laws and regulations is the responsibility of the Ministry of Environment. On a regional basis, environmental controls are carried out through regional environmental authorities that are connected to the Ministry. The wastewater discharge standards are given under two different categories; 1) For the industries that discharge directly into receiving environments, the standards to receiving environments both for woven and knitted textile products and also 2) For the companies that discharge their wastewaters to infrastructures that result with a proper wastewater treatment facility of deep-sea disposal. In addition to these, municipalities and Water and Wastewater Administration Departments in large cities/regions have their own standards.

In regard to the enforcement of the regulations/standards, the following conclusions can be made:

In the rural areas where environmental control is less strict, where only the pH and temperature of waste are monitored, it may be said that infrastructures of environmental management are minimal.

On the other hand, the companies located in geographical areas where enforcement of regulations and standards is carried out successfully have their own wastewater treatment plant due to the fact that they are subject to greater control. Moreover, it should be indicated that there are an increasing number of companies that have set the ISO 14001 certification as their target, and so they are working to improve waste management.

Annual water consumption in the dyeing, finishing and printing subsectors

Water consumption is greatly variable in accordance with the machinery employed, the complexity of the process, etc. Generally, it is at between 60 and 120 l/kg of material produced for cotton processes. This value can be up to 200 l/kg for woollen processes.

Environmental management costs in the dyeing, finishing and printing subsectors

Costs vary according to the company's geographical location.

In the Marmara region (especially for Istanbul and for some other places in the region) for example, companies pay a levy for both the water consumed and the water discharged. They also pay for the treatment of the water prior to the process as well as any treatment it may receive once used. Thus, the amount of money given over to water is high in comparison with the company's annual turnover. The total cost of water processing would be the equivalent of 0.98 €/m^3.

State aid

The information received indicates the proportion between the public investment made in the textiles industry and the total for the industrial sector.

In 1998, the government invested 14.4% of its aid to the textiles industry. This percentage decreased in 1999 to 4.2%. Investment made by the government in the industrial sector as a whole was 48.7% in 1998 and 44.3% in 1999.

Common environmental practices in the dyeing, finishing and printing industries

Most companies comply with the Eko-Tex 100 standard. There are a number of companies that aspire to ISO 14001 certification, and so they must comply with the applicable environmental standards and implement systems of cleaner production. For example, they are starting to cease to use chemical products that are forbidden by the EU and to implement systems of collection and storage of solid waste at the plants. Nevertheless, since legislation concerning this issue is less strict, the companies do not make so much effort to reduce the amount of energy, water and chemical products they consume.

The degree of knowledge and application of clean technologies can be considered as being relatively high. However, areas where there is significant room for improvement can be appreciated. The identification of these areas by the textiles companies can occur when the appropriate information is available.

The companies, in general, have generic information that can allow them to assess their environmental behaviour, but the information that is required to be able to take a decision to integrate clean technologies is of a different nature. The companies usually know how to generate such information (for example, by means of the assessment of the functioning of its production processes), but rarely is this information processed and transformed so that it promotes the application of clean technologies.

On the other hand, most companies process fabrics for third parties and so are limited regarding their capacity to plan production and the products they offer. The choice of their products and production schemes are greatly determined by their clients' demands. For its survival, the sector considers its ability to use existing equipment, with the necessary modifications, as effectively as possible as being crucial for different objectives. Although this point of view provides the versatility and flexibility considered to be crucial, it has a negative effect on the levels of efficiency and significantly limits the potential for improvement.

Environmental legislation

The development and application of environmental legislation is the responsibility of the Ministry of the Environment. On the regional scale, environmental controls are carried out by regional environmental authorities that work in contact with the Ministry of the Environment. However, the municipalities can also apply their own norms and make sure they are complied with providing they are not laxer than the Ministry's.

Turkey possesses environmental legislation related to standards on wastewater discharge criteria/classification of wastewater, the elimination and management of waste and the control of atmospheric emissions and other legislation on hazardous waste and control, solid waste management, EIA etc.

Enforcement of legislation shows variations at the regional level. In certain regions (Marmara Region) most of the companies meet the limits of legislation. On the other hand, it is also indicated that in the broader industrial areas, less compliance with the regulations is required than in areas where industry is isolated. It should also be noted that environmental legislation and its compliance is stricter in big cities than in smaller municipalities.

3.2. COMPARISON OF THE TEXTILES SECTOR AMONG THE MAP COUNTRIES

3.2.1. Introduction and preliminary comments

- It should be noted that the information received on the different aspects investigated in this study, relating to the textiles sector and in particular with the dyeing, finishing and printing subsectors of the different countries that make up the Mediterranean Region, was remarkably diverse, both due to its type and origin and its representativeness in relation to the corresponding country as a whole. Thus, for example, in some cases, all information refers to a specific area of a country, while in others, data has been received which does not offer a breakdown of the subsector of interest.

- For these reasons, the comparative summary presented below may suffer some bias (derived from the heterocliticity of the information received or its partial or even total absence in some cases) if we aim to perform a mechanical extrapolation on the Mediterranean Region as a whole, since herein, only data received have been gathered and grouped together if they were considered as being more or less concomitant. Further information may be consulted in the summaries that appear in the previous section to this report and in the original questionnaires and additional information supplied by the different countries that participated in this study.

- The aspects that are commented on below refer to production, economic social and labour significance of the textiles sector, with special emphasis on the dyeing and finishing and printing subsectors, as well as existence of infrastructures of environmental treatment, consumption (of water, energy and chemical products and similar materials), the fate of wastewater and waste, the degree of establishment of good housekeeping practices, the existence of environmental laws for the different vectors and the availability of economic aid and/or subsidies for the introduction of a variety of environmental improvements.

- It is also important to consider that the information dealt with in the different epigraphs in this chapter comes from the questionnaires completed by those responsible in each of the countries as well as additional information received.

3.2.2. Production of the textiles sector and the dyeing, finishing and printing subsectors in the countries of the Mediterranean Region

As can be seen in the previous chapters, most countries have not presented information concerning the volume of production, and so the information received cannot be compared. On the other hand, it should be borne in mind that it is precisely the production factor (in the textiles sector and/or the subsectors of interest) that determines when establishing quantitative relationships between different environmental aspects such as water consumption, the production of waste products, etc.

Concerning the specific data received related to the production of the studied subsectors, some cases should be highlighted, such as that of Spain (whose annual production for the dyeing and finishing and the printing subsectors is 550,000 t/year and 58,800 t/year, respectively), France (with an annual production just for the dyeing and finishing subsector of 300,000 t/year), Syria (with annual production for the dyeing, finishing and printing of wool of 120,000 t/year) and, on a smaller scale, Morocco (with annual production for dyeing, finishing and printing of 24,600 t/year), Egypt (with an annual production for the dyeing and finishing of wool of 19,000 t/year), Libya (with annual production of 15,900 t/year and 884 t/year for dyeing & finishing and printing respectively) and Croatia (with annual production for dyeing and finishing of 9,861 t/year).

Other countries, such as Algeria and Bosnia-Herzegovina, have provided more generic data on the production of the textiles industry as a whole. Thus, for the case of Algeria, the corresponding annual production is 427,312 t/year, while that of Bosnia-Herzegovina is of 431 t/year.

3.2.3. Contribution to the GDP of the textiles sector and the dyeing, finishing and printing subsectors in the countries of the Mediterranean Region

The economic significance of the textiles industry related to the GDP should be highlighted for Tunisia (8%) Libya (10%), Turkey (8.4%) and, above all, the singular piece of data corresponding to the case of Syria (23%).

In the case of Morocco, the data provided refers to contribution to the Industrial GDP of the textile and leather sector, which is 17%.

In other countries, the contribution to GDP by the production of textiles is clearly lower, such as in Albania (3.7% for the textiles industry as a whole and 2.1% for the dyeing, finishing and printing sectors), Croatia (1.3%, only for the dyeing, finishing and printing subsector), Egypt (3% for the textiles industry as a whole), Israel (1% for the textiles industry as a whole and 0.5% for the dyeing, finishing and printing subsectors), Malta (4% for the textiles industry as a whole) and Spain (1.8% for the textiles industry as a whole).

3.2.4. Employment significance of the textiles sector and the dyeing, finishing and printing subsectors in the countries of the Mediterranean Region

From the specific information received concerning the number of companies and workers who are active in the textiles sector and, in particular, in the dyeing, finishing and printing subsectors, in order to illustrate its socio-economic importance, the following data should be highlighted:

Textile sector

Egypt (with 10,444 companies and 213,103 workers), Syria (with 8,893 companies and 77,886 workers), Spain (with 7,615 companies and 278,200 workers), Tunisia (with 1,806 companies and 240,000 workers), Morocco (with 1,440 companies; the number of workers is not available), France (with 1,300 companies and 122,000 workers) and Turkey (with 650 companies and 400,000 workers).

Dyeing, finishing and printing subsectors

Spain (with 490 companies and 17,880 workers), Albania (with 251 companies and 3,762 workers), France (with 240 companies and 14,000 workers), Morocco (with 138 companies and 11,500 workers) and Israel (with 22 companies and 1,300 workers).

It should be noted that the ratio between the number of workers and the number of companies in the textiles sector indicates that the size of such companies, in general, should be situated in the framework of SMEs, although in the previous chapter, in some cases such as that of Egypt or Libya, there are also some large companies. This same trend can be observed for the companies in the dyeing and finishing subsectors with the peculiarity of the case of Israel, where it seems that the aforementioned ratio for the companies in these subsectors is far higher than that for the textiles sector globally speaking.

3.2.5. Environmental management infrastructures in the countries of the Mediterranean Region

With regard to this section, the information received has been rather lacking in some cases (for example, as far as the countries of the EU are concerned), probably as they are highly fragmented in origin or due to other causes.

On the other hand, apparently, for all countries that have provided specific data (with the possible exceptions of the cases of Egypt, for the wastewater treatment plants, urban solid waste landfills and waste product valorisation plants, Morocco, for the wastewater treatment plants and the plants for reuse of packaging, Tunisia for the wastewater treatment plants and Albania with regard to urban solid waste landfills), the general lack of wastewater treatment plants, urban solid waste landfills and valorisation plants and/or waste recycling plants is quite singular, bearing in mind that the data provided refer to all the productive sectors on the national scale.

3.2.6. Water consumption and source in the companies of the dyeing, finishing and printing subsectors in the countries of the Mediterranean Region

Data concerning the consumption and sources of water have been provided as being significant for different countries: Albania (with an annual consumption of 49.6 Mm^3/year of water from the network and 28 Mm^3/year of surface water), Algeria (with an annual consumption of 4.8 Mm^3/year of water from the network and 0.8 Mm^3/year of ground water), Bosnia-Herzegovina (with an annual consumption of 4.8 Mm^3/year of water from the network), Croatia (with an annual consumption of 1.8 Mm^3/year of water from the network, 1.3 Mm^3/year of surface water and 1 Mm^3/year of ground water), Egypt (with an annual consumption of 400 Mm^3/year of water from the network and 100 Mm^3/year of ground water), France (with a total annual consumption of 31 Mm^3/year), Israel (with an annual consumption of 7 Mm^3/year of water from the network), Libya (with an annual consumption of 18 Mm^3/year of water from the network and 0.3 Mm^3/year of ground water), Malta (with an annual consumption of 8,000 m^3/year of water from the network and 8,659 m^3/year of reused water), Morocco (with an annual consumption of 5.68 Mm^3/year of water from the network and 4.42 Mm^3/year of ground water), Spain (with a total annual consumption of 55 Mm^3/year) and Tunisia (with an annual consumption of 3.4 Mm^3/year of water from the network and 1 Mm^3/year of ground water).

3.2.7. Energy consumption by the companies of the dyeing, finishing and printing subsectors in the countries of the Mediterranean Region

As far as the consumption of energy and its different forms, the following aspects may be mentioned:

Electrical energy consumption (in MWh/year)

Noteworthy are: Albania (124,200 MWh/year), Bosnia-Herzegovina (21,627 MWh/year), Croatia (150 MWh/year), Egypt (1,100,000 MWh/year), France (495,500 MWh/year), Israel (458,300 MWh/year), Morocco (30,500 MWh/year) and Spain (1,014,775 MWh/year).

Diesel oil and fuel oil consumption

The following are worthy of mention: Albania (14,400 t diesel oil/year), Croatia (7000 t diesel oil+fuel oil/year), Egypt (68,538 t diesel oil+fuel oil/year), Libya (361.8 t diesel oil/year and 1,180 t/fuel oil/year), Morocco (112,000 t fuel oil/year), Spain (2,300 t diesel oil/year and 9,400 t/fuel oil/year) and Syria (310,000 t diesel oil/year).

Natural gas consumption

Worthy of mention are: Croatia (9,000 m^3/year), Egypt (500,000,000 m^3/year), France (89,140,645 m^3/year) and Spain (7,872,000 m^3/year).

The case of Morocco should be pointed out, since there is no consumption of natural gas but liquefied petroleum gases (LPG) are consumed, basically propane and butane. No data referring to this consumption has been provided.

3.2.8. Consumption of chemical products and similar materials by the companies of the dyeing, finishing and printing subsectors in the countries of the Mediterranean Region

The only comprehensive information available on this field was supplied by Albania, Algeria and Spain. The difference between the relative consumption of solvents in Spain and Albania was extraordinary. Albania, with significantly lower production than Spain consumes over ten times more solvents than Spain. This may be due to the difference between the types of pigments and colouring agents that are most frequently used in either case.

3.2.9. Wastewater generation and fate in the companies of the dyeing, finishing and printing subsectors in the countries of the Mediterranean Region

Regarding the production and treatment of wastewater, from the information received, the cases corresponding to Israel and Tunisia are noteworthy where it is indicated that practically all companies in the dyeing, finishing and printing subsectors carry out some kind of treatment of their wastewater at source.

The percentages of the application of this measure for the case of other countries varies between 10 and 65%, specifically citing the cases of Albania at 10%, Algeria at 31%, Bosnia-Herzegovina at 25%, Egypt at 65%, France at 65%, Morocco at 40%, Spain at 30% and Syria at 30%.

3.2.10. Waste generation and fate by the companies of the dyeing, finishing and printing subsectors in the countries of the Mediterranean Region

The information received was quite unspecific and highly heterogeneous, with the following cases being worthy of mention:

Albania

It is indicated that solid waste is disposed of at urban solid waste landfills, while liquids are discharged together with wastewater. On the other hand, the estimated quantities of waste products and their types are presented. It seems, however, that recycling and valorization practices are not contemplated.

Algeria

Information is given concerning the fact that 632.15 t/year of liquid auxiliary chemical products waste are discharged with wastewater, 11,700 t/year of oils and 430.5 t/year of left-over fabrics are recovered, 208 t/year of remains of containers are valorised and part of the 68.3 t/year of packaging waste are recycled (the rest is disposed of at landfills) as well as the 13 t/year of other products.

Bosnia-Herzegovina

Similar generic information to that concerning Albania is presented, but without quoting the estimated quantities of waste production. As in the case of Albania, it seems that recycling and valorization practices are not contemplated either.

Egypt

Generically, the fate of waste, according to its nature, is indicated, with the following options being contemplated: controlled landfills, recycling, joint valorization and discharge in the wastewater.

France

It is indicated that annually some 9 t of pigment waste as well as a variety of chemical products and solvents are generated (a quantity which could be considered singularly low). In this case, we also cite the quantities that are produced annually of packaging waste, leftover fabrics and treatment plant sludge (75% of which goes to compost, 25% is disposed of at landfills or incinerated) and other unspecified waste products.

Israel

It is indicated that the annual production of waste that can be attributed to mineral salts (considered a critical pollutant in Israel) totals 130,000 t (of which 3,202 are treated, while the rest, it is inferred, is disposed of at unloading points that may correspond to landfills). On the other hand, no information is given concerning the production of packaging waste, chemical products, etc., generated by the dyeing, finishing and printing subsectors.

Libya

Only the total amount of waste has been indicated, corresponding to the whole textiles sector of some specific areas.

Malta

Only data concerning the production of leftover fabric and treatment plant sludge by one industry is indicated. They are recycled and/or valorized and disposed of at landfills accordingly.

Morocco

The data presented correspond to the quantities generated of the following waste: colouring and pigment agents, inorganic salts, empty containers, packaging waste, leftover fabrics and sludge from rinsing baths, as well as the most frequent methods of waste management or treatment. Uncontrolled landfill is the most usual management system for waste pigment and colouring agents, auxiliaries and salts, while valorisation and/or recycling is more frequent in waste from packaging and containers, leftover fabrics and sludge.

Spain

The data presented correspond to Catalonia (the country's main textiles area, with 65% of all companies), indicating data concerning the annual production and the final fate of solid and liquid pigment and colouring agent waste, of solvents (distinguishing between those which are halogenated and those which are non-halogenated), of chemical product containers, packaging remains, leftover fabrics, treatment plant sludge and others.

Syria

It is indicated that waste (supposedly solid) from the dyeing and finishing subsectors end up at public landfills. The quantities generated annually are unknown.

Tunisia

A classification is made of the total waste produced (consisting of a variety of chemical products) in the finishing subsector (11,175 t/year) and in the jeans stone washing sector, which generates 17,103 t/year of pumice stone. No information is given concerning the fate of these waste products.

3.2.11. Application of good housekeeping practices in production by the companies in the dyeing, finishing and printing subsectors in the countries of the Mediterranean Region

The information received in this epigraph is broken down according to the different practices contained herein. It should be noted that different data presented in this chapter correspond to estimates:

- **Companies with Environmental Management Systems (ISO-14001 or EMAS):** the percentages corresponding to Spain (2%), Egypt (2%), Morocco (1%) and Syria (1%) are given with similar orders of magnitude. Italy indicates the existence of 9 certified companies in the Prato region. Other countries report the non-existence of companies with certified EMS.
- **Reuse of water:** the effective percentages corresponding to Spain (50%), Egypt (60%), Morocco (1%), Israel (30%) and Syria (1%) are given, highlighting the proportion of companies that apply this strategy in the cases of Egypt and Spain.
- **Reuse of baths:** the effective percentages corresponding to Spain (50%), Egypt (15%), Morocco (60%), Israel (20%), Syria (1%) and Tunisia (10%) are given with greatly diverging orders of magnitude, highlighting the proportion of companies that apply this strategy in the cases of Israel, Morocco and Spain.
- **Reuse of solvents:** the effective percentages corresponding to Spain (10%) and Egypt (25%) are given. In the case of Morocco, the data is not available but it is mentioned that reuse of solvents is a frequent practice. For the remaining countries, either recycling is not carried out or no information has been supplied regarding recycling.
- **Prevention of expiry:** the effective percentages corresponding to Spain (70%) and Tunisia (40%) are given. For the remaining countries, either such practice is not carried out, or no information has been supplied in this respect.
- **Automatic colour laboratories:** the effective percentages corresponding to Egypt (10%), Spain (70%), Israel (100%), Morocco (2%) and Tunisia (5%) are given, highlighting the case of Israel.
- **Automatic dosage:** the effective percentages corresponding to Bosnia-Herzegovina (6%), Egypt (50%), Spain (50%), Morocco (30%) and Israel (100%) are given, highlighting the case of Israel.
- **Recovery of printing pastes:** the effective percentages corresponding to Spain and Israel are given, highlighting the case of Israel with a proportion of 100%, compared with that of Spain, at 30%.
- **Optimisation of the size of containers:** the effective percentages corresponding to Egypt (3%), Spain (70%) and Israel (100%) are given, highlighting the case of Israel.

- **Preventive maintenance:** the effective percentages corresponding to Egypt (10%), Spain (75%), Israel (50%), Morocco (85%), Syria (50%) and Tunisia (50%) are given, highlighting the cases of Morocco and Spain.
- **"On-line" process control systems:** the effective percentages corresponding to Egypt (10%), Spain (70%), Morocco (99%) and Israel (100%) are given, highlighting the two latter cases.
- **Water treatment at source:** the effective percentages corresponding to Albania (10%), Bosnia-Herzegovina (26%), Egypt (20%), Spain (30%), Israel (100%), Morocco (5%) and Syria (15%) are given, highlighting the case of Israel.

3.2.12. Environmental legislation in the countries of the Mediterranean Region

In most countries there is a legislative framework in existence that encompasses the different environmental fields, the only exceptions being those that refer to the case of Bosnia-Herzegovina which, due to the country's special circumstances, has a set of environmental laws currently being prepared, Albania (regarding wastewater and soil pollution), Algeria (as far as atmospheric emissions are concerned) and Tunisia (regarding waste and the soil pollution).

3.2.13. Aid and/or subsidy programmes relating to environmental issues for companies in the textiles sector in the countries of the Mediterranean Region

In this section, of the information received deemed worthy of special mention is, on the one hand, the existence of an important programme of aid in Egypt, Morocco and, on a smaller scale, in Bosnia-Herzegovina and Spain and, on the other hand, the total non-existence of such programmes in countries such as Albania, Israel, Syria or Libya (the non-existence of aid for the latter case is attributable to the fact that the companies are state companies).

4. DESCRIPTION OF THE DYEING, FINISHING AND PRINTING PROCESSES

4.1. TEXTILES ENNOBLING

The textiles ennobling subsector includes all those industries whose main activity is to provide textiles material with the suitable characteristics for their use as an intermediate or end product.

These characteristics are:

- Colour and technical specifications of the colour (fastness)
- Lustre
- Texture
- Dimensional stability
- Tailority

Generally speaking, the material is prepared for dyeing or printing, is dyed or printed and, then, the sizing and finishing processes are applied.

These processes are determined by a series of fundamental factors, such as:

- The fibres
- The textile products (types of yarn and types of weave to make the fabrics)
- The dyes
- The auxiliary and chemical products
- The temperature
- The dyeing time
- The machinery used
- The water (quality and quantity)

The relationship between these factors depends on the following conditions:

- Each type of fibre requires a certain family of dyes

- Each fabric requires certain, more suitable handling conditions (in rope form or open-width)

- A cycle of temperature variation with time and specific physical-chemical conditions of the aqueous dye solution (pH, redox potential, conductivity, etc.), which together must be optimised in each case, corresponds to the system which consists of the fibre, the dye and the type of machine.

- The textile machinery conditions the type of textile product and the dye cycle temperatures that are usable.

- The water affects the rest of factors.

The dyeing process may be optimised by varying the parameters to obtain a top quality dye at the lowest possible cost.

There are numerous dyeing systems and they include everything from consignment processes (batches by a defined weight and length) to semicontinuous processes (open-width or in rope form) to continuous processes (open-width or in rope form).

Depending on the fibres and dyes used, dyeing is carried out at between 20º and 135ºC in high-temperature systems.

Types of fibre

Depending on their origin, fibres can be classified into:

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

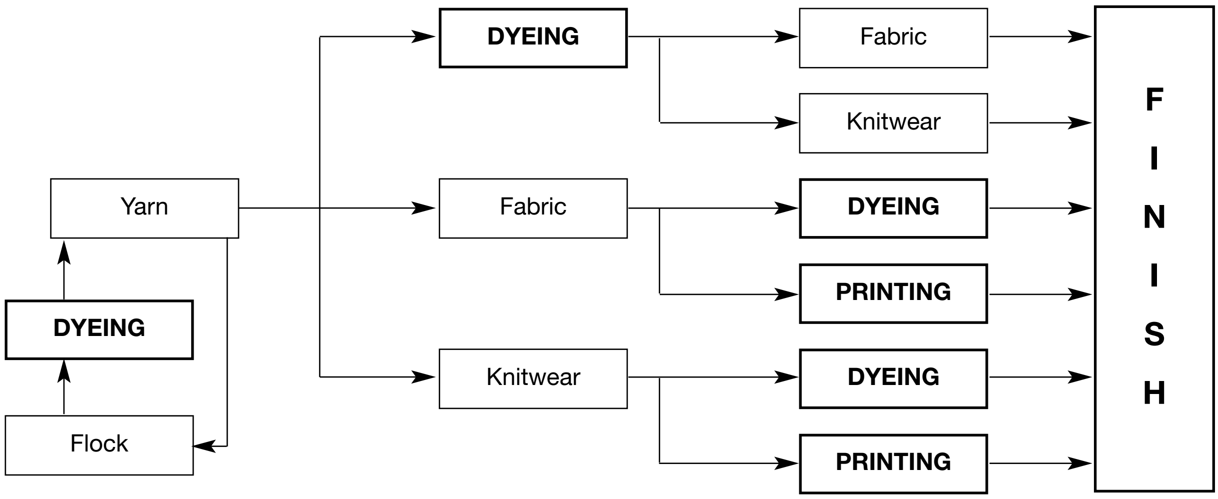
Textiles products

The dyeing of textiles fibres can be done on intermediate products or end products.

Below the most significant products are described:

- Cable: the parallel union of a high number of filaments, generally to be converted into cut fibre
- Flock: fibres of a length of 2 to 30 cm
- Flock: fibres of a length of less than 1 mm
- Rovings and slivers: the union of fibres which come from napping, combing or from the roving frames
- Parallel multifilament / textured multifilament
- Yarn: generally from the stretching with twist of an appropriate sliver. It is presented in hank or bobbin form
- Warp beam: parallel disposition in beam form of all yarn necessary for the manufacture of fabric of predetermined width
- Woven fabric: laminar textile structure generally formed by the orthoganal interweaving of warp thread, with weft threads
- Knitwear: laminar textile structure formed by the interweaving of one or more threads on the base mesh structure

ENNOBLING: DYEING, PRINTING & FINISHING



4.2. DYEING AND FINISHING PROCESSES

Here we present the basics of the most common dyeing and finishing processes. For each process, the most frequent unitary and auxiliary operations are analysed and the commonly used raw materials and chemical additives are identified.

Most operations are performed “wet” and take place in a receptacle or vat filled with liquid (usually water), into which the raw materials and additives have been dissolved or in which they are suspended. The textile material is submerged in this liquid. Immediately following this, this material is pressed in order to remove the excess liquid, which is returned to the receptacle for reuse.

Next, the washing operations are carried out in order to eliminate the remains of additives whose permanence in the material is not desired, so as not to hinder subsequent following operations.

Many operations such as colour scaling, the cleaning and preparation of the facilities, emptying, draining and rinsing the machinery, which is usually done before the processes, are not dealt with in this chapter.

The machinery used depends on the type of operation and the form of presentation of the textile material.

4.2.1. Preparation

Preparation includes all operations prior to dyeing, whose aim is to ensure the physical and chemical properties of both the finished textiles, and, in some situations, of the intermediate products, favouring the later reactions that take place in dyeing.

For this reason, some of these operations may be considered similar to the finishing operations and, in fact, they are not very different at all.

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

Among preparation operations, the following are noteworthy:

- Mercerising
- Scouring
- Degreasing
- Carbonisation
- Fulling
- Singeing
- Quenching
- Heat setting
- Chemical washing
- Solvent washing
- Chemical bleaching
- Optical bleaching

4.2.2. Description of the dyeing process

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

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

- First stage: transfer of the dye from the dye bath to the fibre surface.

- Second stage: diffusion or migration of the dye molecules from the surface of the fibre to the interior of the material to be dyed.

- Third stage: fixing of the dye on the reactive points of the fibre's molecular structure.

Batch or discontinuous dyeing

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

The use of chemical auxiliary additives, as well as the control of the bath environment (physical variables, basically the temperature) can accelerate this operation and optimise it. Once the dye is fixed in the fibre, the fibre goes through a washing process in which both the dye which has not become fixed and the auxiliary products used to help the fixation process are eliminated.

The theory of bath exhaustion

The maximum exhaustion that a given dye can reach is related to the affinity of the dye with the fibre and the bath ratio worked with, leading to the following equation:

$$E = \frac{K}{K+L}$$

Where:

E= exhaustion
K= dye affinity
L= bath ratio

Dye affinity is defined as: $K = C^f/C^s$

C^f= concentration of the dye in the fibre
C^s= concentration of the dye in the solution

Both values obtained in the equilibrium stage at constant temperature.

The value of K may vary between 50 and 1,000 for different combinations of fibre and dyes.

The practical values of L oscillate between 5 and 30 depending on the way the bath is applied and the machinery used. (From 1 kg textile cloth/5 l bath, to 1/30).

With these values, the coefficient E for exhaustion is obtained between 0.5 and 1, that is to say, between 50% and 100%.

In accordance with this approach, if the bath ratio is increased, exhaustion is reduced and, therefore, the waste concentration of the exhausted bath is increased.

This effect is greater in the dyes which have a low affinity. Hence the importance of knowing the affinity value and a correct operation.

That is to say, in order to reduce the dye content in wastewater, high-affinity dyes should be selected or the bath ratio must be reduced if the affinity is low.

The same dye can present different affinities for one or another fibre and, consequently, the generalisation of the exhaustion associated to each dye is most difficult, and requires systematic testing in the laboratories of each industry.

Machinery used

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

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

Continuous dyeing

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

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

Machinery used

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

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

“Jet”: is a rope form dyeing machine. The fabric is set in motion by the action of a nozzle (hence the denomination jet), through which the bath passes, where both the bath and the fabric are in simultaneous movement. The high speed produced by the injection in the bath causes turbulence, which facilitates the penetration of the dye solution towards the interior of the fabric and good equalisation of the dye, in a shorter space of time, and with lower water consumption than in the old winches.

“Airflow”: is similar to a “jet” but with the impulse of a mixture of air and dye solution, which allows a more delicate treatment of the fabric. Water consumption is greatly reduced since only the necessary amount of dye is added, eliminating the concept of bath accumulation.

“Overflow”: the fabric and the bath are in motion. As in the case of the “jets”, the bath acts on the fabric but in this case, the fabric is dragged by a winder and not just by the action of the nozzle. It is usually used for the dyeing of many types of fabric in rope form, from the most resistant to delicate fabrics.

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

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

The dyeing process may be applied to any stage of the state of the textile element and to any type of material.

Below is a table of all possible combinations of dye applications.

Table 6: Combination of possible dye operations

TYPE OF TEXTILES ELABORATION	FIBRE CLASS
Flock and yarn	Cotton and blends
	Wool and blends
	Cellulosic and blends
	Synthetic fibres and blends
Fabric	Cotton and blends
	Wool and blends
	Cellulosic and blends
	Synthetic fibres and blends
Knitwear	Cotton and blends
	Wool and blends
	Cellulosic and blends
	Synthetic fibres and blends
Garment	Cotton and blends
	Wool and blends
	Cellulosic and blends
	Synthetic fibres and blends
Bulk polymer	Synthetic fibres

4.2.3. Dyes used in the dyeing process

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

Direct dyes

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

Chemically, direct dyes belong to the following types:

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

Insoluble azo dyes

The basis of dyeing with insoluble azo dyes lies in the formation of coloured pigment on the fibre, which is achieved when treating the textile, generally in two baths, with the two components that form the dye. The first component, the so-called developer, is a naphthenic derivative that contains amino and hydroxyl groups.

Nowadays, mainly hydroxylated derivatives are used as developers, and so this dyeing is also known as dyeing with naphtholes.

The textile material impregnated with the developer is put into a second bath in a diaze solution, which, when it reacts with the developer produces the insoluble azo dye on the fibre. This dyeing procedure gives extraordinary wash fastness, far higher than that offered by direct dyes themselves, though with far higher production costs.

Sulphur dyes

The chemical make-up of these dyes is not easy to define. They are given this name because they contain sulphur, generally forming a chain (Ar-S-S-Ar’ or Ar-S-S-S-Ar’). The sulphur may be easily oxidised to become sulphuric acid. The traditional dyes, which are generally low in cost, contain a high concentration of impurities such as salts, sulphides and polysulphides. In an alkaline medium and in the presence of reductive agents, they are transformed into soluble leuco derivatives which are easily absorbed by the fibres.

The dyeing operation using these dyes consists of the following stages:

- Dissolving the dye using a reductive agent: sodium sulphide, sodium bisulphide, ammonium sulphide, sodium hydrosulphite or glucose.
- Dyeing with the addition of a neutral electrolyte, such as sodium chloride and wetting agents.
- Oxidation of the dye absorbed in the fibre with oxidising systems based on bromates, iodates, chlorites, potassium dichromate (practically out of use), peroxides or oxygen.
- Later treatment with metallic salts, detergent, sodium acetate or with sodium dichromate and acetic acid to increase the wash fastness of the colours against light, washing, rubbing, etc.

Soluble sulphur dyes

This type of dye is a variant of the previous ones, synthesised with thiosulphate groups. The formation of insoluble pigment is done by a reaction with sodium polysulphide in a second bath.

These dyes are suitable for application in continuous mode following the sequence:

- Padding of the dye
- Drying of fabric
- Padding with sodium polysulphide
- Washing
- Soaping

Vat dyes

Of different chemical constitution (that may derive from indigo or from anthraquinone), they are insoluble in water, and are transformed by reduction in an alkaline medium into hydrosoluble leuco derivatives with substantiveness for textile fibres, on which they develop the prime colour by ulterior oxidation.

The dyeing operation with these dyes consists of the following stages:

- Reduction of the dye with sodium hydrosulphite, formaldehyde or acetaldehyde sulphoxylate, using caustic soda as an alkali.

- Dyeing with the addition of electrolyte (common salt or sodium sulphate), wetting agents and levelling agents.

- Oxidation by washing with cold water or treatment with oxygenated water or potassium dichromate and sulphuric acid.

- Later washing and soaping treatments.

Reactive dyes

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

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

The dye operation using these dyes consists of the following stages:

• Absorption, analogous to the dyeing with direct dyes.

• Reaction, in which the dye chemically combines with the fibre by means of a covalent bond.

• Later treatment to eliminate the hydrolysed dye.

The application of these dyes can be done either in continuous mode or in batches, which, in the case of yarn is usually done by packing in an autoclave.

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

Specifically for wool, the operations are:

• Exhaustion dyeing, which may be used for flock, combing, hank and fabric spinning.

• Dyeing through padding-cold rest, only applicable for knitwear.

Acid dyes

These dyes colour the wool and proteic fibres in an acid or basic solution. They may be classified into five large groups:

• Azo dyes
• Anthraquinonic dyes
• Derivatives of triphenylmethane
• Azinic type
• Xanthene type

The last two are frequently used in obtaining certain shades.

In the dyeing process with these dyes, several auxiliary agents are used such as:

• Levelling agents, which may be anionic compounds which are similar to the fibre or cationic or pseudocationic compounds, which are similar to the dyes, such as, for example, sulphated castor oils, oleic and sulphated polycastor acids or alkylaryl sulphonates.

• Acetic or formic acid to exhaust the dye onto the fibre

• Sodium sulphate

• Ammonium sulphate

Premetallised dyes

These dyes are composed of a metal atom to which one or two molecules, generally of acid dye, are added, forming a co-ordination complex with affinity for the proteic and polyamidic fibres. The metal is usually chrome, although others may be used such as copper, nickel, cobalt, etc.

The types of premetallised dyes developed are:

- Premetallised dyes 1:1, which dye in a strongly acid bath, formed of chrome and azoic-type dyes.

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

Chrome dyes

The dyes pertaining to this type, which are also called chromable acid dyes, need the aid of a chrome salt to be able to fix perfectly onto the fibre, and they may be classified into the following chemical groups:

- Azo dyes
- Anthraquinonic dyes
- Triphenylmethanes
- Others, such as derivatives of thiazine, of the oxazines and of xanthene

The most commonly used chromium salts are: anhydrous potassium dichromate, sodium dichromate and potassium chromate.

The procedure depends on the dyes used and the type of material dyed. The dichromate may be applied to the wool before dyeing (pre-chroming procedure), with the dye in the same bath (simultaneous chroming procedure) or afterdyeing (afterchroming procedure). These procedures have fallen into disuse and are only used in some very specific cases in place of the “low chrome” procedure.

Disperse dyes

These are non-ionic organic compounds, almost insoluble in water, which are applied in aqueous dispersion, responding to the following structures:

- Dyes with azo groups, principally mono- and some di- azoderivatives, which encompass a broad range of shades.

- Nitrodiphenylamine dyes for yellows and oranges.

- Anthraquinonic dyes for oranges, greens and blues.

The dispersing agents (surfactants) used in the preparation and application of disperse dyes are:

- Esters of sulphuric acid, such as alkylsulphates in chains of 12-13 carbon atoms, sulphated oils, sulphated esters and amides.

• Sulphonic derivatives, in which the radical chain may be alkyl, alkylaryl, amides, esters or lignins. Among the most commonly used are the derivatives of ß-naphthelene sulphonic acid and its products of condensation with formaldehyde.

• Oxyethylene derivatives, for example, alkylaryl oxyethylenes and alkylamine oxyethylenes.

The application methods depend on the way that the textile materials are found. Dyeing can be done by exhaustion at high temperature or with a carrier at temperatures of 100ºC. (The latter case is tending to fall into disuse).

Traditionally, in the case of polyester, following dyeing at 130ºC, a reductive bath is necessary, which is performed at a lower temperature.

Cationic dyes

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

• Derivatives of di- and triphenyl methane.

• Derivatives of diphenyl-amine which includes a series of dyes of a simple structure which belong to the family of azines, oxazines, tiazines, indamines, rhodamines, gallocyanines, etc.

• Azoic or anthraquinonic-type dyes.

• Dyes with a heterocyclic structure containing quaternary nitrogen.

Table 7: Combination of the types of dye used in different applications

DYE TYPES	APPLICATIONS											
	Cotton			Wool			Cellulosic			Synthetic		
	FI	FA	K	FI	FA	K	FI	FA	K	FI	FA	K
Direct	X	X	X	-	-	-	-	X	X	-	-	-
Insoluble azo dyes	X	X	X	-	-	-	-	-	-	-	-	-
Sulphur dyes	X	X	X	-	-	-	X	X	X	-	-	-
Sulphur dyes (soluble type)	-	X	-	-	-	-	-	-	X	-	-	-
Vat	X	X	X	-	-	-	-	X	X	-	-	-
Co Reactive (cotton)	X	X	X				X	-	X	-	-	-
Wo Reactive (wool)				X	X	X						
Acids	-	X	X	X	X	X	-	X	-	X	X	X
Premetallised	-	X	-	X	X	X	-	X	-	-	-	-
Chrome	-	-	-	X	X	X	-	-	-	-	-	-
Disperse	-	X	X	-	-	-	-	-	-	X	X	X
Cationic	-	X	X	-	X	X	-	X	-	X	X	X

FI: Fibre FA: Fabric K: Knitwear

4.2.4. Processes of colour correction

The quality requirements regarding textile products are currently highly demanding. Among the market requirements are the exactness of colour and the uniformity of aspect. Though the industrial laboratories develop processes with the aim of getting things “Right first time”, when this aim is not reached, corrective processes must be introduced:

- Added correction
- Reoperation correction

Added correction

This consists of adding dye to the bath during the dyeing operation or totally or partially emptying the bath to replace it with a new one.

Reoperation correction

This consists of repeating the whole dyeing operation after its total or partial chemical dismantling when the necessary quality has not been achieved. Normally, before repeating the operation, a prior drying process is carried out.

4.2.5. Description of the finishing process

Following dyeing, later treatments may be performed on the fabric in order to achieve special characteristics for the end textile product.

The fabric’s characteristics may be changed by performing physical or mechanical treatments (dry finishing processes) or by applying chemicals (wet sizing processes).

In some cases, the results could be achieved in any of both ways, as is the case of lustre. In others, only one possible way exists, as is the case of impermeability or fire-retardant qualities.

All wet treatments are principally based on the coating or impregnation of the fabric with different substances, which may be applied indistinctly to bleached or dyed fabrics.

Normally, the wet finishing subprocesses follow the operations below:

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

- Fixation by the effect of temperature.

4.2.6. Types of finishing subprocesses

4.2.6.1. Mechanical finishing

The most common mechanical finishing processes are described below:

Heat setting

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

Brushing and raising

These are used to reduce the fabric’s shine due to rubbing against a surface, changing the appearance of the fabric, breaking some individual fibres by means of small hooks.

Softening or calendering

Calendering through the effect of the temperature and pressure gives rise to the softening of the surface of the fabric and lustre increases. In calendering, the fabric passes between two or more cylinders, one of which is made of steel, while the others are made of very soft material (normally the contact surface is cotton).

The steel cylinder may also be heated using gas or steam.

Embossing

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

Chintz effect

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

Shearing

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

Sanforizing

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

4.2.6.2. Chemical finishes

The most common chemical sizing processes have specific functions: softening, hydrophobing, waterproofing, flame-retardant treatment, bactericide, etc.

The main finishing subprocesses are as follows:

Chemical softening

Different types of softeners may be used:

- Cationic softeners such as: quaternary ammonium salts, amino esters and amino amides
- Non-ionic glycolic polyester or polyether glycol-type softeners
- Reactive softeners such as fatty acid amides and triazine derivatives

Anti-static treatment

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

Flame-retardant treatment

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

Shrink-resistant treatment

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

Waterproofing

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

Crease resistant treatment

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

Coating

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

Other textile coating operations are:

- Powder coating (thermoadhesive resins for interfacing)
- Application of paste coating
- Transfer coating

Rot proofing treatment, mothproofing and fungicide treatment

This consists of treating the fabric with an aqueous solution which contains between 0.1-0.25% of mildew-proofing, moth-proofing and fungicide agents, (chlorated aromatic hydrocarbons and copper organic compounds). The moth-proofing treatment for wool is carried out during the dyeing process.

4.3. MAIN DYEING AND FINISHING PROCESSES

4.3.1. Dyeing of fibres and yarn

4.3.1.1. Cotton and blends

The process of the dyeing of cotton fibres and yarn (see Flow chart No.1) consists of the following operations:

- Scouring
- Mercerising (caustisizing)
- Optical and chemical bleaching
- Colouring
- Drying

Scouring

The scouring or cleaning operation aims to eliminate natural impurities contained in the fibre itself, such as waxes, pectins and hemicellulose elements, sizing agents and additives incorporated in the spinning processes.

This operation is performed in continuous or discontinuous systems, through the action of an alkali, such as caustic soda, alone, or along with detergent products to solubilise and/or emulsify the cotton impurities, sequestrants and small quantities of reductive products, such as sodium hydrosulphite. The discontinuous process is done in one or two stages.

Mercerising (caustisizing)

The mercerising operation consists of subjecting the cotton to the action of the concentrated caustic soda (28-30° Be), so as to provide it with some characteristics that it does not possess or that it possesses in insufficient amounts, such as lustre, dye affinity, better dimensional stability, and an 15-20% increase in the mechanical resistance of the yarn.

This is done by subjecting the threads to tension, during or after impregnation in caustic soda of 30°Be at temperatures lower than 20°C and, later, successive washes are performed until the concentration of soda has fallen to values that no longer modify the cotton any more. In order to facilitate the impregnation of the cotton, anionic wetting agents are also added which can be phenolic or non-phenolic derivatives, the latter currently being the most commonly used, which are based on sulphur esters of average molecular weight (4 to 12 atoms of carbon).

The final stage is the neutralisation of the alkaline remains, which are still contained in the thread, if the following operation is not to be performed at alkaline pH, generally with chlorhydric acid or sulphuric acid.

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

Caustisizing needs not be done in the mercerising machines themselves.

Optical and chemical bleaching

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

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

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

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

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

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

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

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

Dyeing

The families of dyes used for cotton fibres, both when alone and when accompanied by other fibres, are the following:

- Direct dyes
- Insoluble azo dyes
- Sulphur dyes
- Vat dyes
- Reactive dyes

The auxiliary products used according to the type of dye are found in the Flow chart table No. 1.

Drying

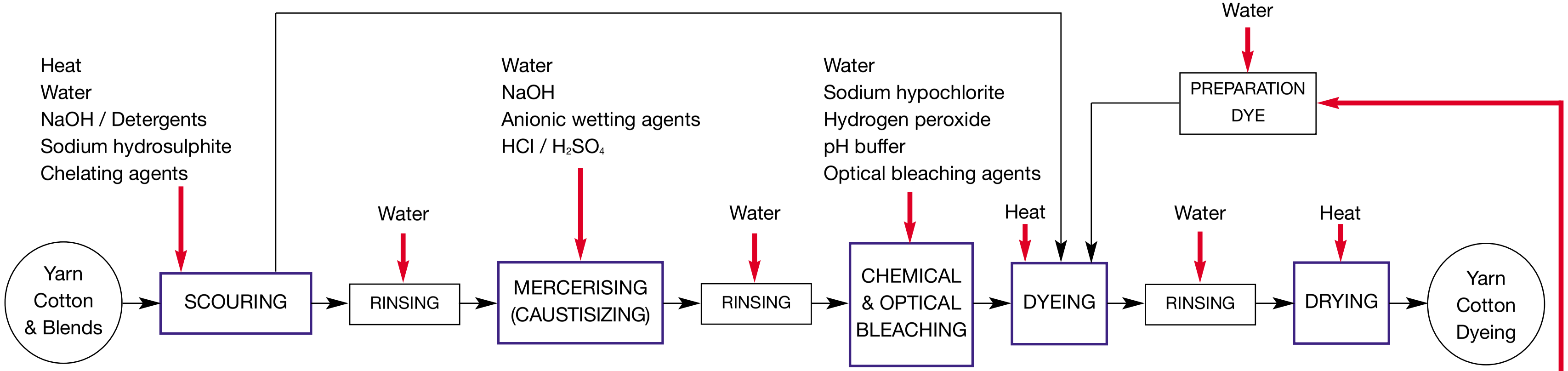
Following dyeing, the last operation is drying which is generally performed in two stages:

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

Dryers may be:

- Convectors (chamber type)
- By countercurrent (perforated tape-type in a tunnel)
- By high frequency radiation or microwaves

Flow chart No. 1
FLOW CHART OF COTTON FIBRES & BLENDS DYEING PROCESS



AUXILIARY MATERIALS ACCORDING TO TYPE OF DYE				
Direct	**Insoluble azo dyes**	**Sulphur**	**Vat**	**Reactive**
Neutr. electrolyte Wetting agents Equalisers	Acid Detergent Wetting agent	Reductive agent Neutr. electrolyte Wetting agents Oxidant Detergent Sodium acetate	NaOH Sod. hydrosulphite Neutr. electrolyte Wetting agents Equalisers Oxidants Detergent	Neutr. electrolyte (NaCl mainly, or Na_2SO_4) Wetting agents Alkali (NaOH, $NaHCO_3$ or Na_2CO_3)

4.3.1.2. Wool and blends

The process of dyeing wool yarn fibres (see Flow chart No. 2) consists of the following operations:

- Preparation of combing or spinning of wool and blends
- Anti-felt treatment of combing
- Degreasing
- Optical and chemical bleaching
- Centrifuging
- Dyeing
- Drying

Preparation of combing or spinning of wool and blends

The preparation of combing or spinning of wool and blends is done, when necessary, by means of a series of mechanical operations such as: blending and recombing.

Anti-felt treatment of combing

The special combing treatments aim to reduce the tendency of wool to felt with use and the washing of garments and are normally done on wool which is to be used for knitwear, socks, sweaters, underwear or blankets.

All of these treatments modify the superficial structure of the wool fibre, hardly affecting the rest of its properties.

The processes used in the special combing treatments may be divided into the following groups:

- *Chlorination systems,* which are the oldest, among which the following are included:
  - The Negafel procedure, which employs sodium hypochlorite and formic acid, with later antichlorine treatment.
  - Gas chlorination, which consists of subjecting the dry wool (< 10% humidity) to the action of chlorine gas in the absence of air.

- *Oxidation systems,* which are more recent than the previous ones, among which the following are included:
  - The Dylan procedure, with permonosulphuric acid followed by treatment with sodium sulphite.
  - The W B-7 procedure, based on the treatment of wool with potassium permanganate in a concentrated solution of sodium sulphate and a subsequent treatment with sodium bisulphite in order to eliminate the manganese dioxide deposited on the wool.

- *Fibre coating systems:*
  - Processes based on the application of ester copolymers and methalacrylic acids.

- The Wurlan process, based on the interfacial polymerisation of polyamides, polyesters, polyurethanes, etc.
- The Lanaset and Resloom process, consisting of depositing a thermoset resin on the wool fibre, obtained by the reaction of melanin and formaldehyde in the presence of acid catalysts.

Degreasing

The degreasing operations of both wool slivers and yarn are based on the use of generally alkaline solutions of sodium carbonate and soap. In degreasing, synthetic detergents are also used such as fatty sulphated alcohols, sodium salts and non-ionic surfactants, at concentrations in proportion to the concentration of oils and other hydrophobic substances on the fibre.

Optical and chemical bleaching

The chemical bleaching operation, whose aim is to eliminate the natural colour of the wool fibre, may be done by means of:

- Reductive agents such as gas sulphurous anhydride, liquid sulphurous anhydride, sulphurous acid, sulphite, bisulphite and hydrosulphite.

- Oxidising agents such as oxygenated water and persalts.

As in the case of the cotton process (see section 4.3.1.1.) in the bleaching of wool fibres and yarn, optical bleaching agents of the same type as those mentioned in said process may also be used.

Centrifuging

The aim of centrifuging is to eliminate the majority of water contained in the fibre after wet treatments.

Dyeing

The families of dyes used for the dyeing of wool combing and yarn are:

- Acid dyes
- Premetallised dyes
- Chromable acid dyes
- Reactive dyes

The auxiliary products used according to the type of dye are found in the table corresponding to Flow chart No. 2.

Drying

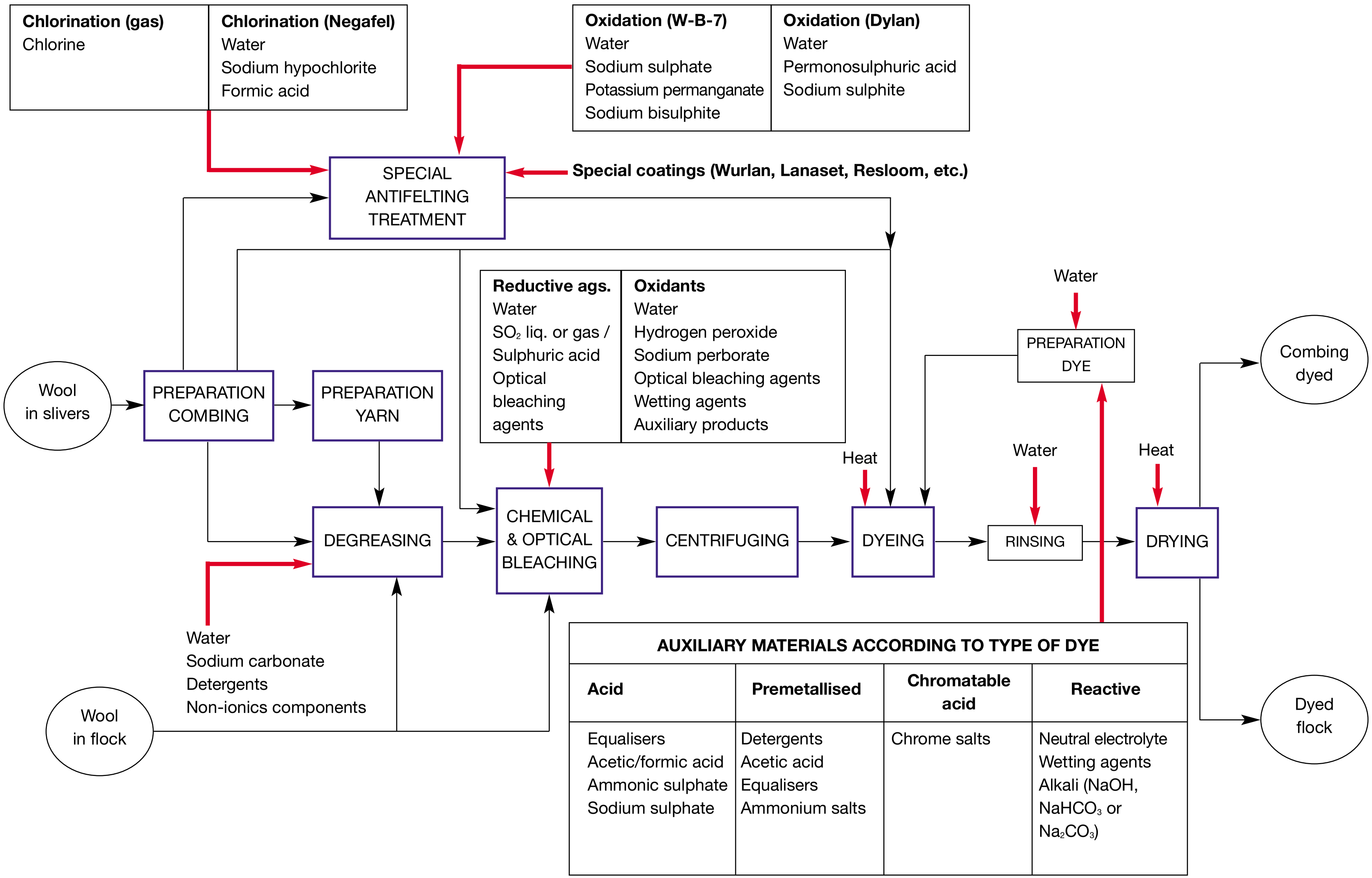
Following dyeing, the last operation is drying, which is generally done in two stages:

- The mechanical elimination of water (hydro-extraction)
- Drying by thermal energy

The dryers may be:

- By convection (chamber type)
- By countercurrent (punched tape-type in tunnel)
- By high frequency radiation or microwaves

Flow chart No. 2
FLOW CHART OF WOOL FIBRES & BLENDS DYEING PROCESS



4.3.1.3. Cellulosics and blends

Rayon fibres may be dyed:

- By mass dyeing
- By spinning (with blends)

Mass dyeing is done with the polymer in gel form during the polymer coagulation stage within the wet spinning process, which is what fibre producers call the form of continuous filament at the stage at which a polymer is manufactured.

If dyeing is done with the fibre cut, the operation is similar to the process for dyeing cotton fibres (see section 4.3.1.1).

The operations are as follows (see Flow chart No. 3):

- Scouring or washing
- Optical and chemical bleaching
- Dyeing and finishing
- Drying

Scouring or washing

Rayon fibres do not contain too many impurities and, in any case, they are fatty substances that are added in order to facilitate the mechanical spinning process, which are easily extractable. Therefore, in many cases, the pre-wash has not been done as a separate operation and, if done, consists of an aqueous wash with anionic surfactants and sodium carbonate, followed by rinsing with water with or without the addition of acetic acid.

Optical and chemical bleaching

The bleaching operation is only performed when the final colour is white given that rayon fibres have a high degree of whiteness and are apt for their later dyeing. This operation is done by means of combined optical and chemical bleaching, using hydrogen peroxide in an alkaline medium or sodium chloride in acid medium and the optical bleaching agent, followed by rinsing with water.

Dyeing

The dyes used for the yarn dyeing of cellulosic fibres are habitually reactive, and are applied in over 30% of cases. The next most important are sulphur, direct and vat dyes.

Drying

The drying operation is similar to those done on cotton and wool yarn (see sections 4.3.1.1 and 4.3.1.2).

4.3.1.4. Synthetics and blends

The process for synthetic fibres (see Flow chart No. 3) basically consists of the following operations:

- Scouring or washing
- Steaming
- Bleaching (only when necessary)
- Dyeing
- Drying

The scouring, bleaching and drying operations are identical to those for cellulosic fibres (see section 4.3.1.3).

Steaming

The steaming operation should be applied to the synthetic fibre yarn alone or in blends with wool, cotton or cellulosics as a treatment prior to dyeing. The aim is to free the synthetic fibres of the tensions to which they have been subjected in the course of drawing during spinning, and taking them through the process of thermal relaxation of the internal tensions to a state of balance that protects them from later deformation.

Dyeing

The dyeing of synthetic fibres is done using specific dyes for each type of fibre:

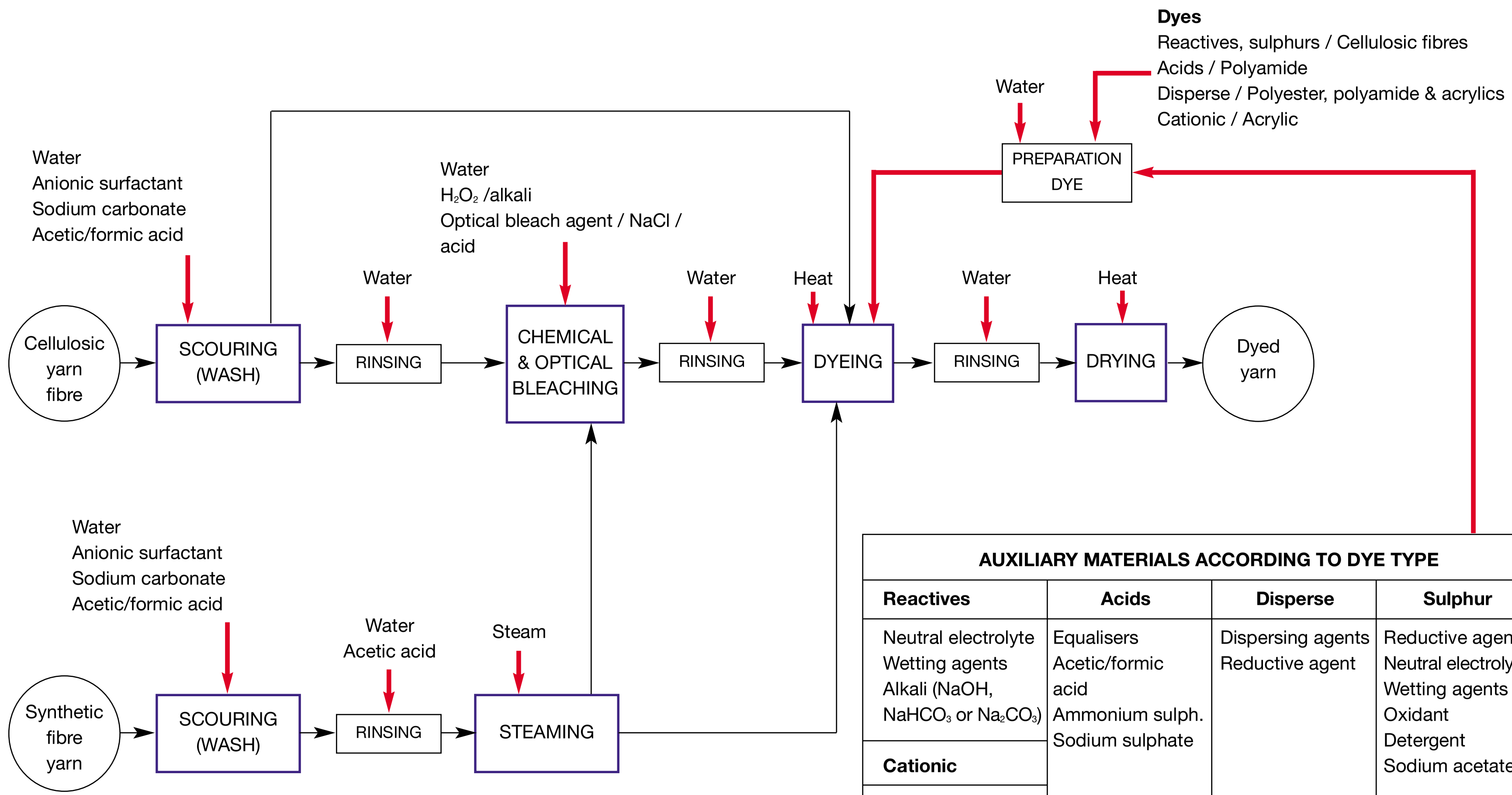
- Disperse dyes, for polyester, polyamides and acrylics
- Acid dyes, for polyamides
- Cationic dyes, for acrylics

In the case of polyester or blends, following dyeing, a reductive bath is normally carried out to eliminate the disperse dye which remains on the surface of the fibres. The main components of this bath are usually:

- Caustic soda
- Sodium hydrosulphite
- Dispersing agent

Flow chart No. 3

FLOW CHART OF CELLULOSIC/SYNTHETIC FIBRE DYEING PROCESS



AUXILIARY MATERIALS ACCORDING TO DYE TYPE			
Reactives	**Acids**	**Disperse**	**Sulphur**
Neutral electrolyte Wetting agents Alkali (NaOH, $NaHCO_3$ or Na_2CO_3)	Equalisers Acetic/formic acid Ammonium sulph. Sodium sulphate	Dispersing agents Reductive agent	Reductive agent Neutral electrolyte Wetting agents Oxidant Detergent Sodium acetate
Cationic			
Acetic/formic acid Retarding agents (cationic or anionic) Equalisers			

4.3.2. Dyeing and finishing of fabrics

4.3.2.1. Cotton and blends

The process of dyeing and finishing for cotton fibres and its blends (see Flow chart No. 4) basically consists of the following operations:

- Singeing
- Quenching
- Scouring
- Mercerising and rinsing
- Optical and chemical bleaching
- Drying
- Heat setting
- Dyeing and rinsing
- Final drying
- Finishing

Singeing

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

Quenching

Quenching or desizing aims to eliminate the pastes which are added to the warp for weaving.

Desizing procedures are selected according to the type of sizing in the fabric:

- Desizing of starch pastes

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

- Desizing with polyvinyl alcohol (PVA), carboxymethyl cellulose (CMC), (CMA), etc.

  Since they are hydrosoluble pastes, they are directly eliminated by washing with a detergent at a suitable pH, depending on the case in question.

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

Scouring

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

Mercerising and bleaching

Mercerising and bleaching operations are similar to those described for the process of dyeing cotton yarn (see section 4.3.1.1).

Drying

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

Heat setting

Heat setting must be applied to all fabrics that contain synthetic fibres either on their own or in blends with natural or artificial fibres, as a treatment before dyeing or printing and as a final treatment. Its aim is to free the synthetic fibres of the tensions to which they have been subjected in the course of drawing during spinning and taking them through the process of thermal relaxation of the internal tensions to a state of balance that protects them from later deformation.

In order that no deformations are suffered during later hot processes, the fabric must not be subjected to treatment at a temperature higher than that of the heat setting process. It is performed in a stenter, with the fabric open-width in order to allow its relaxation and dimensional fixing.

Dyeing

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

- Direct dyes
- Insoluble azo dyes
- Sulphur dyes
- Soluble-type sulphur dyes
- Vat dyes
- Reactive dyes
- Disperse dyes
- Acid dyes
- Cationic dyes
- Premetallised dyes

The auxiliary products used depending on the type of dye are to be found in the table of Flow chart No. 4.

Final drying

The final drying operation is similar to that carried out for cotton fibres (see section 4.3.1.1).

Finishing

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

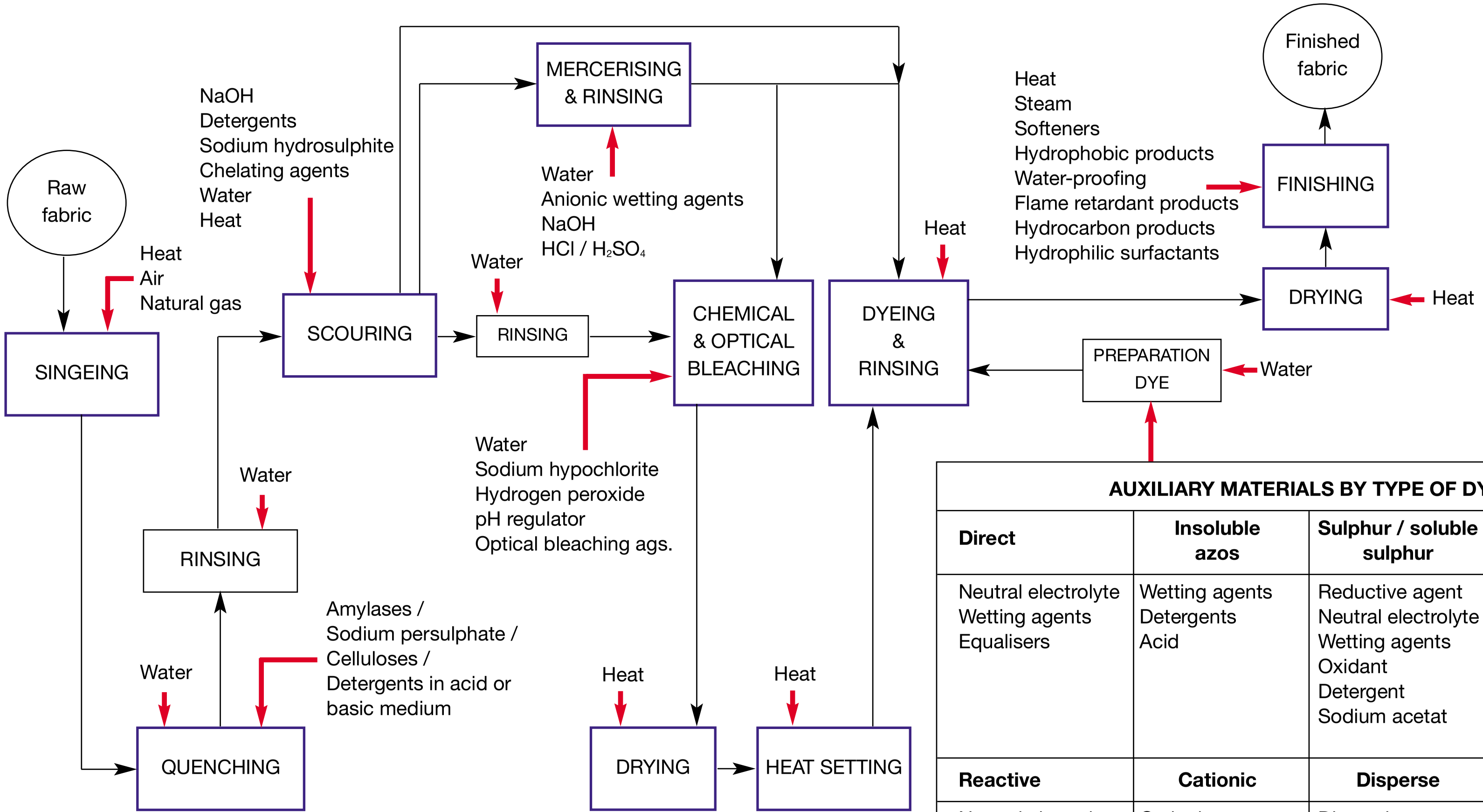
• Mechanical:

- Calendering
- Shearing
- Brushing
- Wetting
- Raising
- Palmer machine

• Chemical:

- Crease resistant treatment
- Waterproofing
- Softening
- Hydrophobic
- Wash and wear
- Stain resistant treatment
- Flame-retardant treatment

Flow chart No. 4
FLOW CHART OF DYEING & FINISHING PROCESS FOR COTTON FABRICS & BLENDS



AUXILIARY MATERIALS BY TYPE OF DYE

Direct	**Insoluble azos**	**Sulphur / soluble sulphur**	**Vat**
Neutral electrolyte Wetting agents Equalisers	Wetting agents Detergents Acid	Reductive agent Neutral electrolyte Wetting agents Oxidant Detergent Sodium acetat	NaOH Reductive ag. Electrolyte Wetting agents Equalisers Oxidants Detergent
Reactive	**Cationic**	**Disperse**	**Premetallised**
Neutral electrolyte Wetting agents Alkali (NaOH, $NaHCO_3$ or Na_2CO_3)	Cationic or anionic retarders Equalisers Acetic / formic acid	Dispersing agents **Acid** Equalisers Acetic/formic acid Ammonium sulph. Sodium sulphate	Detergents Acetic acid Equalisers Ammonium salts

4.3.2.2. Wool and blends

The process of dyeing and finishing for wool fabrics and blends thereof (see Flow chart No. 5) basically consists of the following operations:

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

Carbonisation

Carbonisation aims to chemically eliminate the remains of cellulosic matter, which accompany wool as impurities.

It is done by impregnating the wool with strong mineral acids or with salts that generate these acids, followed by drying and later treatment at a temperature of 105-115º C.

The carbonisation process of wool in continuous mode consists of the following stages:

- Impregnation with an aqueous solution of sulphuric acid and with the addition of a stable wetting agent in acid medium.

- Drying in two chambers, the first at 60º C and the second at 80 to 90º C.

- Carbonisation in an oven at 105-110º C.

- Beating in a beating machine in order to eliminate the carbonised vegetable particles adhered to the wool.

- Neutralisation of the acid contained in the fibre, followed by a thorough wash in order to eliminate any excess of alkalinity on the fibre.

Chemical or solvent washing

The washing of wool fabric is an operation that can be performed and repeated at several moments throughout the process. Thus, for example, they are done on the material leaving the loom, on the material leaving the fulling machine, or on the material leaving the dyeing stage.

It is used whenever necessary in order to eliminate traces of foreign substances, which have still not been removed from the fibre or that have deposited on the fabric by accident; or to neutralise the bad smell that the fabric sometimes has.

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

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

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

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

The degreasers employed in solvent washing are mixtures of emulsions of organohalogenated compound solvents (trichloroethylene and perchloroethylene).

These exhausted solvents can be regenerated by a distillation process.

Fixing

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

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

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

- Fixing in a crabbing machine is done by making the fabric pass completely open-width through boiling water, beaming it under pressure in a steel cylinder which is previously submerged in water at the desired temperature (70-100° C). Once beamed, it continues to turn in the boiling water for the necessary length of time in order to achieve the degree of fixing required. Finally, the fabric is submerged in cold water to cool it, keeping it beamed in the same way. The solutions used may vary from water to soap or alkaline, but generally, the treatment is done with just water.

- Fixing in the decatising machine consists of beaming the woollen fabric accompanied by a cotton or polyester fabric, in a copper cylinder with holes in it, to later subject it to the action of steam. The intensity of fixation depends on the length of time that the steam acts, the temperature of the steam and the degree of cooling carried out on the fabric before unrolling.

Fulling

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

It is done in the so-called fulling machine, in which the fabric, in endless rope form, is compressed in order to facilitate felting, which is produced in the presence of humidity and an acid or alkaline medium. The ideal values for felting in an alkaline medium are pH 10 and 44° C, and for acid pH 0.5 and 44° C. In alkaline felting, it is preferable to use soap rather than sodium hydroxide or carbonate, given that it acts as a lubricant facilitating considerably the movement of the fibres.

Optical and chemical bleaching

The operation of bleaching wool fabrics and blends has similar characteristics to those described in section 4.3.1.2. for the process of dyeing wool fibres and yarn.

Heat setting

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

Dyeing

The families of dyes used for the dyeing of wool fabrics are:

- Cationic dyes
- Acid dyes
- Premetallised dyes
- Chrome dyes
- Reactive dyes for wool

The auxiliary products used according to the type of dye are found in the table of Flow chart No. 5.

Drying

As in the case of other processes, the drying operation is done after the wet treatments, generally in two stages:

- Mechanical elimination of water
- Drying using thermal energy

Finishing

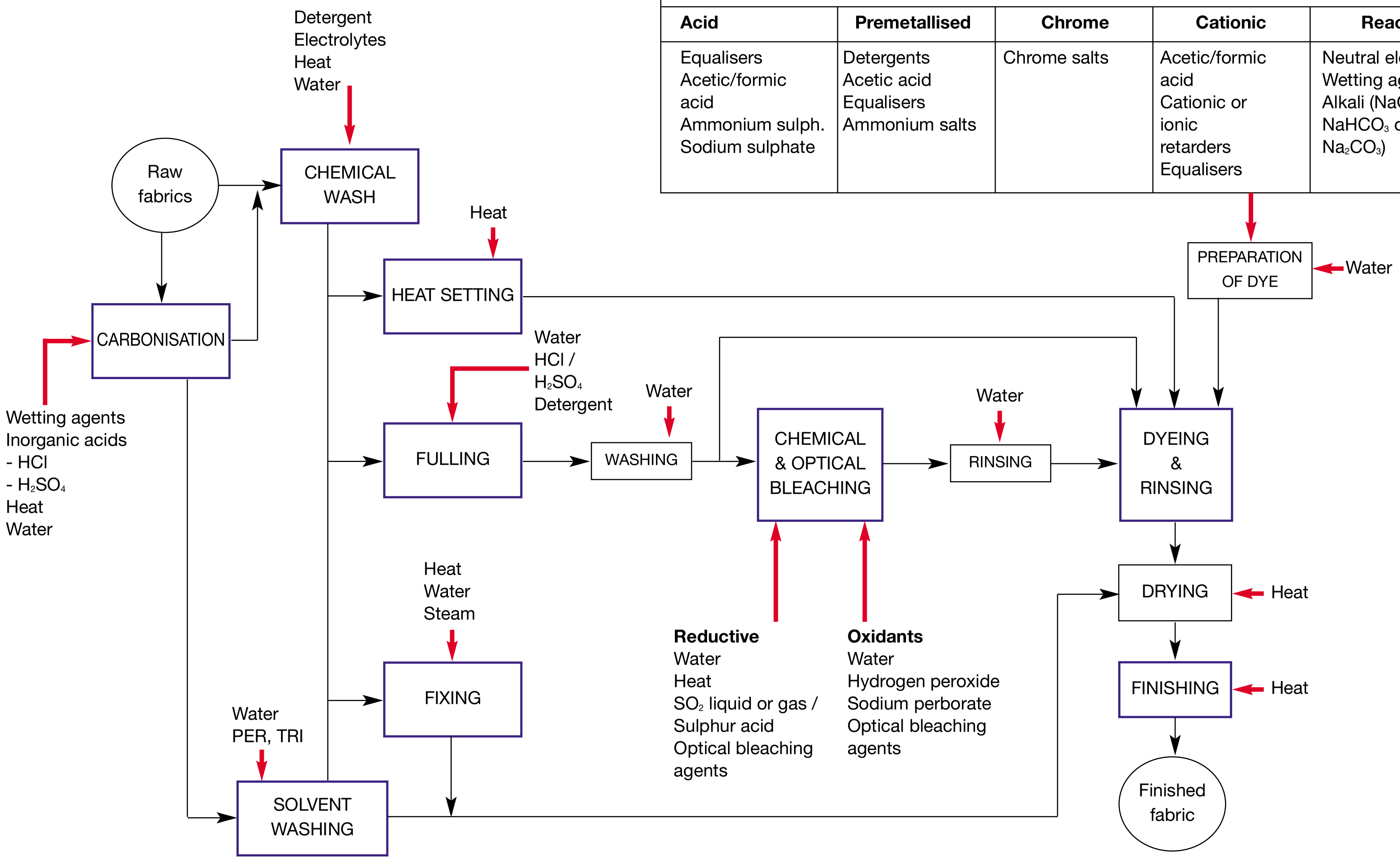
Finishing is the last operation. In wool fabrics, mechanical finishing is most commonly applied:

- Permanent fixing
- Raising
- Shearing
- Brushing
- Wetting
- Pressing
- Decatising
- Calendering

Flow chart No. 5
FLOW CHART OF DYEING AND FINISHING PROCESS FOR WOOL FABRICS AND BLENDS

AUXILIARY MATERIALS BY TYPE OF DYE

Acid	Premetallised	Chrome	Cationic	Reactive
Equalisers Acetic/formic acid Ammonium sulph. Sodium sulphate	Detergents Acetic acid Equalisers Ammonium salts	Chrome salts	Acetic/formic acid Cationic or ionic retarders Equalisers	Neutral electrolyte Wetting agents Alkali (NaOH, $NaHCO_3$ or Na_2CO_3)



4.3.3. Dyeing and finishing of knitwear

The production of knitwear requires efficient lubrication of the mechanical elements of the weaving machine and the needles, which implies that the thread which is threaded through the needles during the manufacturing process drags and retains part of the lubricants that are used.

Depending on the type of fibres that make up the knitted fabric, the textile ennobling process may start with washing operations in an aqueous medium, or with heat treatment, generally in a stenter, with the aim of dimensionally stabilising the knitted fabric (heat setting).

4.3.3.1. Cotton and blends

Tricot for underwear is usually made of 100% cotton or with a high proportion of cotton and an important part of them are only bleached and receive a softening finishing process.

The dyeing processes that may be done on the garment or tricot item follow the same operations (except the desizing) as in the case of dyeing cotton fabrics (see section 4.3.2.1). On the other hand, singeing, which is quite common in fabrics, is not so common for tricot.

Some cotton knitwear textiles may later be subjected to a printing process (see section 4.4).

4.3.3.2. Wool and blends

The process of dyeing and finishing for wool knitwear and blends (see Flow chart No. 6) includes the following operations:

- Washing / degreasing
- Solvent washing
- Optical and chemical bleaching
- Dyeing and rinsing
- Drying
- Finishing

Washing/degreasing

The washing or degreasing of wool knitwear and blends is similar to that described in the process of dyeing and finishing for wool fabrics and blends (see section 4.3.2.2).

Solvent washing

Due to the fatty characteristics of most materials that contain wool fibres, their elimination is also done by means of chlorinated organic solvent washing, fundamentally trichloroethylene or perchloroethylene, in which a small amount of water is emulsified. The washing process may be done in batches or in continuous mode at facilities that incorporate systems to recover the solvent through distillation.

Optical and chemical bleaching

The bleaching operation for wool fabrics and blends has similar characteristics to those described in section 4.3.1.2 for the process of dyeing wool fibres and yarn.

Dyeing and rinsing

The families of dyes used for the dyeing of wool knitwear:

- Cationic dyes
- Acid dyes
- Premetallised dyes
- Chrome dyes
- Reactive dyes

The auxiliary products used according to the type of dye are found in the table of Flow chart No. 6.

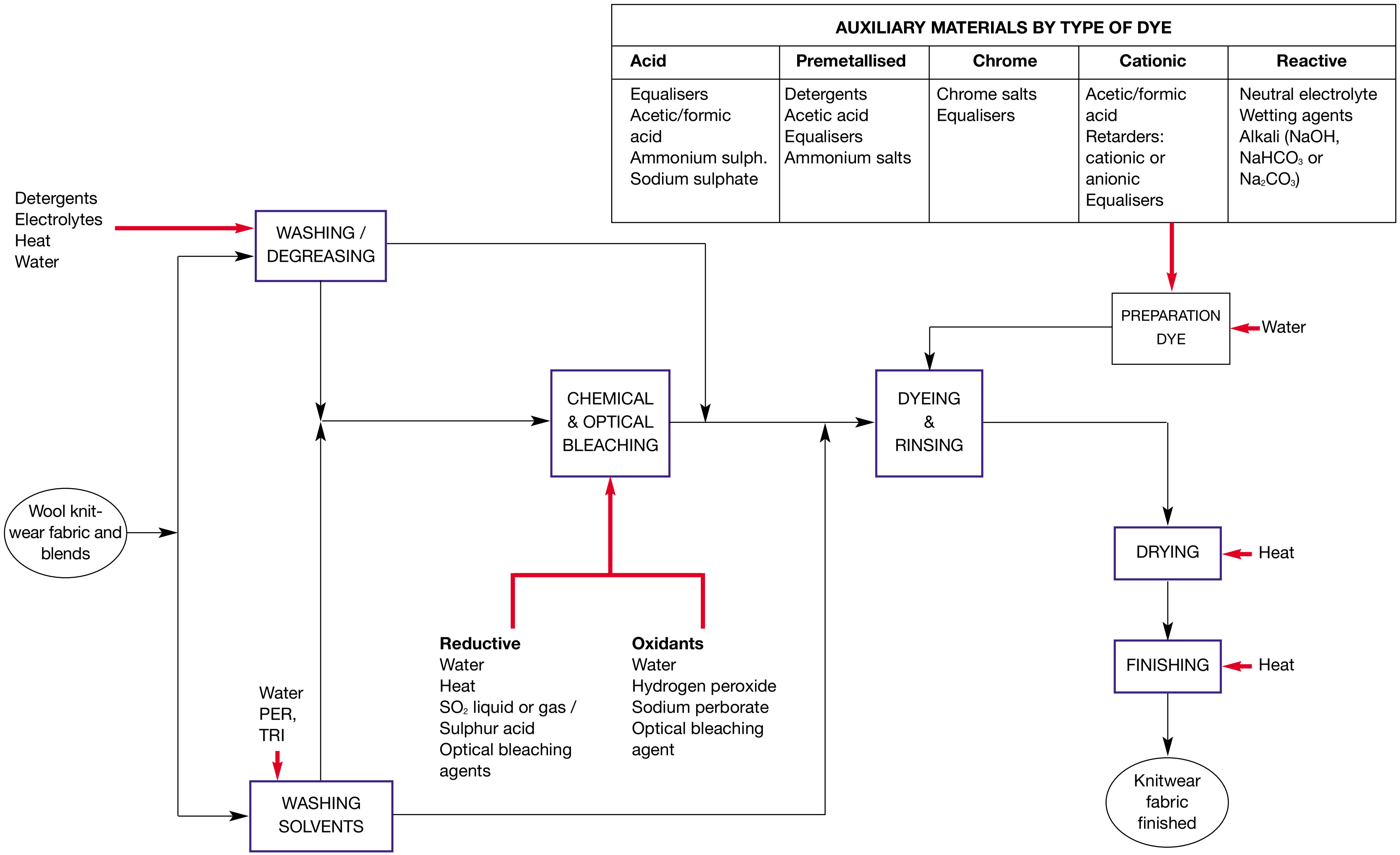
Drying

As in the case of other processes described, the drying operation is done after the wet treatments, generally in two stages. The types of dryers used are similar to those mentioned in the previous sections on drying.

Finishing

Lastly, the finishing operations for wool knitwear and blends are of the mechanical type, the same as those applied to wool fabrics (see section 4.3.1.2).

Flow chart No. 6
FLOW CHART OF DYEING AND FINISHING PROCESS FOR WOOL KNITWEAR & BLENDS



AUXILIARY MATERIALS BY TYPE OF DYE				
Acid	**Premetallised**	**Chrome**	**Cationic**	**Reactive**
Equalisers Acetic/formic acid Ammonium sulph. Sodium sulphate	Detergents Acetic acid Equalisers Ammonium salts	Chrome salts Equalisers	Acetic/formic acid Retarders: cationic or anionic Equalisers	Neutral electrolyte Wetting agents Alkali (NaOH, $NaHCO_3$ or Na_2CO_3)

4.3.3.3. Cellulosic fibres and blends

The dyeing process for cellulosic knitted fabric and blends (see Flow chart No. 7) includes the following operations:

- Scouring
- Optical and chemical bleaching
- Dyeing
- Drying
- Heat setting
- Finishing

Scouring and bleaching

Scouring and bleaching operations are similar to those described for the cotton process for the dyeing of combing and yarn, in section 4.3.1.1.

Dyeing

Among the types of dyes used in this operation, the following are included:

- Direct dyes
- Sulphur dyes
- Soluble sulphur dyes
- Vat dyes
- Reactive dyes

The auxiliary products used according to the type of dye are found in the table of Flow chart No. 7.

Drying

As in the case of other processes described, the drying operation is done following wet treatments, generally in two stages. The types of dryers used are similar to those mentioned in section 4.3.2.1.

Heat setting

The heat setting operation, as we have previously commented (see section 4.3.1.4) is applied to knitwear that contains a high percentage of synthetic fibres.

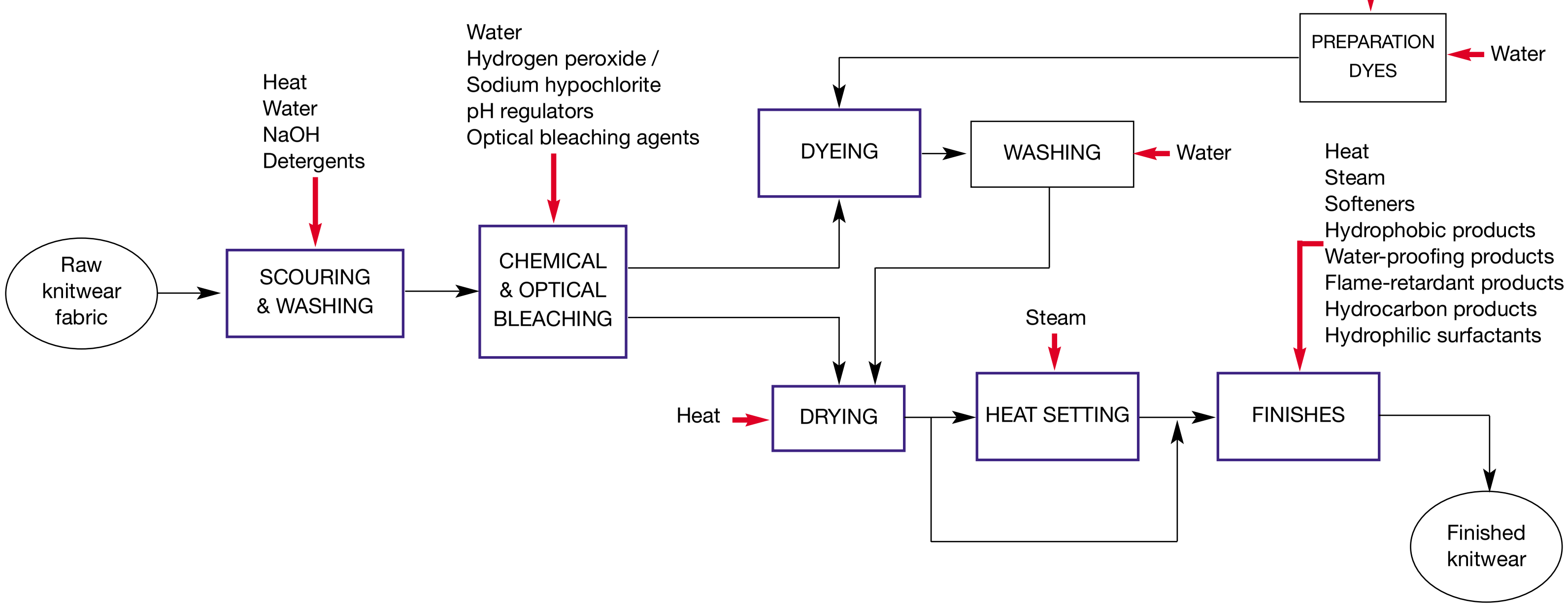
Finishing

The finishing operations for cellulosic knitwear and blends, are similar to those mentioned in section 4.3.2.1 for the finishing of cotton fibres and blends.

Flow chart No. 7

FLOW CHART OF DYEING & FINISHING PROCESS FOR CELLULOSIC KNITWEAR AND BLENDS

AUXILIARY MATERIALS BY TYPE OF DYE			
Direct	**Sulphur**	**Vat**	**Soluble sulphur**
Neutral electrolyte Wetting agents Equalisers **Reactive** Neutral electrolyte Wetting agents Alkali (NaOH, $NaHCO_3$ or Na_2CO_3)	Reductive agent Neutral electrolyte Wetting agents Oxidant Sodium acetate	NaOH Reductive Electrolyte Wetting agents Equalisers Oxidants	Equalisers Neutral electrolyte Wetting agents Oxidant Detergent Sodium acetate



4.4. PRINTING AND FINISHING PROCESSES

4.4.1. Description of printing processes

Printing is another type of process in which colour is given to the fabric. This colouring is not done uniformly but rather in the form of a drawing with the use of different technologies.

Printing techniques may be classified as follows:

Direct printing

Printing pastes contain the dyes with which the different colours of printed fabric are obtained. Generally, printing is done on fabric which is bleached and prepared for printing. Direct printing includes a whole set of technologies:

- Direct printing with soluble dyes (the printing paste contains the suitable dyes for each type of fibre to be printed).
- Direct printing with pigments (the printing paste contains binders and cross-linking agents which are capable of physically fixing the pigment to most types of fibres and blends).
- Direct printing by transfer (a previously printed piece of paper using the direct technique with inks of sublimatable disperse dyes, brought into contact with a polyester fabric, by means of the action of the temperature and the pressure, the dyes are transferred to the fabric by a process of sublimation.

Printing by corrosion

The printing paste contains corrosion agents of the dyes which have been previously applied to the fabric by different procedures. They are divided into:

- White corrosion printing: The printed patterns are the result of the white corrosion of the dyes of the background of the fabric.
- Illuminated corrosion printing: in addition to the corrosion agents, the printing paste incorporates dyes which are resistant to the corrosion agents and are capable of fixing onto the fabric.

Reserve printing

A reserve agent is printed onto the bleached fabric, which either totally or partially prevents the penetration of the dye during the fabric dyeing process.

One complementary criterion arises concerning the printing machinery, which is as follows:

- Long table
- Rotating table
- Garment printing machine: oval or star shaped

• Automatic machine: flat screens or microperforated cylinders
• Machine with gravure cylinders
• Machine for printing carpets
• Digital printing machine

4.4.2. Dye pastes used in the printing process

The printing pastes are composed of:

• Dyes
• Thickeners
• Auxiliary agents

Dyes

The dyes used in printing, as in dyeing, depend on the fibre to be worked with and the fastness and other qualities required by the item, but, in printing, the method of application also has an effect. In the following table, there is a breakdown of the commonly dyes used in the printing of different fibres.

Table 8: Combinations of dyes and pigments in printing

TYPES OF DYES	APPLICATIONS			
	COTTON	WOOL	CELLULOSIC	SYNTHETIC
Direct	X	-	X	-
Vat	X	-	X	-
Reactive	X	X	X	-
Acid	-	X	-	(PA)
Disperse	-	-	-	X
Premetallised	-	X	-	(PA)
Pigments	X	-	X	X

Thickeners

The thickeners used in textile printing may be natural or synthetic, however the former are more commonly used, although synthetic and chemically modified natural thickeners are gaining importance for certain special applications.

The selection of thickeners for application in specific types of dyes depends, in general, on the printing method and the type of fabric to be printed.

These are some of the thickeners used:

• Starches, dextrines and modified starches
• Tragacanth

- Senegal gum and gum arabic
- Mucilage
- Synthetic thickeners

Auxiliary agents

These are some of the auxiliary agents used:

- Mordants of vegetable origin, such as tannins

- Metal mordants, such as acetates, sulphoacetates and basic acetates of aluminium and iron

- Hydrotrope agents consisting of:
  - Short chain aromatic sulphonates
  - Products that contain carbonyl groups
  - The so-called ureic types (urea, formamide, acetamide, acetone, acetic ester, etc.)
  - Carriers of OH groups, such as mono- and polyvalent alcohols

- Corrosives:
  - Oxidants
    The oxidants used most commonly as corrosives are: potassium dichromate, potassium chromate, sodium dichromate and chromate, sodium and potassium chlorate, potassium ferricyanide, alkaline and aluminium bromates, persulphates and perborates and some peroxides such as manganese and lead peroxide.

  - Reductive agents
    Reductive agents have several applications: to reduce dyes such as indigo in order to be able to eliminate them albeit partially; and, in the case of azoic type dyes, to produce the destruction of this group transforming the dye into practically colourless products.

    Among the most commonly used reductive agents are: zinc powder, tin chloride, sodium hydrosulphite, sodium formaldehyde sulphoxylate, glucose, alkaline sulphite and bisulphite.

4.4.3. Main operations in the printing process

In the different printing systems (see Flow chart No. 8) all or part of the following operations are performed:

- Fabric preparation
- The printing of the different pastes (colours) and drying
- Colour fixation (steaming)
- Washing
- Polymerisation
- Finishing

Fabric preparation

Preparation consists of auxiliary operations of the fabric, so that it will have high, uniform hydrophility, and a fibre-free surface, and a suitable degree of whiteness.

Printing and drying

This consists of the application of the printing paste onto the textile material.

The printing techniques are:

- Direct
- By corrosion
- By reserve

In the case of direct printing or printing by corrosion, the drying process following printing is done in different types of drying apparatus after the printing process, depending on the type of fibre and the operation implemented.

The most commonly used system today is that of drying the printed fabric with hot air.

In reserve printing, the fabric must be subjected to dyeing, and a later process of washing and finishing.

Colour fixation

Fixation is carried out following printing and drying, to avoid the running of the colours or staining.

The most common fixation method is steaming. Its mission is to produce, by means of steam, a solubilisation of the dye, which, together with the temperature effect, facilitates the passage of the paste to the fabric's interior.

The conditions of steam pressure and temperature, steaming time, as well as the use of saturated or reheated steam depend on the type of fibre, the dye used and the printing operation implemented. It is performed in chambers or autoclaves depending on whether the process is continuous or discontinuous.

Washing

The function of washing is to eliminate the thickening agent used and all other components of the printing pastes that are not fixed to the fabric, and the means of performing this depends on the following four factors:

- The printing system
- The type of dye
- Thickener
- Type of fabric

Polymerisation

The polymerisation operation, whose aim is to polymerise and cross-link the binders in the system of printing with pigments, consists of subjecting the printed textile in a hot air chamber to a temperature of 150-170° C for periods in the order of 5-6 minutes.

Sizing

The incorporation of chemicals that improve the characteristics of the fabric. For example, softening, waterproof qualities, fire-retardant qualities, etc.

4.4.4. Other printing processes

Spray printing

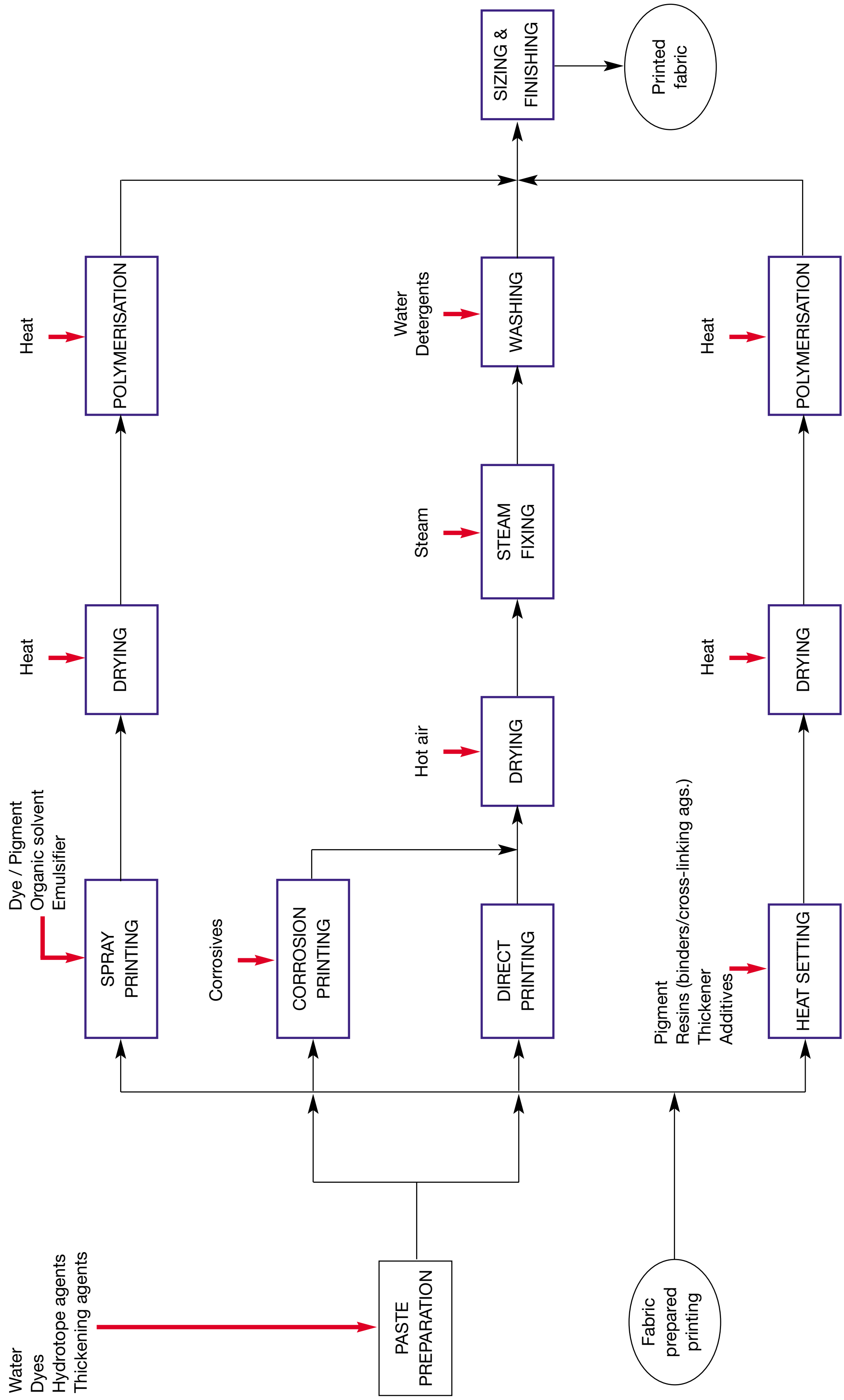
Spray printing is a subprocess of relatively recent application. It consists of the application of the dye or pigment onto the fabric by aspersion with compressed air (by means of a gun), using an aqueous solution or in the presence of low-viscosity organic solvents, through a stencil containing the design to be printed.

Following the application of the dye pigment, the print is air dried, which induces the replacement of aqueous formulas with others containing organic solvents which evaporate more quickly. The composition of the dye to be applied takes into account both the solvents used to fluidify the dispersion of the pigment and the resins that are necessary to bind the dye to the surface of the fabric.

4.4.5. Finishes of printed fabrics

Following printing, the same finishing processes as those used in the process of fabric dyeing may be performed.

Flow chart No. 8
FLOW CHART OF PRINTING & FINISHING PROCESS (FABRICS, KNITWEAR)



5. IDENTIFICATION AND DESCRIPTION OF WASTE FLOWS

The processes described in the previous chapter generate waste flows, which appear below in order of importance:

- Wastewater
- Waste
- Emissions into the atmosphere

Wastewater in general presents problems of colour, relatively high temperatures and high concentrations of BOD_5, COD, suspended solids, toxicity and conductivity. Its characteristics may present large variations due to the broad spectrum of dyes, pigments, auxiliary products and the processes used.

Both the wastewater and the other waste flows are analysed in this chapter according to their nature, and we present them as follows:

- Specific waste flows generated by the operations of the processes themselves
- Associated waste flows
- Other waste flows

5.1. MAIN WASTE FLOWS GENERATED BY THE PROCESSES

5.1.1. Dyeing of fibres and yarn

5.1.1.1. Cotton and blends (see Flow chart No. 9)

Wastewater

In the **scouring** operation, the water from rinsing and the bath itself has a high organic matter content and alkalinity, due to the detergents used in basic medium, which, in addition, include all impurities contained in the fibre itself such as waxes, fats, sodium salts and calcium salts.

Mercerising generates highly alkaline wash water, except if the alkaline traces that remain in the fibre are neutralised, and the wash water is then acid.

If anionic wetting agents have been used, they will be present in the wash wastewater. The exhausted bath, with high soda concentrations, is not mixed with the wash wastewater, but is recovered.

Wastewater that comes from the rinsing and the **bleaching** bath contain organic salts, traces of oxidising agents and optical bleaching agents. If chlorine or chlorine compounds are used for bleaching, volatile organochlorine compounds are formed in the water.

Wastewater from the rinsing of the **dye** and the exhausted dye bath in addition to traces of dye, contain auxiliary products used as seen in the table of Flow chart No. 1.

The mixture of all the water from baths and washes, which contains all the auxiliary materials, dyes and impurities from the fibres, means that the integrated wastewater from the cotton fibre dyeing operations has the following pollutant characterisation:

Table 9: Characterisation of cotton fibre dyeing wastewater

PARAMETER	RANGE OF CONCENTRATION
pH	10-12
COD mg/l	800-1,200
BOD_5 mg/l	200-400
Suspended solids mg/l	50-100
Colour mg Pt- Co/l	300-1,000
M.I. equitox/m^3	3-10
Conductivity µS/cm	3,000-6,000

The main pollutants are listed in table 25.

Waste

In **dye preparation** waste may be generated if excess dye has been prepared.

Emissions into the atmosphere

In **scouring,** alkaline vapour emissions are released into the atmosphere, which are given off in the boiling process, between 50 and 100° C.

In **dyeing** operations, volatile organic compound emissions are produced.

The **drying** operation produces the emission of water vapour and volatile organic compounds.

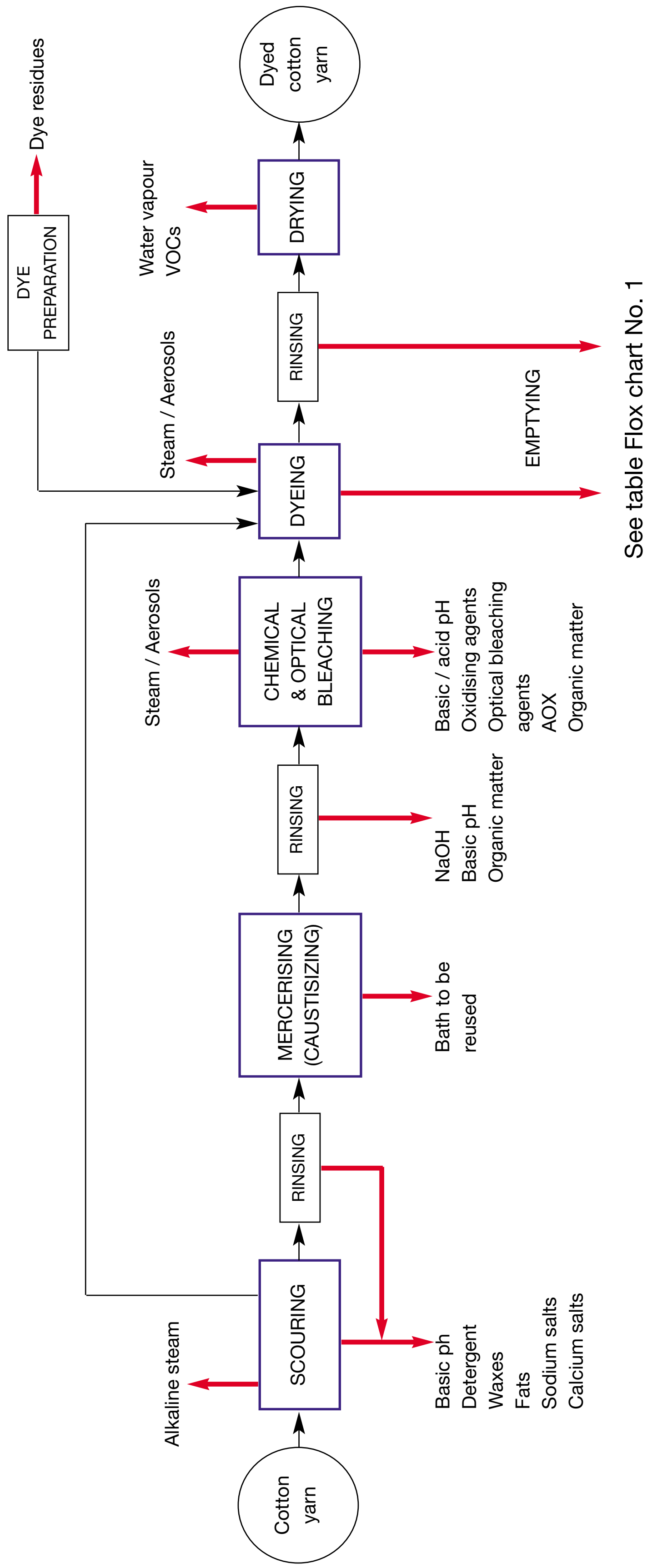
Table 10: Origin of wasteflows
Cotton fibre dyeing process

OPERATION	WASTEWATER	WASTE	EMISSIONS INTO THE ATMOSPHERE
Scouring	COD Alkalinity Dirt from fibres	—	Alkaline vapours
Scouring rinse	COD Alkalinity	—	—
Mercerising	Alkalinity (*)	—	—
Mercerising rinse	COD Alkalinity	—	—
Optical and chemical bleaching	Oxidising agents AOX COD	—	Vapours Aerosols
Dye preparation	—	Remains of dyes	—
Dyeing and rinsing	Colour COD (+)	—	Vapours Aerosols
Drying	—	—	Water vapour VOCs

(*) If soda is not reused
(+) See table Flow chart No. 1

Flow chart No. 9

FLOW CHART OF DYEING PROCESS FOR COTTON FIBRE & BLENDS



5.1.1.2. Wool and blends (see Flow chart No. 10)

Wastewater

The **special treatment** operation for combed yarns generates acid wastewater, with the presence of oxidising agents or reductive agents and, if chlorination is used, of organochlorine compounds.

The **degreasing** operation incorporates detergents and wetting agents into the rinse water, in addition to alkaline solutions of sodium carbonate and soap, and so the wastewater contains organic matter, basicity and conductivity.

Optical and chemical bleaching generates wastewater in accordance with the use of the reductive or oxidising process, including traces of optical bleaching agents if they are used.

In the **centrifuge** operation, wastewater has the same characteristics as the rinse water from the bleaching rinse.

In **dyeing** operations, in addition to the dye used, the auxiliary materials are present in the rinse wastewater, which may be seen in the table attached in Flow chart No. 2.

The incorporation of all of these auxiliary materials, from the preparation and wool yarn dyeing operations to contribute the following pollutant characteristics of the wastewater:

Table 11: Characterisation of wastewater from wool fibre and yarn dyeing

PARAMETER	RANGE OF CONCENTRATION
pH	10-12
COD mg/l	500-900
BOD_5 mg/l	150-300
Suspended solids mg/l	50-100
Colour mg Pt- Co/l	300-1,000
M.I. equitox/m^3	3-10
Conductivity µS/cm	3,000-6,000

The main pollutants are listed in table 25.

Waste

In **combing and spinning preparation** operations, remains of fibre and lint are produced.

In **dye preparation,** waste may be generated if excess dye has been prepared.

Emissions into the atmosphere

Vapours and aerosols are produced in the following operations:

- Special treatments
- Degreasing
- Optical and chemical bleaching
- Dyeing
- Drying

If gas chlorination is used in the **special treatment,** chlorine gas is emitted.

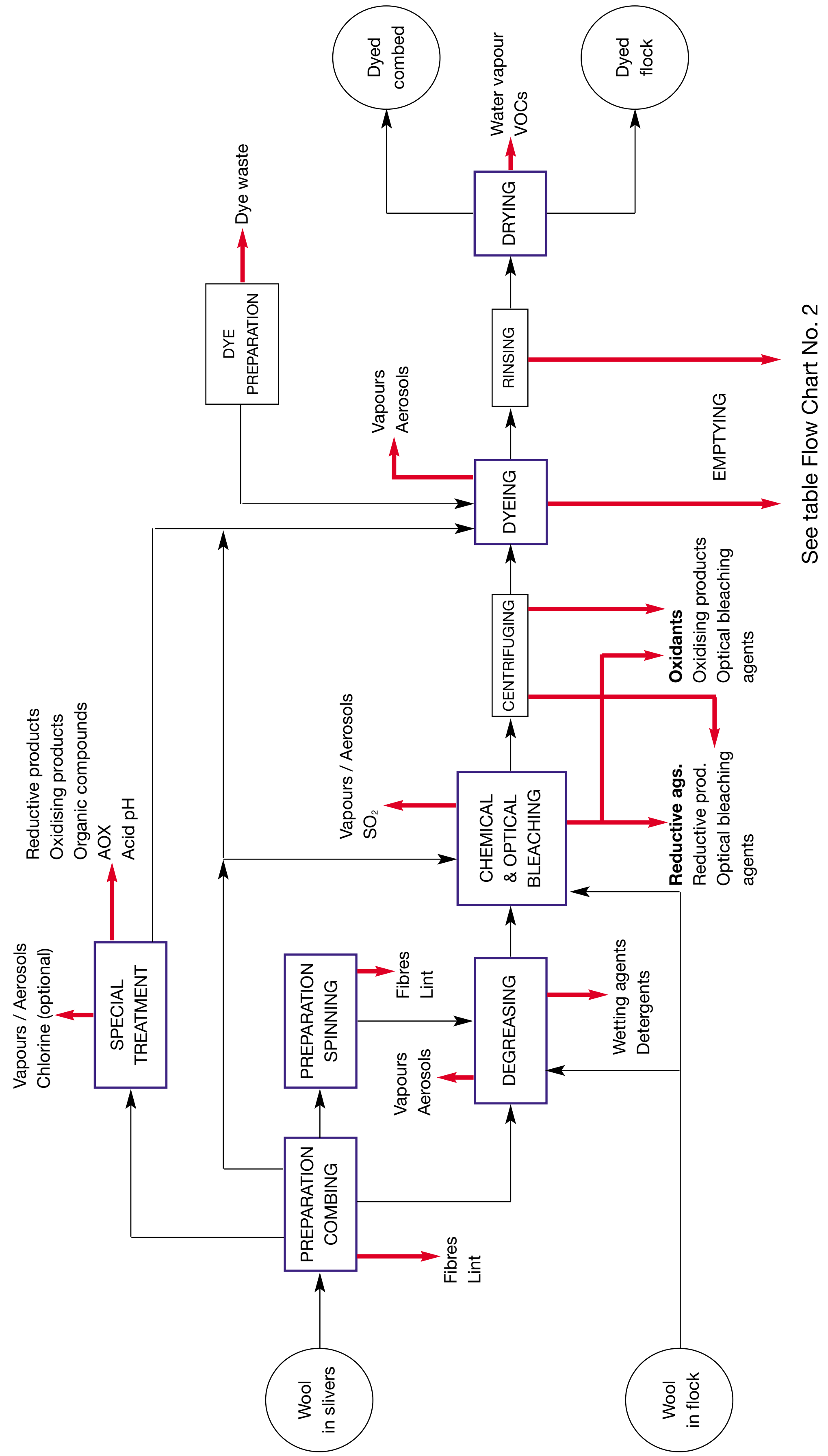
If the **bleaching** method is used by means of reductive agents, sulphur dioxide may be emitted, and the same is true of the **dyeing** operation if sulphur dyes are used.

Table 12: Origin of wasteflows
Wool yarn dyeing process

OPERATION	WASTEWATER	WASTE	EMISSIONS INTO THE ATMOSPHERE
Combing preparation	—	Fibres Lint	Fibres Lint
Spinning preparation	—	Fibres Lint	Fibres Lint
Special treatments	Acidity AOX(*) Oxidising / reductive agents COD	—	Vapours Aerosols Chlorine(*)
Degreasing	Basicity COD Conductivity	—	Vapours Aerosols
Optical and chemical bleaching	Oxidising / reductive agents COD	—	Vapours Aerosols SO_2(**)
Centrifuging	Oxidising / reductive agents COD	—	—
Dye preparation	—	Remains of dyes	—
Dyeing and rinsing	Colour COD (+)	—	Vapours Aerosols
Drying	—	—	Water vapour VOCs

(*) Chlorination treatment
(**) Bleaching using reductive agents
(+) See table Flow chart No. 2

Flow chart No. 10
FLOW CHART OF DYEING PROCESS FOR WOOL AND BLENDS FIBRES AND YARN



5.1.1.3. Cellulosics and blends (see Flow chart No. 11)

Wastewater

The **scouring, washing** and **bleaching** operations, under normal conditions, are not carried out as separate operations. In many cases, advantage is taken of the dyeing operation itself in order to eliminate the chemical fibre impurities. This is due to the fact that the fibres do not contain impurities given that they have already been synthesised by chemical reaction and, in any case, only contain fatty substances to enhance the mechanical process of spinning.

Scouring, washing or bleaching operations ought to be performed when, in the technician's opinion, it is essential as a consequence of accidental staining, yellowing through storage in improper conditions, etc.

The water from the **dye** rinse, in addition to the dye, contains auxiliary materials, according to the table of Flow chart No. 3.

The wastewater from cellulosic fibre dyeing operations has the following characteristics:

Table 13: Characterisation of wastewater cellulosic fibre dyeing

PARAMETER	RANGE OF CONCENTRATION
pH	10-12
COD mg/l	500-900
BOD_5 mg/l	150-300
Suspended solids mg/l	50-100
Colour mg Pt- Co/l	300-1,000
M.I. equitox/m^3	3-10
Conductivity µS/cm	3,000-6,000

Waste

In the **preparation of the dye,** waste may be generated if excess dye has been prepared.

Emissions into the atmosphere

Vapours and aerosols are produced in the following operations:

- Optical and chemical bleaching
- Dyeing
- Drying

Emissions of volatile organic compounds may also be produced.

Table 14: Origin of wasteflows
Cellulosic fibre dyeing process

OPERATION	WASTEWATER	WASTE	EMISSIONS INTO THE ATMOSPHERE
Scouring / washing and rinsing	COD Alkalinity	—	Alkaline vapours
Optical and chemical bleaching (*)	Oxidising agents COD	—	Vapours Aerosols
Dye preparation	—	Traces of dyes	—
Dyeing and rinsing	Colour COD (+)	—	Vapours Aerosols
Drying	—	—	Water vapour VOCs

(*) Only done for final white colour
(+) See table Flow chart No. 3

5.1.1.4. Synthetics and blends (see Flow chart No. 11)

Wastewater

Wastewater generated in the dyeing of synthetic fibres does not present any problem and pollutants may be assimilated by the cellulosic fibre dyeing water. Optionally, acetic acid is used with the rinsing of the **scouring** operation.

Waste

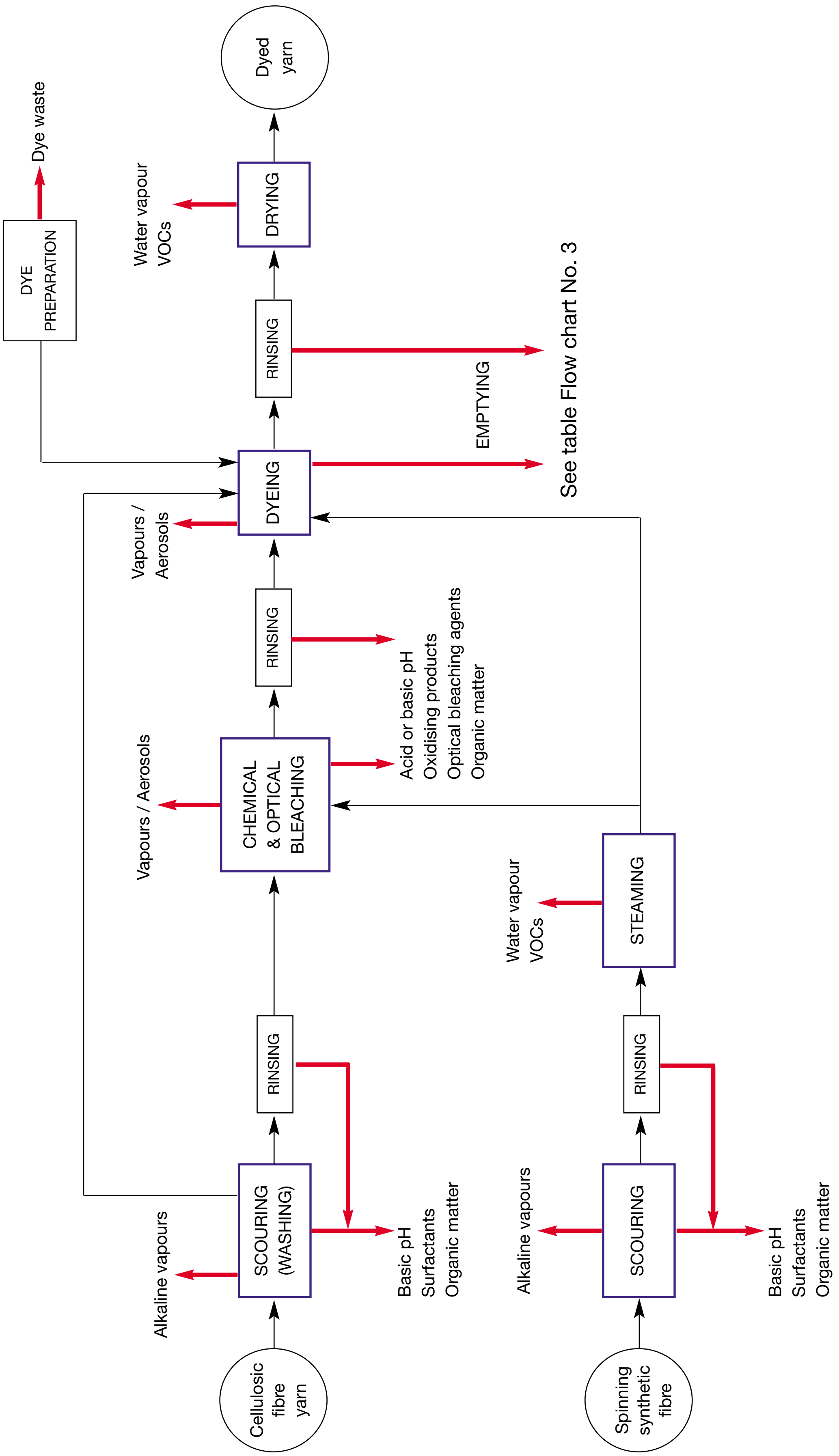
In the **dye preparation** operation waste may be generated if excess dye has been prepared.

Emissions into the atmosphere

Emissions are the same as in the process of dyeing cellulosic fibres. Additionally, there is a significant focus in the **heat setting** operation.

Flow chart No. 11

FLOW CHART OF CELLULOSIC / SYNTHETIC FIBRE DYEING PROCESS



5.1.2. Dyeing and finishing of fabrics

5.1.2.1. Cotton and blends (see Flow chart No. 12)

Wastewater

The **quenching and steaming** operation is one of the main sources of pollution in the later rinse water. Starch pastes are hydrolysed and incorporated into the wastewater in the form of organic matter.

The **scouring** operation also incorporates all of the impurities contained in the fabric into the water, consisting of waxes, fats, sodium and calcium salts, apart from the products used in the operation, such as caustic soda and detergents, and so the rinse wastewater is basic and has a high organic matter content and conductivity.

Mercerising and bleaching generate similar wastewater to that generated by these same operations in the process of dyeing cotton fibres (see chapter 5.1.1.1).

The procedure used in the **dyeing** of cotton fabrics depends on the type of dye used. In the table of Flow chart No. 4, there is a list of the pollutants used as auxiliaries that are incorporated into the wastewater. Although the pollutant load of the dye baths and later rinses is qualitatively equal, the concentration of the different pollutants is obviously far higher in the dye baths. In general, we may speak of high organic matter content, colour and conductivity. The pH may be basic or acid depending on the dyes used and in some cases, there may be metals.

Chemical finishing operations pass large quantities of products that are hardly biodegradable into the wastewater. Some products used, such as mothproofing treatment products, mildew-proofing products are similar to pesticides and biocides.

The characterisation of the wastewater generated by the dyeing and finishing of cotton fabric is as follows:

Table 15: Characterisation of cotton fabric dyeing and finishing wastewater

PARAMETER	RANGE OF CONCENTRATION
pH	10-12
COD mg/l	1,500-2,800
BOD_5 mg/l	400-900
Suspended solids mg/l	100-150
Colour mg Pt- Co/l	1,000-3,000
M.I. equitox/m^3	4-15
Conductivity μS/cm	4,000-9,600

The main pollutants are listed in table 25.

The dyeing and finishing of cotton fabrics generate wastewater with highest concentrations of organic matter (BOD_5 and COD) and also greatest coloration.

The **desizing** operation is responsible for 50%-75% of the pollutant load due to the organic matter of global effluents.

Another characteristic of wastewater is its alkalinity, with pHs of between 10-12. This is principally due to **desizing, mercerising, bleaching and dyeing** with reactive, vat and sulphur dyes.

Waste

In the **dye preparation** operation waste may be generated if excess dye has been prepared.

In **mechanical finishing** processes, fibre dust may be generated which, if collected by end-of-pipe filtration/cyclone systems, becomes a waste product.

Emissions into the atmosphere

The **singeing** operation generates combustion gases.

The **scouring and mercerising** operations, as in the cotton fibre and yarn dyeing process, emit basic and corrosive vapours into the atmosphere.

Heat setting, drying and finishing operations generate the emission of hydrocarbons, volatile organic products, since these operations may reach temperatures of 200º C. Here the most significant factor is the finishing vapours.

In the case of **mechanical finishing,** as has been previously mentioned, fibre dust may be generated.

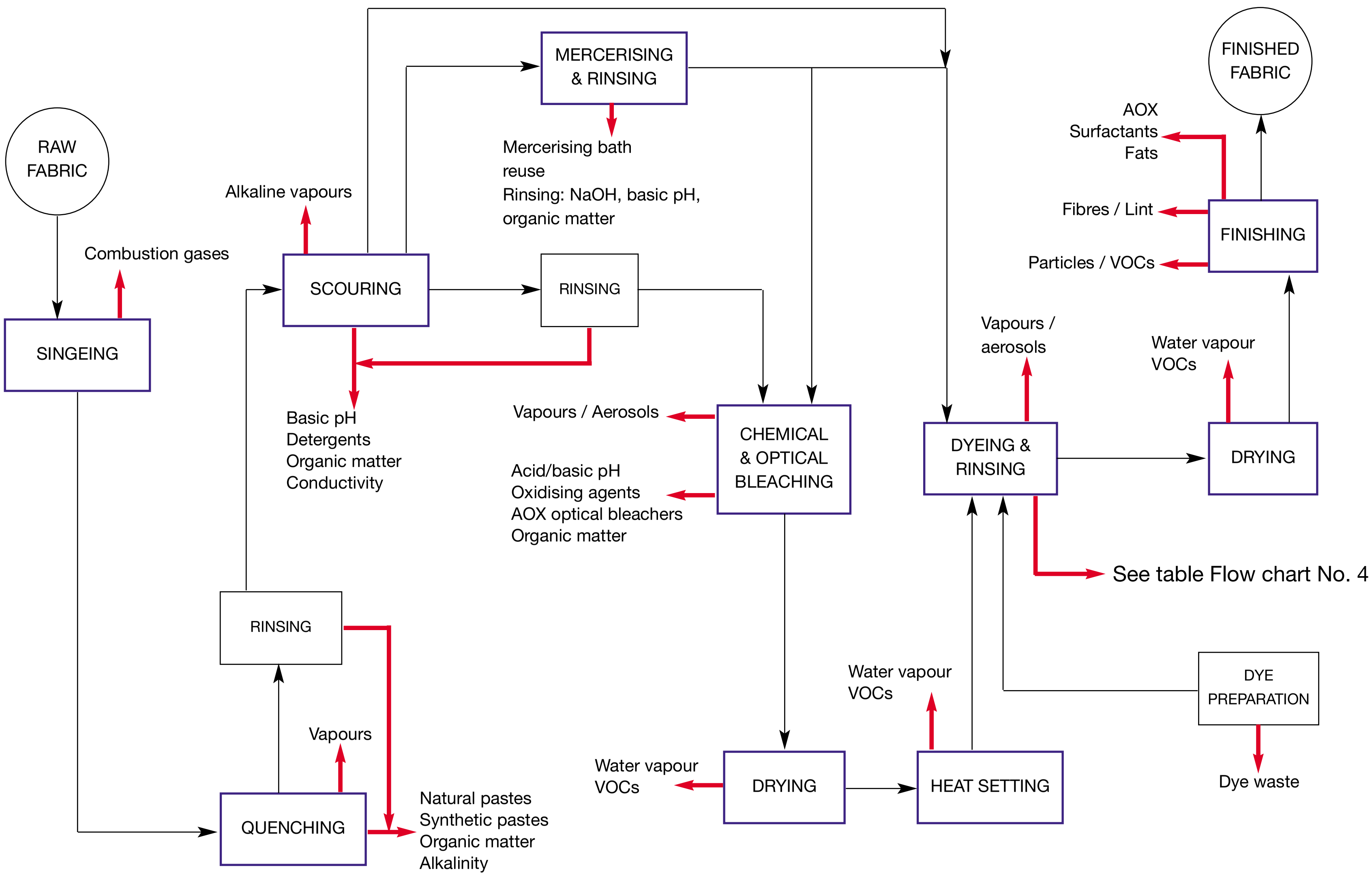
Table 16: Origin of waste flows
Cotton fabric dyeing and finishing process

OPERATION	WASTEWATER	WASTE	EMISSIONS INTO THE ATMOSPHERE
Singeing	—	—	Combustion gases
Quenching and steaming	COD BOD Alkalinity	—	Vapours
Scouring and rinsing	COD Alkalinity Dirt from fibres	—	Alkaline vapours
Mercerising and rinsing	COD Alkalinity	—	—
Optical and chemical bleaching	Oxidising agents AOX COD	—	Vapours Aerosols
Drying	—	—	Water vapour VOCs
Heat setting	—	—	Water vapour VOCs
Dye preparation	—	Remains of dyes	—
Dyeing and rinsing	Colour COD Alkalinity (+)	—	Vapours Aerosols
Drying	—	—	Water vapour VOCs
Finishing	High COD Low BOD_5 (*)	Fibres Lint	VOCs Fibre particles and dust

(+) See table Flow chart No. 4
(*) Specific pollutant load according to type of finish

Flow chart No. 12

FLOW CHART OF DYEING & FINISHING PROCESS FOR COTTON FABRICS & BLENDS



5.1.2.2. Wool and blends (see Flow chart No. 13)

Wastewater

Carbonisation generates acid water from the impregnation of the fabric and, later, basic wash water for the neutralisation of the fibres of the fabric.

The **chemical washing** of wool fabric and its rinsing produce wastewater, which, depending on the type of solution used, may be neutral or alkaline. This water also incorporates waste and foreign substances contained in the fabric.

The **solvent washing** operation in the most conflictive due to the discharge of tetrachloroethylene and trichloroethylene emulsified with water, which ends up in wastewater. These products are strictly regulated by some public administrations.

The **fulling** operation is done in acid medium, at pH 0.5. The later washing process, therefore, generates acid water.

The **bleaching** of wool fabrics generates the same effluents described in section 5.1.1.2 for the process of wool fibres and yarn.

Dyeing generates the same emissions and discharge that are specific to the dyes used. The auxiliary products that are transferred to the wastewater are listed in Flow chart No. 5. Singularly, the moth-proofing treatment finish, necessary for wool fabrics, is applied together with the dye and not at the end, as with the rest of the finishing processes. The products used are toxic and their active ingredients are similar to pesticides and biocides.

The **finishing** operation applied to woollen fabric includes mechanical finishing processes that are done dry and therefore, do not generate wastewater.

All of these operations mean that the wastewater generated in these processes has the following characterisation:

Table 17: Characterisation of wool fabrics dyeing and finishing wastewater

PARAMETER	RANGE OF CONCENTRATION
pH	6-7
COD mg/l	300-1,500
BOD_5 mg/l	250-500
Suspended solids mg/l	100-150
Colour mg Pt- Co/l	500-1,500
M.I. equitox/m^3	5-25
Conductivity µS/cm	2,200-3,000

The main pollutants are listed in table 25.

Normally, wool yarn and blends do not need sizing in order to obtain high weaving yield. Therefore the desizing operation should in general not be carried out before dyeing or finishing. Consequently, the effluents of this process have a lower organic matter content than the cotton fabric dyeing process.

The general characteristics of the effluents of this process are:

- A lower concentration of organic matter (COD and BOD_5) than in the cotton process
- Less coloration of effluents than that from the cotton process
- Effluent pH between neutral to slightly acid
- If moth-proofing finishes are given, there may be point concentrations of toxic products

Waste

The beating stage of the **carbonisation** operation collects the carbonised vegetable particles.

The **dye preparation** operation may produce surplus dye waste.

The **solvent washing** operation generates exhausted solvents that can be recovered by distilling. If these solvents are recovered at source, the distillation bottoms shall be generated as waste products.

Mechanical **finishing** operations generate fibres and lint.

Emissions into the atmosphere

Carbonisation produces combustion gases with acid vapour and drying produces gases containing volatile organic compounds.

As we have shown for the section on wastewater, in the **solvent washing** operation, organochlorine compounds are highly volatile and as a consequence, vaporisation into the atmosphere is produced.

Mechanical **finishing** operations generate fibres and fibre dust.

For remaining operations, the same gas emissions are generated as in the wool fibre dyeing process, according to section 5.1.1.2.

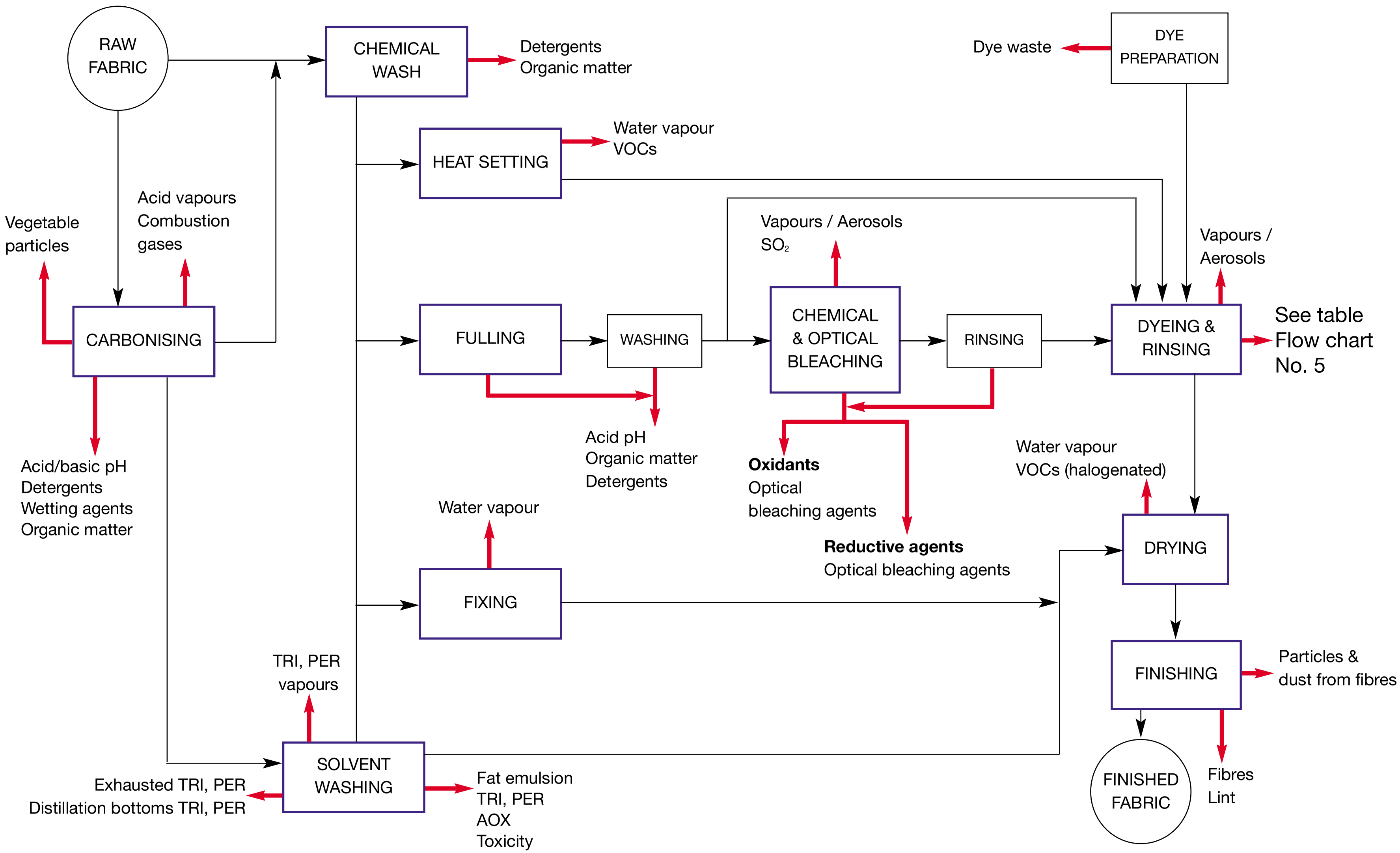
Table 18: Origin of waste flows
Wool fabrics dyeing and finishing process

OPERATION	WASTEWATER	WASTE	EMISSIONS INTO THE ATMOSPHERE
Carbonisation	Alkalinity/Acidity COD	Carbonised vegetable particles	Acid vapour Combustion gases
Chemical washing	Alkalinity COD Conductivity	—	—
Solvent washing	Fatty emulsions AOX (TRI, PER) Toxicity	Exhausted TRI, PER Distillation pastes TRI, PER	TRI, PER vapours
Heat setting	—	—	Water vapour VOCs
Fulling and washing	Acidity COD	—	—
Fixing	—	—	Water vapour
Optical and chemical bleaching	Oxidising / reductive agents COD	—	Vapours Aerosols SO_2 (*)
Dye preparation	—	Traces of dyes	—
Dyeing and rinsing	Colour COD (+)	—	Vapours Aerosols
Drying	—	—	Water vapour VOCs (halogenated)
Finishing	—	Fibres Lint	Fibre particles and dust

(*) Bleaching using reductive agents
(+) See table Flow chart No. 5

Flow chart No. 13

FLOW CHART OF DYEING & FINISHING PROCESS FOR WOOL FABRIC & BLENDS



5.1.3. Dyeing of knitwear

Depending on the type of fibres that make up the knitted fabric, the textile ennobling process can begin with washing operations in aqueous medium, or with heat treatment, generally in a stenter, with the aim of dimensionally stabilising the knitted fabric.

In the latter case, the most volatile components of the oils used for the manufacture of knitted fabric may give rise to fume emission. The engineer in charge of the processes is the person who shall take the decision as to which of the two techniques should be adopted, generally following laboratory tests.

In aqueous medium, these oils should be eliminated from the fabric by emulsifying processes, which implies the use of detergents and emulsifying products in an alkaline medium, antiredeposition agents, working temperatures of between 80 and 100° C and the pollution of wastewater.

5.1.3.1. Cotton and blends

Wastewater

Wastewater fundamentally comes from **bleaching** and **finishing,** for white knitted goods.

If colour dyeing is done, the pollution of effluents is lower than for the process of dyeing cotton fabrics, given that the desizing operation is not performed (knitwear does not require it).

All of these operations lead to the generation of wastewater in this process, with the following characterisation:

Table 19: Characterisation of cotton knitwear dyeing and finishing wastewater

PARAMETER	RANGE OF CONCENTRATION
pH	6-11
COD mg/l	600-800
BOD_5 mg/l	200-300
Suspended solids mg/l	50-120
Colour mg Pt- Co/l	500-1,500
M.I. equitox/m^3	4-10
Conductivity µS/cm	500-9,200

Waste

In **dye preparation** operations, surplus dye may be produced.

Emissions into the atmosphere

The emissions into the atmosphere caused by the processes of dyeing and finishing for cotton knitwear may be compared to those emissions caused by the dyeing and finishing process for cotton fabric (see section 5.1.2.1).

5.1.3.2. Wool and blends (see Flow chart No. 14)

Wastewater

Wastewater generated by the process of dyeing and finishing knitwear made of wool and blends is not very different from that generated by the process of dyeing for woollen fabric (see section 5.1.2.2). It may even be considered that they have lower pollutant load since, in this case, the carbonisation operation does not exist.

The wastewater from the rinsing process following the dyeing of knitwear incorporates the auxiliary products shown in the table of Flow chart No. 6.

Wastewater characterisation is as follows:

Table 20: Characterisation of wool knitwear dyeing and finishing wastewater

PARAMETER	RANGE OF CONCENTRATION
pH	6-11
COD mg/l	800-1,200
BOD_5 mg/l	200-400
Suspended solids mg/l	50-150
Colour mg Pt- Co/l	500-1,500
M.I. equitox/m^3	4-10
Conductivity µS/cm	500-9,200

The main pollutants are listed in table 25.

Waste

The waste products generated are similar to those generated in the process of dyeing wool fabrics (see section 5.1.2.2).

Carbonised fibre waste does not exist as carbonisation does not form part of this process.

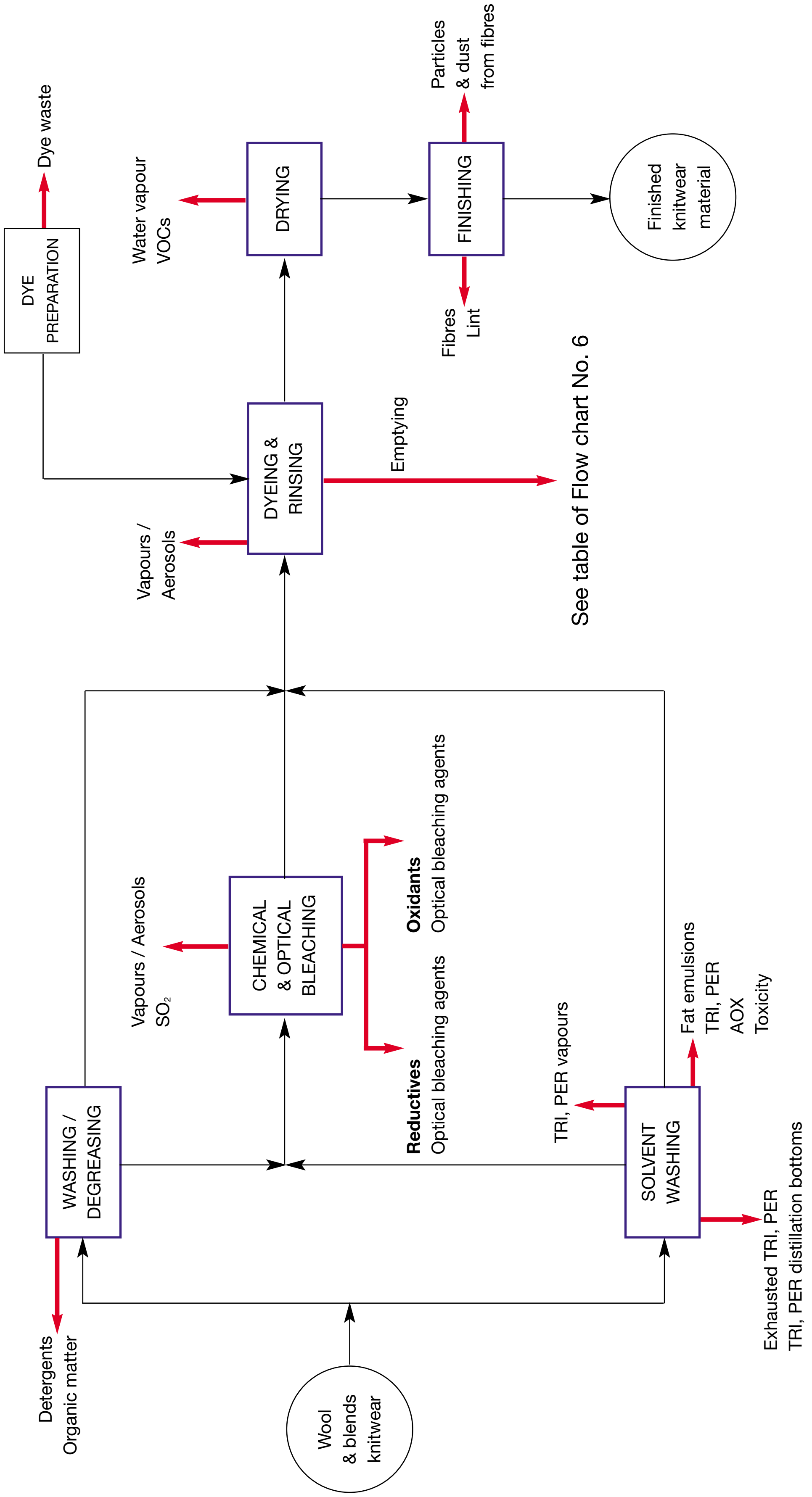
Emissions into the atmosphere

Emissions into the atmosphere are analogous to those generated in the wool fabric dyeing process, for the **washing, bleaching, dyeing, drying and finishing** operations.

It should be noted that carbonisation, heat setting, fulling and fixing operations, all generators of emissions into the atmosphere, are unnecessary.

Flow chart No. 14

FLOW CHART OF DYEING & FINISHING PROCESS FOR WOOL & BLENDS KNITWEAR



5.1.3.3. **Cellulosics and blends** (see Flow chart No. 15)

Wastewater

The wastewater generated from the dyeing process of cellulosic knitwear fibres contains a lower pollutant load than that of the wastewater from the process of dyeing wool and cotton knitwear. There are two reasons for this:

- The desizing operation does not exist.
- The cellulosic fibres and, in general, all fibres which are artificially obtained, have fewer impurities, and so the scouring operation causes less pollution.

The **scouring and bleaching** operations are similar to the cotton fibre dyeing process, and so, the same auxiliary products that remain in the wastewater are used.

The procedures implemented in the dyeing operation depend on the type of dye used. The table of Flow chart No. 6, shows the pollutants that come from the auxiliary products used.

Wastewater which is generated by the **finishing** operation, as we have commented in previous sections, incorporates the unused products left over from the finishing baths.

As a whole, the wastewater which is generated by these operations has the following characterisation:

Table 21: Characterisation of cellulosic knitted goods dyeing and finishing wastewater

PARAMETER	RANGE OF CONCENTRATION
pH	6-11
COD mg/l	800-1,200
BOD_5 mg/l	200-400
Suspended solids mg/l	50-150
Colour mg Pt- Co/l	500-1,500
M.I. equitox/m^3	4-10
Conductivity μS/cm	500-9,200

The main pollutants are listed in table 25.

Emissions into the atmosphere

They may be considered analogous to the emissions generated by the cotton fabrics and blends dyeing and finishing processes.

In knitwear made of blends of cellulosic fibres and synthetic fibres (polyester), subjected to **heat setting,** smoke is generated which is as a result of the oils used in the manufacture of knitted fabric.

Waste

In the **dye preparation** operation excess dye may be produced.

Mechanical finishing operations may generate remains of fibres.

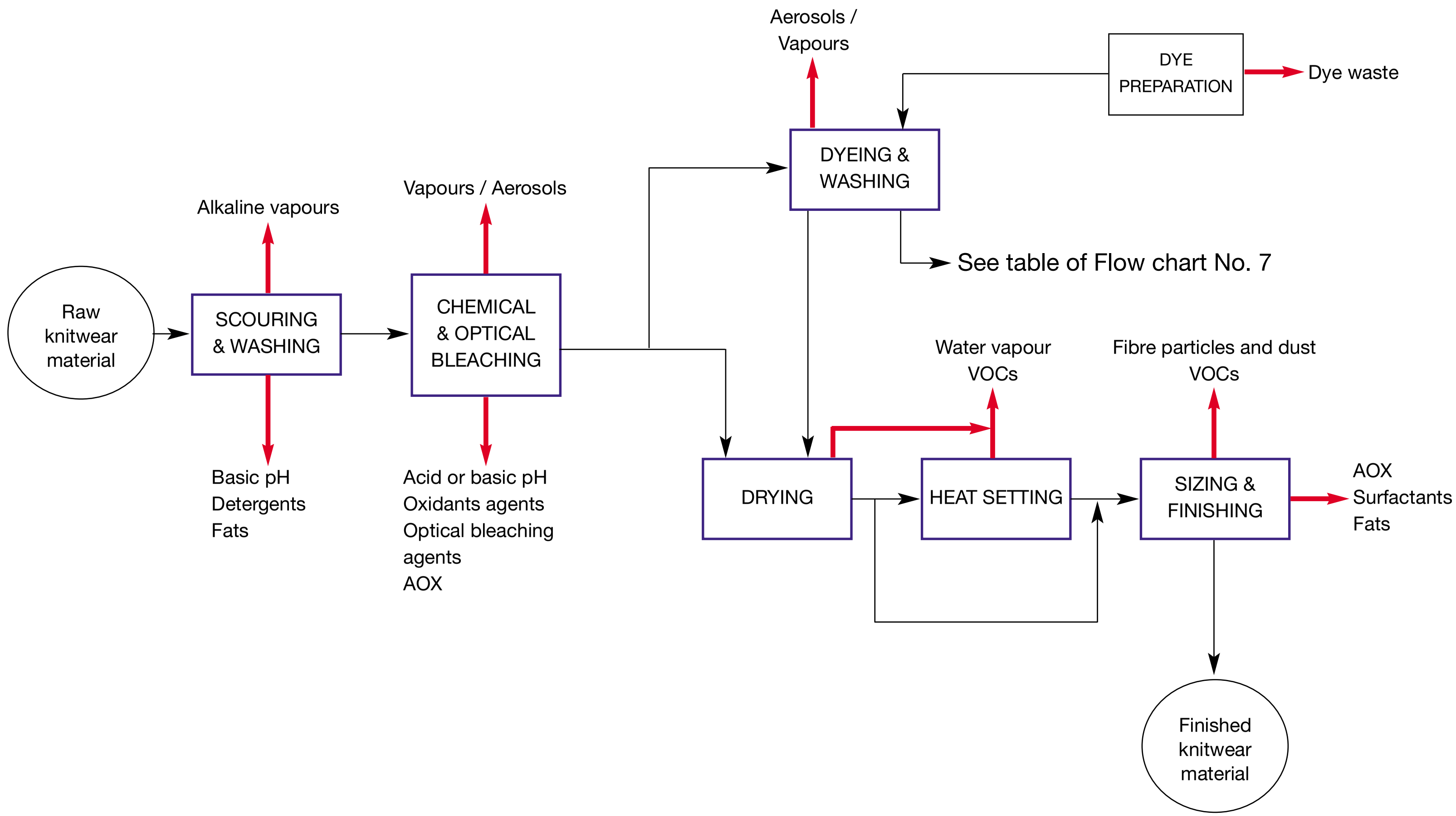
Table 22: Origin of wasteflows
Cellulosic knitwear and blends dyeing process

OPERATION	WASTEWATER	WASTE	EMISSIONS INTO THE ATMOSPHERE
Scouring and rinsing	COD Alkalinity	—	Alkaline vapours
Optical and chemical bleaching	Oxidising agents AOX COD	—	Vapours Aerosols
Dye preparation	—	Remains of dyes	—
Dyeing and rinsing	Colour COD (+)	—	Vapours Aerosols
Drying	—	—	Water vapour VOCs
Heat setting	—	—	Water vapour VOCs
Finishing	High COD Low BOD_5 (*)	Fibres Lint	VOCs Fibre dust & particles

(*) Specific pollutant load according to type of finish
(+) See table Flow chart No. 7

Flow chart No. 15

FLOW CHART OF DYEING & FINISHING PROCESS FOR CELLULOSICS AND BLENDS



5.1.4. Printing and finishing of fabrics and knitwear

The processes of printing and finishing of fabrics and knitwear can be seen in graphic form in Flow chart No. 16 and they use the same type of operations for all types of fibre (cotton, wool, cellulosic and synthetic fibres).

Wastewater

Corrosion printing generates waste products that may include metals, colouring agents and organic matter (according to the procedures).

In **direct and pigment printing,** moreover, water-oil emissions have been gradually reduced. The predominant process is direct printing with pigments.

Regarding the characteristics of **finishing** operations that may take place following printing, they are considered analogous to those operations carried out in dyeing facilities, for the different types of apparel and fibres.

The characterisation of the wastewater generated by the printing process is as follows:

Table 23: Characterisation of printing and finishing wastewater

PARAMETER	RANGE OF CONCENTRATION
pH	6-9
COD mg/l	350-2,300
BOD_5 mg/l	80-750
Suspended solids mg/l	120-530
Colour mg Pt- Co/l	(*)
M.I. equitox/m^3	2-20
Conductivity µS/cm	1,000-8,000

(*) data not available

The main pollutants are listed in table 25.

Waste

The most common waste products are print paste remains, which are prepared in excess or for the making of samples.

Emissions into the atmosphere

In **spray printing,** highly concentrated volatile solvent emanations are produced in the drying process due to the use of highly volatile solvents in order to accelerate the operation.

In **corrosion printing** emissions of volatile organic compounds are produced in the drying, steaming and washing operations.

In **pigment printing** emissions into the atmosphere of volatile organic compounds are also produced in the drying and polymerisation operations.

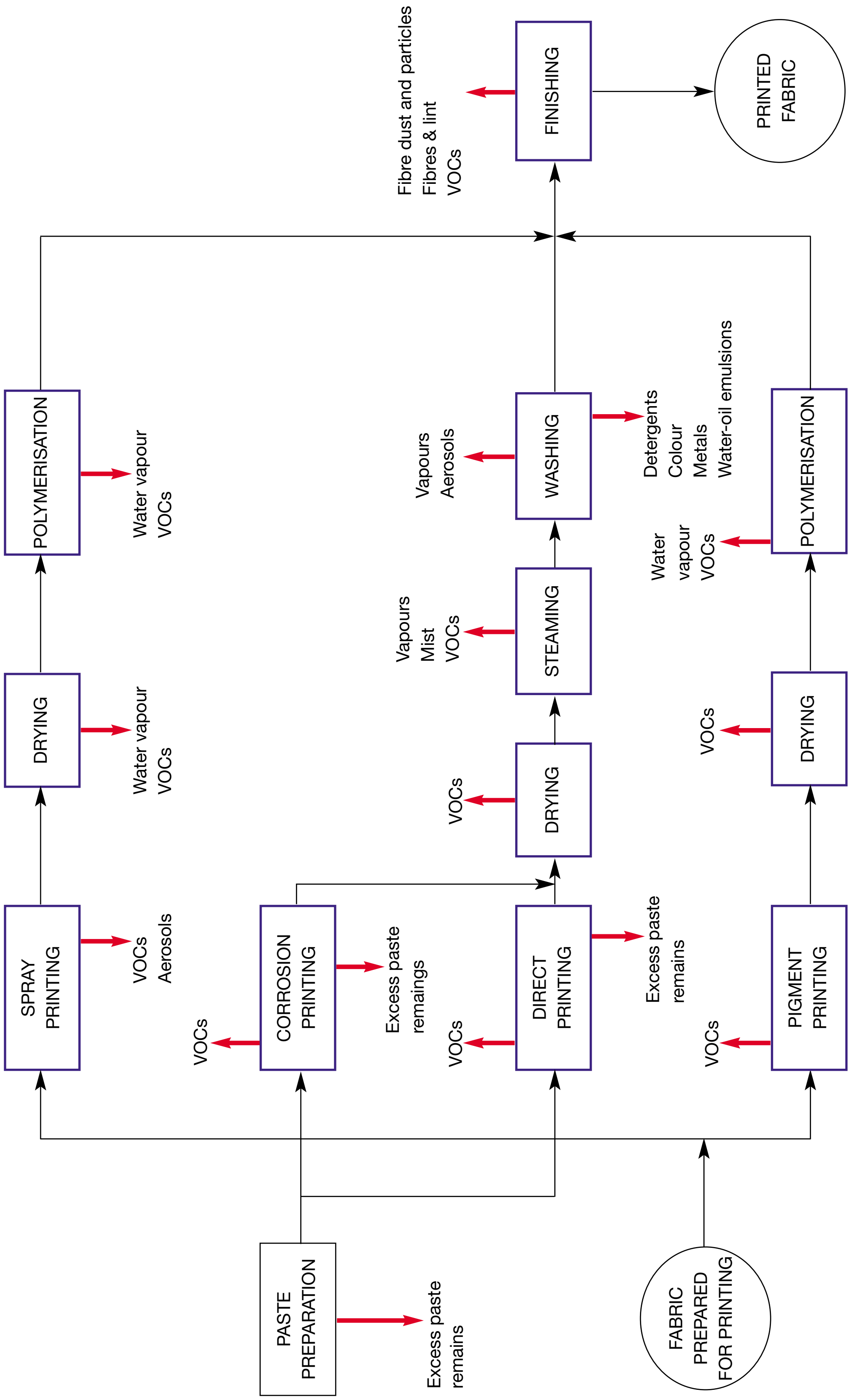
Table 24: Origin of wasteflows
Knitwear finishing and printing process

OPERATION	WASTEWATER	WASTE	EMISSIONS INTO THE ATMOSPHERE
Paste preparation	—	Paste remains	—
Spray printing	—	—	Aerosols VOCs (solvents)
Corrosion	—	Paste remains	VOCs
Direct	—	Paste remains	VOCs
Pigment printing	—	—	VOCs
Drying	—	—	VOCs
Steaming	—	—	Vapours VOCs
Washing	COD Colour Metals (*) Water-oil emulsions (**)	—	Vapours Aerosols VOCs
Polymerisation	—	—	Water vapour VOCs
Finishing	High COD Low BOD_5 (***)	Fibres Lint	VOCs Fibre dust particles

(*) Corrosion printing
(**) Direct printing
(***) Specific pollutant load according to finish

Flow chart No. 16

FLOW CHART OF PRINTING & FINISHING PROCESS (FABRICS, KNITWEAR)



5.2. MAIN ASSOCIATED WASTE FLOWS

5.2.1. Wastewater

In the dyeing, printing and finishing processes, there are some operations exist that are not directly linked to the production process, but that become essential for the sequential development of production.

Although attempts are usually made to perform processes in stages or grouping together the types of dyes and colour of dye in order to minimise “down times” due to stoppages for cleaning and maintenance of the machinery, cleaning operations and the fine-tuning of the facilities cannot be totally eliminated. These operations are usually carried out using water, detergents and cleaning products.

This cleaning, usually employing water and detergents, is performed on:

• The fixed machinery, that is to say, large machinery, in general.

• Normally transportable accessories, such as: moulds, trays, bobbins, roll stands, etc.

The cleaning of accessories may be done in a more automatic procedure with automatic washing systems, brushes, scrapers, etc.

Some cleaners incorporate industrial solvents and organochlorine compounds into their active ingredients in order to boost their cleaning power on remains of dyes and printing pastes.

Cleaning wastewater contains remains of dyes, pastes, fibres, lint, detergents and cleaning solvents.

No reliable data are available on volumes and characterisation of such wastewater.

5.2.2. Waste

The waste products not specifically generated by the processes respond to the most common waste flows, and may be classified as generic or repeated waste from all processes.

There is a wide range of such waste products, which we identify below:

• Obsolete (out of fashion) and out of date dyes
• Wooden pallets
• Paper sacks
• Containers for bulk products
• Metal drums
• Plastic bags and drums
• Cardboard boxes
• Metal rings
• Yarn cones (broken or discarded)

- Dye trays and supports (broken or discarded)
- Used oils and lubricants
- Exhausted cleaning solvents
- Plastic and paper packaging waste
- End products that do not meet specifications
- Rejected textile raw materials
- Spilled solid/liquid products.

There are no data on the bibliography concerning the quantities of these waste products, generated, which, to a large extent, depend on the production capacity, the different processes that are carried out and the nature of the waste products.

5.2.3. Atmospheric emissions

Cleaning with solvents

As we commented in point 5.2.1, operations exist that are not linked directly with the production process, but which become essential in order to develop continuous production.

This is the case for some cleaning done with solvents, which constitute sources of diffuse origin emissions.

These solvents and degreasing agents are used for cleaning printing machines, specifically in the print injectors and other parts which are in contact with dyes, pigments and printing pastes. Also in some dyeing equipment.

Storage of end products

Textiles stored can, in some cases, emit volatile compounds due to their use in the operations to which they have been subjected and the residual presence in manufactured products, especially auxiliary materials, with which the textile products are impregnated.

5.3. OTHER WASTE FLOWS

Although the description of processes has been exclusively limited to direct production processes of dyeing, printing and finishing, some general facilities exist at textiles factories that are necessary for the normal functioning of those processes.

These general facilities or support facilities generate, in turn, waste flows that must also be considered.

5.3.1. Wastewater

Water for supply purposes, used in dyeing, printing and finishing, whether it comes from supply companies, surface catchment or wells, has some conditioning factors regarding its quality and therefore, requires the appropriate treatment.

Such treatment usually includes:

- Elimination of iron and manganese
- Elimination of suspended solids
- Elimination of hardness
- Elimination of salinity

These treatments generate the following wastewater:

- Wastewater from the washing of filters in order to eliminate suspended and precipitated solids.

- Water for the regeneration of the ionic exchange resin beds, or saline rejects from inverse osmosis (if available). In both cases with high conductivity.

The cooling circuits must be purged periodically in order to eliminate concentrations of salt. These purged liquids are eliminated by being incorporated into the wastewater, which increases its conductivity.

The water circuits of the steam boilers must be purged and cleaned, including the steam drums. Apart from the concentrations of salts, basicity and silica from the purging itself, descalers are used for the cleaning of circuits. All of this maintenance operations generate wastewater, containing these products.

5.3.2. Waste

The main source of waste generation from auxiliary facilities is sludge from the wastewater treatment plants.

Lastly, all water treatment previously indicated generates:

- Sludge and sediment from chemical precipitations and mechanical separations (sedimentation, filtration)

- Sludge Remains of containers of products used in such treatment

5.3.3. Atmospheric emissions

The main focal point of the generation of emissions into the atmosphere is the boilers that generate steam.

Wastewater treatment plants (of the aerobic biological or activated sludge types) also generate emissions of volatile organic compounds contained in the wastewater from the dyeing and printing processes.

5.4. MAIN POLLUTANTS IN WASTEWATER

A generic list of the main chemical compounds that can be found in the wastewater of any dyeing, printing and finishing operation is included.

Table 25: Substances that are potentially present in wastewater

SUBSTANCE	DYEING OF COMBED & SPUN YARN			DYEING & FINISHING OF FABRICS		DYEING & FINISHING OF KNITWEAR		PRINTING
	Cotton	Wool	Synthetics	Cotton	Wool	Wool	Cellulosics	
Soaps	X	—	—	X	X	X	X	—
Anionic detergents	X	X	X	X	X	X	X	—
Non-ionic detergents	X	X	X	X	X	X	X	—
Sodium carbonate	—	X	—	X	X	X	—	—
Sodium chloride	X	X	X	X	X	X	X	—
Sodium sulphate	X	X	X	X	X	X	X	—
Fats and oils	X	—	X	X	—	—	X	—
Vegetable impurities	X	—	—	X	—	—	—	—
Starch	—	—	—	X	—	—	—	—
Carboxymethylcellulose	—	—	—	X	—	—	—	—
Methyl cellulose	—	—	—	X	—	—	—	—
Vinyl polyalcohol	—	—	—	X	—	—	—	—
Polyacrylamides	—	—	—	X	—	—	—	—
Polyesters	—	—	—	X	—	—	—	—
Wetting agents	X	—	—	X	—	—	X	—
Softeners	X	—	X	X	—	—	X	—
Nitrogenated compounds	X	—	—	X	X	X	X	X
AOX	X	X	X	X	X	X	X	—
Sodium hypochlorite	X	—	X	X	—	—	X	—
Sodium chlorite	X	—	X	X	—	—	X	—
Optical bleaching agents	X	X	X	X	X	X	X	—
Sulphites	X	X	X	X	X	X	X	—
Bisulphites	X	X	X	X	X	X	X	—
Dyes	X	X	X	X	X	X	X	X
Pigments	—	—	—	—	—	—	—	X
Copper	X	—	—	X	—	—	X	—
Chrome	X	X	—	X	X	X	X	X
Formaldehyde	X	—	—	X	—	—	X	—
Acetic acid	X	X	X	X	X	X	X	—
Naphthol	X	—	—	—	—	—	—	—
Aromatic amines	X	—	—	X	—	—	—	—
Formic acid	—	X	X	X	X	X	X	—
Nickel	—	X	—	—	—	—	—	—
Cobalt	—	X	—	—	—	—	—	—
Phosphates	—	—	X	X	X	—	X	—
Phenoles	X	X	X	X	X	—	—	—
Sulphurs	X	—	—	X	—	—	X	—
Trichloroethylene	—	—	—	—	X	X	—	—
Perchloroethylene	—	—	—	—	X	X	—	—
Titanium dioxide	—	—	—	—	—	—	—	X
Iron	—	—	—	—	—	—	—	X
Aluminium	—	—	—	—	—	—	—	X

6. POLLUTION PREVENTION OPPORTUNITIES

Below we present the most relevant opportunities for preventing pollution, which are classified according to the following breakdown:

OPPORTUNITIES FOR REDUCTION AT SOURCE
- Redesigning of products
- Redesigning of processes
  - Substitution of raw materials
  - New technologies
  - Good housekeeping practices

OPPORTUNITIES FOR RECYCLING AT SOURCE

OPPORTUNITIES FOR WASTE RECOVERY
- External recycling
- Energy recovery

Those sections in which no clear opportunities for pollution prevention have been detected will not be included.

It should also be highlighted that some of the opportunities described could be classified in more than one of the previously mentioned categories. In each case, the most appropriate location has been chosen.

6.1. OPPORTUNITIES FOR REDUCTION AT SOURCE

REDESIGNING OF PROCESSES

6.1.1. Substitution of raw materials

6.1.1.1. Choice of new ranges of reactive dyes

Traditional problem

Reactive dyes are one of the most frequently used families of colouring agents for the dyeing of cotton, rayon and linen fabrics. Due to its inherent chemical characteristics, only part of the dye that is introduced into the dye bath reacts chemically with the fibre by means of a covalent bond. The rest of the dye reacts with the water and is known as hydrolysed dye. A part of the latter remains in dye wastewater and another part remains inside the fibre but without good fastness properties and so it had to be removed in successive warm soapings and rinses.

This meant that a dye containing reactive dyes required the consumption of water for:

1. dye bath
2. warm soaping bath
3. rinsing bath
4. rinsing bath

As an example, a machine for the dyeing of 100 kg of yarn holding 1,000 litres of water meant the consumption of 4,000 l for the correct dyeing of the 100 kg of fabric.

Alternative products

In order to provide a response to the current requirements concerning:

• New standards of domestic washing fastness
• Compliance with the legislation on dumping
• An increase in “right first time” production efficiency
• The use of low bath ratio machinery, and heat recovery systems

New ranges of reactive dyes have been designed:

1. They exhaust more onto the fibre (with this, less dye remains in the dye water).

2. Each molecule of dye contains more reactive groups and so the percentage of dye to react with the fibre is considerably higher (thus lowering the amount of hydrolysed reactive dye, both in the bath and within the fibre).

3. The reactive hydrolysed dye within the fibre is more easily removed (and thus the number of washing baths will be reduced).

4. They combine two or more chromophore groups in each dye molecule in order to obtain high optical density using the same concentration of dyes as in the old ranges. Therefore, the dye concentration increases (and so transport costs are reduced). According to the dyes that are compared, at equal concentrations of the solution, the optical density is between 15 and 65% greater. With new dyes, the same colour intensity is achieved on fabric with a lower % of dye on the fibre weight.

5. They can be applied by reducing the concentration of the electrolyte necessary in the dye bath. This means a reduction in the wastewater pollutant load. It also reduces the cost of the chemical products in the dye formula. For 3% owf dye intensity, with the new dyes, 60 g/l of salt are needed. This represents a 34% reduction compared to traditional formulas.

6. An increase in the adsorption of the dye in the activated sludge of the treatment works, if one is available. Depending on the water hardness, between 150 and 200% more is absorbed into the Wastewater Treatment Plant’s activated sludge compared to the reactive dyes of the old ranges.

Field of application

The new ranges of reactive dyes can be applied in the same machines as traditional reactive dyes. The strong points of this type of dye are the discontinuous dyeing processes or dyeing processes in batches of cellulosic fibre yarn, fabrics made from cellulosic fibre in rope form, and also open-width both in the discontinuous and continuous processes.

Production benefits

The lower the number of washing baths, the greater the increase in productivity of the industrial dye facilities.

Moreover, as has already been described, the following are achieved:

- Lower dye consumption to obtain the same dying results
- Lower consumption of chemical products (electrolyte)

Environmental benefits

Dye wastewater is less coloured with a lower soluble salt content, and the waste dyes are more easily absorbed in the Wastewater Treatment Plants' activated sludge. This facilitates the treatment process.

Economic parameters

As has already been said, a reduction in costs of the chemical products of the dye formula is achieved, as well as transport costs.

Bibliography

- Bradbury, Collishaw, Moorhouse (Dystar), *"Desarrollos en la tecnología de colorantes reactivos"*, Revista de Química Textil issue 153, pp. 75-83 (2001).

- Douthwaite, F. *"Novel series of reactive dyes"*, International Dyer, August 2001, pp. 41-42.

6.1.1.2. Substitution of conventional lubricants with hydrosoluble oils in the manufacturing of knitted fabric

Traditional problem

The production of knitted fabrics requires the efficient lubrication of the mechanical elements of the knitting machine and the needles. The yarn which passes through the needles during the process of fabric manufacturing drags and retains part of the lubricants which then "spray" against the needles and the beds.

Knitted fabric may contain up to between 4 and 8% of its weight in lubricating oil used in weaving.

According to the type of fibre that make up the knitted fabric, and the type of weave, the process of textile ennobling may be begun by washing operations in an aqueous medium, or by heat treatment operations, generally in a stenter, with the aim of dimensionally stabilising the knitted fabric. In the latter instance, the oil's most volatile components may give rise to smoke emission. The engineer in charge of the processes is the person who should take the decision as to which technique to use, generally after laboratory tests.

In an aqueous medium, these oils should be eliminated from the fabric through emulsion processes, which implies the use of detergents and emulsifying products in an alkaline medium, antiredeposition agents, working temperatures of between 80 and 100° C and the pollution of wastewater.

Water consumption is approximately 10 litres per kilo of fabric, the process takes between 30 and 60 min, and washing temperature must be in the region of 100° C.

Alternative products

The substitution of old lubricating oils which are non-biodegradable and non- self-emulsifying with new lubricants of a self-emulsifying nature for the manufacturing of knitted fabric, means that it can be eliminated from fabric in water at a temperature of 40° C, which means that scouring and bleaching can be done on the fabric in a single operation, (in just one bath performing the two operations, or, depending on each case, in just one bath but first performing the scouring and then the bleaching) with the consequent saving of time spent in the machine, a saving in the process time, water consumption and energy savings.

Traditional:

WASH → SCOURING AND BLEACHING

Proposed alternative:

SCOURING AND BLEACHING

Field of application

This technique may be applied to the weaving mills that are already working. Sometimes it may be necessary to substitute the oil conduits in the interior of the knitting machine. In some cases, depending on the types of paint, the machines may get damaged.

Production benefits

The production benefits are not obtained in the weaving company, but rather in the later operations of preparation, bleaching, dyeing, etc. and the following are achieved:

- A reduction in washing time
- A reduction in washing temperature
- A reduction in the process time since in just one operation, the fabric can be washed, scoured and bleached
- An increase in productivity

Environmental benefits

- An important reduction in water consumption
- An important reduction in energy consumption

Economic parameters

The cost involved in implementing this technique is no greater than that of the previous technique if all economic parameters to be taken into account are considered, that is, from the cost of the new oils, which is undoubtedly greater, to the washing costs, which are lower, and the costs of treatment which are also seen to be reduced. It may be hoped that in the future, the percentage of oil contained in the knitted fabric may be reduced when manufactured in state-of-the-art generation machinery, with which yet greater savings will be made.

6.1.1.3. Substitution of surfactants with biodegradable surfactants

Traditional problem

In the textiles industry, surfactants are consumed in practically all processes from the preparation and bleaching stage to the finishing of fabrics. After the dyeing and printing processes, habitually the fabric is subjected to one or several washes in which surfactants are used as washing agents, which often cause problems of pollution in wastewater due to the presence of foam and deficient biodegradability.

Alternative products

The aim consists in replacing conventional surfactants with others giving by 80-90% biodegradability after 24 hours, that generate a lower COD, have a high dispersing power and very low foaming power.

The new washing formulas imply incorporating a concentration of the new product, which is similar to the traditional formulations, into the treatment baths. Naturally, the concentration of biodegradable surfactant used in each case depends on the type of fabric, the type and quantity of impurities to be eliminated, and the system of machinery, at the temperature and time which are appropriate to the characteristics of the final product.

Field of application

In the textiles industry, surfactants are consumed in practically all processes, from the preparation and bleaching stage to the finishing of the fabric. The new surfactants can be applied in all available facilities.

Production benefits

The production parameters are kept in the same order as with the previous surfactants.

Environmental benefits

In this way, an increase in the efficiency of the wastewater treatment plants is achieved. In addition, the biodegradable surfactants reduce the risk of alterations to the hormonal system of fish.

Economic parameters

Despite the fact that the new biodegradable surfactants are significantly more expensive than the previous ones, the good management of the wastewater treatment plant recommends the implementation of this technique.

Some Spanish companies have already begun to work with biodegradable surfactants, and it is noted that the higher price of these products may be compensated by the greater efficiency of the wastewater treatment plant, leading, therefore, to a favourable final balance, both from the environmental and the economic view point.

Bibliography

- *Sturm test (OECD 301 B)*
- *Technical Information provided by Bayer, Basf, Color Center S.A., Tenycol S.A.*

6.1.1.4. Replacement of the afterchroming wool dyeing process with the dyeing process using reactive dyes

Traditional problem

The dyeing of yarn or woollen fabric with chromed dyes and afterchroming allows good final fastness of the dye. However, this process has some serious disadvantages:

- Production is carried out in two stages
- Inevitably, the wastewater contains heavy metals (e.g. chrome)
- The final colour of the dye not only depends on the dyeing process with the acid dye but also on the afterchroming process

Alternative products

An alternative exists which is based on the application of the reactive dyes for wool, which do not contain heavy metals, give excellent final fastness and are applied in a single operation.

Field of application

Machinery which is suitable for dyeing yarn or woollen fabric is adequate for this new dyeing process.

Process benefits

- A reduction in dyeing time
- A reduction in the dyeing temperature
- Greater safety in the final shade of the dye

Environmental benefits

The elimination of the heavy metals in wastewater.

Economic parameters

- Greater productivity of the dyeing facilities
- More possibilities for the automation and robotisation of the dyeing processes

6.1.1.5. New selected sulphur dyes

Traditional problem

Sulphur dyes are widely used throughout the world for the dyeing of cellulosic fibres. The traditional dyes, generally low cost dyes, contain a high concentration of impurities such as salts, sulphur and polysulphides. They are usually present in relatively low concentrations and give a low dyeing yield (that is to say that in order to achieve intense shades, large amounts of dye must be added to the bath).

These are dyes with low exhaustion and, therefore, the wastewater which is generated remains coloured to such an extent that the dyes are only economical when the bath is reinforced and reused for successive dyeing.

Alternative products

The new sulphur dyes offer improvements compared to the traditional ones. The main improvements are:

- They are practically free of sulphur and polysulphides

- An increase of between 100 and 150% of the concentration at which they may be acquired.

- The use of binary systems of reductive agents, replacing the traditional systems based on sodium sulphide in an alkaline medium, which give very good results, both from the technical and the environmental points of view. The main binary systems of reductive agents are:

- Glucose + hydrosulphite
- Glucose + hydroxicetone
- Glucose + formamidine-sulphinic acid
- Glucose + hydroxymethane sulphinic acid

Field of application

The new sulphur dyes are adequate both for discontinuous and continuous system dyeing and are applicable in the same industrial facilities in which the old ones were applied.

Process benefits

With the new dyes, the productivity of the industrial facilities may increase.

Environmental benefits

The use of these new sulphur dyes allows:

- A reduction in the generation of empty dye containers which must be handled, and transport costs
- The minimisation of SO_2 emissions into the atmosphere
- A reduction in water consumption
- A reduction in the pollutant load of the effluents generated in the dyeing process and subsequent washes, which present far lower quantities of sulphurs and polysulphides, reductive chemical species that significantly contribute to the COD

Economic parameters

The use of these new sulphur dyes allows for the reduction in waste handling costs as well as the costs of wastewater treatment.

Bibliography

- *Technical information supplied by Clariant Ibérica S.A. Diresul RDT concentrado.*
- *Revista de Química Textil issue 113,* 1993, pp. 74-86.

6.1.1.6. New oxidising system for dyes made with sulphur dyes

Traditional problem

Oxidation is an unavoidable stage in the process of dyeing with sulphur dyes. Oxidation produces a change in the colour of the dye molecule and insolubilises it within the fibre.

The use of oxidising systems based on bromates, iodates and chlorites is common, which, due to the presence of halogens, produce AOX indices above the legal limits in the wastewater generated by the process.

Though they may generally be considered as being out of use, this oxidation may also be carried out with dichromate-based oxidising systems, which generate the presence of heavy metals in water.

Alternative products

The use of peroxides instead of the previously mentioned oxidising systems means that this problem can be avoided. The new oxidising agent, Diresul EF, achieves a full oxidising effect with the following advantages:

- A lower contribution to the wastewater COD level
- The absence of heavy metals
- An AOX index within the legal limits

Field of application

The new oxidising system can be applied in all companies and there are no limitations as far as its use is concerned, whether regarding the volume of application or any other circumstances.

Process benefits

The new oxidant acts in a similar way to those used traditionally but allows an improvement in the quality of the product as it produces uniform oxidising effects.

Environmental benefits

- A decrease in the COD of oxidising baths
- The absence of heavy metals in waste baths
- The absence of halogens and, therefore, a decrease in the AOX parameter

Economic parameters

Savings can be forecasted in the costs of water treatment as well as in production costs given that more uniform oxidation is achieved.

Bibliography

- *Technical information supplied by Clariant Ibérica S.A.*
- *Revista de Química Textil issue 113,* 1993, pp. 74-86.

6.1.1.7. New formulas for reductive baths following polyester dyeing with disperse dyes

Traditional problem

The dyeing of yarn and polyester fabric with disperse dyes requires a later process of elimination of the disperse dye that remains on the surface of the fibres by means of so-called reductive clearing, the formula of which is:

- 1-2 g/l sodium hydrosulphite (reductive agent)
- 1-2 g/l NaOH
- 1 cm^3/l dispersing agent

The reductive bath is taken to a temperature in the region of 70° C for 20 min.

The use of sodium hydrosulphite to excess, which may in addition contain free sulphide, causes high levels of COD in wastewater.

Alternative product

The general aim consists limiting the use of sodium hydrosulphite.

The replacement products are:

- Thiourea dioxide
- Hydroxyacetone (COD = 1080 mg/l for the pure product)
- Sodium borohydride

Below are several examples of the use of these replacement products:

Example 1

10 g/l of sodium hydrosulphite may be replaced by 2.5 g/l of sodium hydrosulphite + 0,75 g/l of thiourea dioxide.

Example 2

The combination of sodium borohydride with sodium hydrosulphite may also lead to the same results as sodium hydrosulphite alone.

Example 3

From 1 to 3 g/l of hydroxyacetone is enough to replace sodium hydrosulphite as a reductive bath for polyester dyeing with disperse dyes.

Field of application

These products may be applied in companies that are equipped for the dyeing of polyester fibres with disperse dyes.

Production benefits

The rubbing and washing fastness of the fabric washed with these products are the same as with the traditional reductive bath.

Environmental benefits

The environmental balance is positive given that a reduction in the COD found in wastewater is achieved.

Economic parameters

The economic benefits are essentially those that are derived from the environmental benefits given that a reduction in the cost of wastewater treatment is achieved.

6.1.2. New technologies

6.1.2.1. The Econtrol process for the dyeing of cellulosic fabric with selected reactive dyes

Traditional problem

The dyeing of cotton fabric and of other cellulosic fibres with reactive dyes is currently one of the most important. This dyeing may be performed either in discontinuous, semi-continuous or continuous processes.

The continuous dyeing processes, of which there are many variants, are essentially based on the following:

1. Impregnation of the fabric with the solution of reactive dye together with the auxiliary products, among which urea is incorporated due to its hygroscopic nature.
2. Drying.
3. Steaming: during the steaming stage, the presence of urea helps to maintain a degree of humidity on the fibre which is necessary in order to ensure the good diffusion of the reactive dye towards the interior of the fibre and its later chemical reaction.
4. Washing the fabric to remove all dye that has not reacted with the fibre.

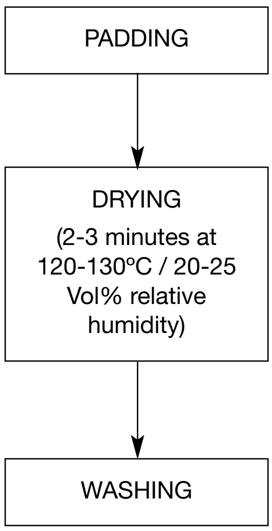
Several systems exist to carry out the dyeing of fabric. The use of any of these systems with reactive dyes implies the consumption of certain chemical products that will inevitably appear in the process wastewater in addition to presenting some quality problems depending on the fabric to be processed.

One such chemical product, as we have already mentioned, is urea.

Urea contributes to increasing the degree of nitrogen in wastewater and therefore its progressive reduction is advisable.

Alternative technique

The Econtrol process provides a fixing route in one stage, which allows, in today's industry, for the efficient dyeing of long or short batches, avoiding long beaming times. The fundamental sequence of stages is shown in the figure below:

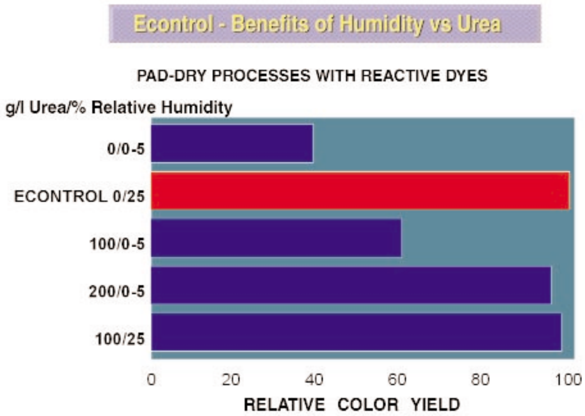


This innovation uses the physical laws of the evaporation of water from the cellulose to provide the optimum temperature and humidity conditions in the hot air drying chamber (Hot Flue), which is ideal for the efficient fixing of the specially selected reactive dyes. The introduction of new dyes, with a relatively high reactivity, such as Levafix CA, has given a broader application to the Econtrol process.

The principles of fixing by means of Econtrol are based on the temperature of the fabric reached during the drying process, which depends on the relative humidity inside the hot air drying chamber (Hot Flue).

Under these conditions, the reactive dye starts its fixation to the cellulose during the prolonged stage at a bulb temperature of 68-69º C, completing fixation during the rapid rise in temperature until the final value of 120º C is reached.

Furthermore, the Econtrol process avoids the need to use urea, obtaining maximum colour yield. In the following figure the comparison is shown between the colour yield obtained in a Pad-dry[6] process with reactive dyes, with and without Econtrol (with different conditions of urea concentration and relative humidity).



Econtrol Process: Concentration of urea / Humidity vs Heat yield

The general recipe of the padding process by means of Econtrol would be:

X g/l of reactive dye
Y g/l of alkali (depending on the reactive dye)
1-2 g/l of wetting agent
0-10 g/l of antimigrant (depending on the fabric)

Field of application

Currently, Econtrol is a well-established process with demonstrable advantages over more traditional padding processes. As the technical and commercial demands in the textile industry increase, the Econtrol process tends to contribute greatly to the provision of quick continuous production of economically feasible and environmentally acceptable, high quality died fabrics.

[6] **Pad-batch:** the fabric is impregnated by the bath of open-width dyeing in a foulard and, later, passes between two rollers, which perform an open-width pressing. Then, the fabric is rolled on a constant tension beam and covered with plastic film to avoid localised evaporation. The beam is kept rotating, cold, for as many hours as are necessary for the reaction to be produced.
Pad-dry: the fabric is impregnated by the dye bath, or the open-width finishing in a foulard and, later, heat treatment is applied in a stenter. Drying is also performed open-width (many finishes at the end of the process are applied in this way).
Pad-dry heat setting: as above, but with a later stage of heat setting in a stenter.

Production benefits

Benefits of machinery:

- The infrared pre-dryer is not necessary
- The steamer is not necessary
- Batch/rotation stations are not required
- An increase in the machinery's service life given that chemical auxiliaries such as salt or silicates are not used
- The ideal process for versatile technologies
- Energy efficiency by controlling optimal humidity

Process benefits:

- The continuous process is simpler and shorter
- Unproductive beaming sequences are avoided
- Better colour fixing yields are obtained than with the pad-batch system
- The ideal option for short batches
- Efficient washing in the absence of salt

Benefits for fabric:

- Ease of manipulation due to soft fixing conditions
- Minimisation of migration due to rapid fixing and humidity control - specially important in fabrics with pile
- No breakages in fabrics with pile (frequent in the pad-batch system)
- Improves the rubbing fastness of fabric with pile due to better dye migration to the extremes
- Improves penetration into difficult fabric (compared to pad/thermofixing) due to the presence of humidity at high temperatures of the fabric
- An improvement in the coverage of green cotton compared to the pad-batch system or dyeing by exhaustion
- Better diffusion in regenerated cellulose fabric than other pad-dry/thermofixing methods
- Versatility – a great variety of fabrics can be dyed
- No moiré effect

Environmental benefits

- Neither urea nor salts are consumed (chloride/sulphate), or sodium silicate, and so a reduction can be achieved in the wastewater pollutant load.

- Energy consumption is reduced.

Economic parameters

The application of this technique requires the acquisition of the facilities described above.

The economic benefits of the Econtrol process have been amply documented. They include:

• Lower costs of chemical auxiliary agents, since the use of sodium silicate, sodium chloride or urea is not required in the formulation of the dye bath. In many cases, the consumption of dyes is also lower in the Econtrol process compared to other processes such as the pad-batch

• Lower steam cost

• Lower costs derived from energy consumption

• Lower cost of wastewater treatment

If we bear in mind the increased productivity due to the elimination of high beaming times, it is clear that the Econtrol process can offer significant savings over the pad-batch (Table 1). Despite the lower cost of machinery of the pad-batch process, the Econtrol process has been confirmed as being the most effective in cost reduction in terms of the total cost of the process.

Table 26: Dye consumption / chemical products
(Mercerised cotton, 300 g/m², 75% pick-up of padding bath)

	PAD-BATCH (Sodium silicate method)	ECONTROL	DIFFERENCE (%)
Levafix Yellow CA Levafix Red CA Levafix Navy CA	15,0 g/l 12,0 g/l 10,4 g/l	13,7 g/l 11,6 g/l 10,1 g/l	-8,7 -3,3 -2,9
Total dye	**37,4 g/l**	**35,4 g/l**	**-5,3**
Urea	100 g/l	—	-100
Wetting agent	2 g/l	2 g/l	0
Sodium silicate 38° Bé	50 ml/l	—	-100
Caustic liquor 50%	14 ml/l	6 ml/l	-57
Sodium carbonate	—	10 g/l	—
Total chemical products	**166 g/l**	**18 g/l**	**-89**
Digestion	12 hours	2 minutes	

6.1.2.2. Colorite

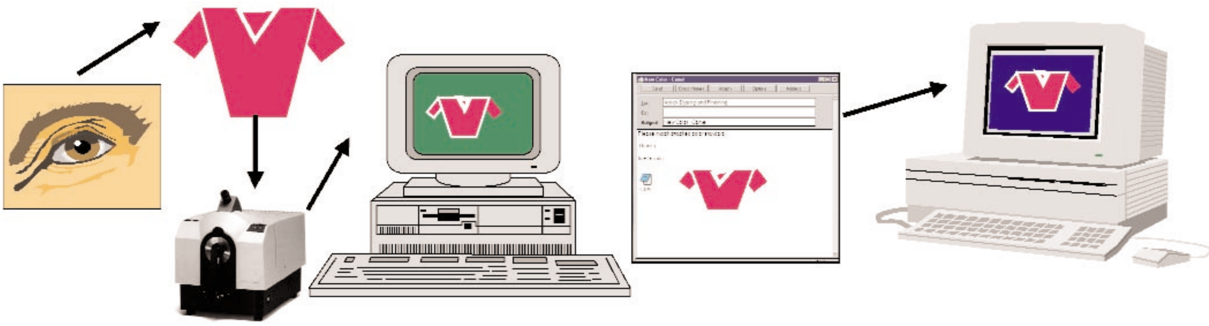
Traditional problem

Habitually, the manufacturer of finished fabric must provide his clients with samples of the fabric, in the colours requested by the client.

On other occasions, physical models of some sizes must be produced before the client decides to purchase a consignment. This involves a highly complex process of dyeing, printing and finishing of small yardages and garment-by-garment sewing, which lead to the consumption of resources and the generation of proportionally more effluents and waste products than those which are generated by larger consignments.

Alternative technique

Colorite is a computer programme by means of which it is possible to visualise the true colour of a sample on the screen and on different textures. It is possible to send this information via e-mail to any other part of the world with full guarantees that wherever it is sent, it will be seen in exactly the same colour (true colour). It is a new tool for colour.



Field of application

Adaptable to any operational plant that works with colour communication: dry cleaners', dressmakers, designers, etc.

Production benefits

The most significant benefits are:

- A reduction in time and cost of sending samples
- Greater facility in the communication of the right colour
- A reduction in defective consignments thanks to the visual control of the colour via a monitor

Environmental benefits

The need for fewer samples has the knock-on effect of eliminating waste (remains of dyes and test auxiliaries, finishing remains, print paste remains, etc.) and the wastewater generated in the preparation of samples.

Economic parameters

Although the application of this technology requires the initial cost of purchase, this amount is quickly payed-back thanks to the savings made on expenses for sending samples, and the making of disposable samples or samples that are finally discarded.

More and more companies have introduced this new communications technique. Among them are:

• USA: Wal-Mart, Burlington, Burke Mills, Fruit of the Loom, Guilford Mills.
• Europe: Oaxley Threads, Penn Nyla, Marks & Spencer, Textured Jersey, Triumph, Courtalds.

6.1.2.3. Recovery and reuse of printing pastes

Traditional problem

The printing paste that remains in the rotary printing system after the printing process finished is eliminated during the cleaning of the different elements of the equipment: moulds, scraper systems, conduits, drums, etc. This involves a great loss of dyes and printing paste, with all the chemical products that are necessary, and the corresponding wastewater pollution.

The loss in production as a consequence of the time needed to wash the whole system should also be mentioned.

If no paste recovery facilities exist, for each colour printed, it is estimated that approximately 2.8 kg of printing paste are lost in a narrow machine and 3.8 kg of printing paste in a wide machine. When this amount is multiplied by the number of colours that a design may have (8-9) and by the number of printing changes that may take place in the course of a year (approx. 6,000), it can be seen that on an annual basis, between 134 and 205 t of printing pastes are lost which, principally, end up in the wastewater or, in the best of cases, are partially segregated as waste.

Alternative technique

The new patented technology (the system was developed by Stork Brabant, Boxmeer, the Netherlands) is capable of cleaning and recovering the printing paste from the print system's conduits.

With this paste recovery system, it is estimated that remains would be 1.1 kg of paste in the narrow machine and 1.8 kg in the wide machine.

The recovered paste (between 60 and 75%) could be reused as a component for later printing pastes if colourimetry equipment is available and the software suitable, or it could be managed as waste.

Field of application

This technique may be applied in most rotary printing machines by means of microperforated cylinders and, preferably in the Stork printing machines.

Production benefits

The production benefits derive from the lower consumption of printing dyes and pastes thanks to the recovery that is achieved.

Environmental benefits

Paste recovery allows:

- A reduction in the wastewater pollutant load generated in the cleaning of printing equipment
- The correct management, as a waste product, of the recovered pastes that have not been reused
- A reduction in the consumption of water for cleaning operations
- A reduction in the consumption of reactives and energy in the treatment of wastewater

Economic parameters

Although the installation for the recovery of pastes requires an initial investment, annual savings could be as much as 48,000 Euro.

6.1.2.4. Reductive treatment following the dyeing of polyester with disperse dyes in the same dye bath

Traditional problem

Traditionally, after polyester dyeing at 130ºC, the dye bath should be cooled to 70ºC and then thrown away, and the following products are added to the new bath:

- NaOH
- Sodium hydrosulphite (reductive agent)
- Dispersing agent

The reductive bath is performed at 80ºC for 20 min. Then, the water is thrown away and one or two additional baths must be used in order to eliminate the reductive agents and waste alkalis.

Alternative technique

A new formulation of surfactant products often allows the reductive bath to be done in the same dye bath during the cooling cycle between 130 and 70ºC.

At the end of dyeing at 130ºC, bath cooling is started. When a temperature of approximately 98ºC is reached, the following products are put in the machine:

Tenyclear PES.....................3g/l (a product that contains thiourea dioxide, alkali, dispersing agents, etc.)

During the cooling process to 70ºC for 20 min, the product performs the reductive clearing of the polyester.

Field of application

Dyeing machinery must be prepared for the programmed addition of the products at temperatures close to 100ºC.

Production benefits

An increase in factory productivity due to the reduction in the overall process time.

Environmental benefits

- A reduction in water consumption
- A reduction in energy consumption
- A reduction in the wastewater pollutant load generated

Economic parameters

If the available machinery for dyeing does not allow the programmed addition of chemical and auxiliary products at temperatures close to 100ºC, the cost of investing in new machinery must be taken into consideration.

On the other hand, there is a reduction in the overall cost of the dyeing process due to the lower consumption of resources and chemical products.

Bibliography

- *Technical information supplied by Tenycol S.A*

6.1.2.5. Jet-overflow dyeing machine with fabric movement by means of an air-water system

Traditional problem

Machines like the jet-overflow achieve greater dye bath-fabric contact by means of a coaxial flow of the dye bath and of the fabric.

Most of these machines operated with bath ratios (proportion of kg of fabric to litres of bath) of between 1:8 and 1:12, according to the type of machine and the type of fabric to be processed.

Alternative technique

This is a machine that, with a water-air system, can guide the fabric inside the machine. This permits operativity at a very low bath ratio, in the order of 1:4, with faster cooling and heating cycles than in conventional machines.

Field of application

This machine implies the replacement of traditional machines, and they may be installed in the same plants as the previous ones.

Production benefits

The machine is fully automatic as far as the dyeing cycles, product addition, etc. are concerned.

The new system achieves a smooth movement of the fabric and causes the folds of the fabric to vary their position with each turn of the yarn, thus avoiding permanent creases which would reduce the quality of the product.

Environmental benefits

This machine means energy saving, as it has faster cooling and heating cycles than in the conventional machines and a saving in water, given that it works with a very low bath ratio.

Economic parameters

The cost of purchasing the new machine must be considered.

As far as the savings are concerned, it should be taken into account that the system implies a reduction in the consumption of water and energy.

Bibliography

- *Technical information supplied by the "Airtint" machine. Argelich and Termes.*

6.1.2.6. Liposomes as auxiliaries for the dyeing of wool

Traditional problem

The dyeing of wool is, generally speaking, a long, costly process. Given that wool fibre is capable of felting and may be deformed due to its hydrothermoplastic nature, the end quality of the fabric largely depends on the process time as well as the temperature and the bath pH. In addition to containing the necessary dyes and chemical products, dye baths must have sufficient quantities of equalising products and electrolytes (soluble salts), and thus the COD of dye wastewater is high.

Alternative technique

The use of liposomes as auxiliary products in the dyeing of wool with acid dyes makes it possible to dye wool obtaining good exhaustion, at 80ºC (this temperature is lower than that used in the traditional system) for 40 min, which implies:

- Less superficial damage to the wool
- Energy savings
- Not using electrolyte
- Lower COD in dye wastewater

The use of liposomes as auxiliary products in the dyeing of wool with acid dyes in a bath that contains:

- Lipopur (liposome)........0.1-0.2% owf
- Formic acid ....predetermined pH
- Acid dye

In the case of wool/polyester mixtures, the temperature should go up to 100°C, adding a low concentration of carriers, in such a way that the disperse dye exhausts onto the polyester.

Nevertheless, it should be borne in mind that the liposomes may lead to the diffusion of the disperse dye to the interior of the wool fibre and so it is necessary to carry out tests on the disperse dyes for dyeing with liposomes so as to avoid problems of dye fastness at a later date.

Field of application

All plants that are equipped for the dyeing of wool can use liposomes to dye wool.

Production benefits

In addition to the increased productivity of the dyeing facilities as a consequence of the aforementioned data, the quality of the dyed articles improves.

The treatment of wool at lower temperatures leads to a softer fabric.

Environmental benefits

The dyeing process does not consume electrolyte and so the conductivity of the wastewater generated is reduced.

The formulation of the dye bath with liposomes presents a lower COD (a reduction of up to 50%) than traditional dye baths.

Economic parameters

The higher cost of liposomes is compensated by the energy savings (lower temperature) and better fabric quality and so the overall cost favours the new process.

1. A saving in chemical products in euros for 100 kg of dyed wool

Table 27

PRODUCT	NORMAL DYE COST (€ /100 kg)	COST OF DYEING WITH LIPOSOMES (€ /100 kg)
Sulphuric acid	0.23	0.23
Anhydrous sodium sulphide	0.95	—
Esterol Pag	1.45	—
Lipopur	—	0.57
Total cost	**2.63**	**0.81**
Saving		**69.4%**

2. Energy saving in euros for 100 kg of dyed wool

Table 28

TIPE OF DYEING	KG OF STEAM	COST (€ /100 kg)
Normal dyeing	0.09	0.43
Dyeing with liposomes	0.08	0.36
Saving		**15.6%**

3. Total saving in euros for 100 kg of dyed wool

Table 29

PROCESS	CHEMICAL PRODUCTS	STEAM	TOTAL
Normal dyeing	2.63	0.43	3.06
Dyeing with liposomes	0.81	0.36	1.16
Saving			**62%**

4. Saving in the effluent charge

In a specific case, dyeing with liposomes has meant a 30% reduction in the concentration of sulphates and a reduction of the COD by 200 units. The reduction in the level of the parameters from which the effluent charge is calculated, has meant a reduction of 0.2 €/m^3.

Bibliography

- *Technical information supplied by Color Center S.A.*

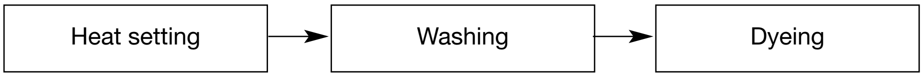
6.1.2.7. Washing of knitted elastic fabric prior to the thermofixing process

Traditional problem

Knitted elastic fabrics made of chemical fibres (polyester or polyamide) with Spandex filaments, are usually subjected to a preliminary stage of fabric thermofixing, which is done in a stenter in order to avoid flaws in the later stages of washing and dyeing.

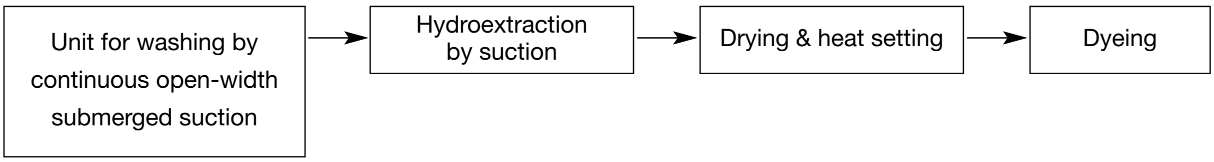
The Spandex filaments contain high quantities of oils that come from the weaving stage, which must be eliminated prior to dyeing. These oils give rise to important smoke emissions during the thermofixing process. The waste oils which are still present in the fabric after thermofixing are more difficult to eliminate in the successive washes, which may compromise the final quality of the dyeing.

Traditional process:



Alternative technique

The new process proposes the washing of the knitted elastic fabric in order to eliminate the weaving oils prior to thermofixing.



The application of this technology means that smoke emissions in the stenter can be minimised, water for the washing process can be saved and productivity increased.

To obtain an optimal result when applying this technique, it is useful to replace the traditional oils with hydrosoluble oils during the production of knitted fabric, given that the hydrosoluble oils are more easily eliminated during a preliminary stage of continuous washing.

This initial wash in continuous mode is carried out in a SHARK-2000 submerged suction (two stages) unit made by TVE-Escalé, with a later stage of hydroextraction by suction. Then, the knitted fabric is passed through the stenter, where the thermofixing takes place. With this, the fabric can enter the stenter moist but not wet, and so in the first fields of the stenter, while this moisture is being eliminated, the overall structure of the knitted fabric becomes more uniform.

In the TVE-Escalé washing unit, the washing bath flow through the fabric can be regulated to between 100-2,000 l/min. All water used for washing is recycled. As the fabric leaves the bath, it passes through an air spray section and pressure rollers that achieve the hydroextraction.

A system of compensators controls the fabric tension and the regularity of the feeding to the stenter.

Once the wash and the thermofixing have been done, dyeing and finishing can begin.

Field of application

The application of this new technology requires incorporating the washing unit described above, which may be adapted just before the stenter machine in which the drying and thermofixing will be performed.

Production benefits

The overall productivity of the process of washing and dyeing of knitted elastic fabrics increases in the order of 20%.

Environmental benefits

- A reduction in smoke emissions coming from the weaving oils
- A 50% saving of water from the washing processes
- An improvement in the quality of the working environment

Economic parameters

The machine described above must be acquired.

As far as savings are concerned, they derive basically from the lower water consumption in the washing processes.

Bibliography

- *Technical information supplied by TVE-Escalé*
- *International Dyer, October 2000, p. 28*

6.1.2.8. Easy care finish low in formaldehyde

Traditional problem

The “easy care” finish on cellulosic fibres is a finish which is resistant to washing, which enhances comfort and provides easy washing characteristics, implying the following for the consumer:

- Better dimensional stability
- Better recovery from creasing
- Easy ironing

These effects are achieved by applying resins that react with the cellulosic chain of the fibre and together, in the presence of an appropriate catalyst, under predetermined conditions of temperature and reaction time. With certain chemical products and certain finishing processes, if the finished fabric must be washed industrially and the chemical products have generated free formaldehyde, this product could appear in the wastewater that goes to the wastewater treatment plant causing serious difficulties. Depending on the finishing process, if the last stage is to pass through the stenter and if free formaldehyde has been generated, this could appear in the air from the stenter outlet.

Alternative technique

Given that cotton and viscose garments with easy iron properties, good recovery from creasing and good dimensional stability and form are more and in more demand by the consumers, it is necessary to obtain these properties with a low free formaldehyde content in the fabric so as to preserve the health of the consumer avoiding, as far as possible, this product's emission into the atmosphere.

The main aim is to achieve a free formaldehyde content of less than 75 ppm (in accordance with law 112 (Japan)).

One of the most commonly used products, to substitute formaldehyde, is based on chemically modified dimethyldihydroxyethylene urea (modified DMDHEU).

To carry out this process, three different procedures can be used:

1. Dry cross-linking
2. Moist cross-linking
3. Wet cross-linking

Due to its complexity, procedure 3 is not used. In the European industry, the most common procedure is number 1, dry cross-linking, which requires a foulard for the impregnation of the resins in open width, and a stenter with a sufficient number of temperature fields as to carry out the process at an industrially competitive speed. The majority of companies that perform textile ennobling in Spain have this equipment.

The production throughflow is as follows:

FABRIC IMPREGNATION
padding bath with the finishing solution
(80% of impregnation of the bath on the fabric):
- DMDHEU
- Catalyst
- Softener
- Acetic acid

↓

DRYING AND CONDENSATION IN THE STENTER
(160-170ºC for 30-40 s)

↓

WASHING

↓

DRYING

Field of application

- Woven fabric, of cotton and viscose
- Knitted fabrics, of cotton and viscose

Dyeing and/or finishing companies that, naturally, have the necessary machinery available.

Production benefits

The interest in the new technique is based on the compliance with a more demanding environmental law, and hence, production remains unaltered.

Environmental benefits

When reducing the level of free formaldehyde, its presence is reduced, both in the wastewater and in the emissions into the atmosphere.

Economic parameters

If the machinery for cross-linking is not available, it will have to be acquired.

As consumers start to appreciate environmentally friendly garments, so the process will progressively start to gain importance.

6.1.2.9. The bioscouring process of cotton fabric and blends in overflow-type discontinuous processes

Traditional problem

Cotton material, be it flock, thread or fabric, that is to be bleached and/or dyed, must be previously subjected to a scouring process that is done using sodium hydroxide, detergents, sequestrants and small quantities of reductive products. With this, and working at temperatures of 100ºC and times of 1 h to 1.5 h the cotton's waxes, pectins and hemicellulose are chemically attacked, extracted and pass through the bath in such a way that alkaline wastewater is generated with an important organic matter content.

The scouring process of cotton is essential in order to guarantee the subsequent processes of bleaching, dyeing, printing and finishing.

This process is neither selective nor specific, and leads to a loss of weight of between 3 and 6%, which corresponds to the impurities that accompany the cellulose in the fibre. The process must also eliminate the added hydrophobic substances, such as yarning and weaving oils in the case of knitted fabric, etc.

The fabric must be washed with water, and depending on the needs of the following process, must be neutralised, which implies a second bath.

SCOURING		WASHING / NEUTRALISING
R/b: 1:10 T= 100ºC t= 60 min + NaOH + Detergent + Hydrosulphite + Chelating agent	→	R/b: 1:10 T= 40ºC t= 30 min HCOOH

The set of the two stages implies:

Water consumption: 20 l/kg of fabric
Process time = 90 min
Wastewater characteristics: BOD - high
COD - high
Soluble salts (conductivity)

Alternative technique

The idea is to substitute traditional chemical scouring with a scouring enzyme.

It is of great importance to perform a study of dyeability in each of these cases given that, depending on the scouring process, the affinity and exhaustion of the dyes used in the later cotton dyeing process will be different.

ENZYMATIC SCOURING
Enzyme Detergent T= 40-60ºC t= 30 min R/b= 1:10 (if the bath is reused, 1:5)

The bioscouring process with enzymes is specific and only degrades the impurities that need to be eliminated. The weight loss of the fabric is lower and there is practically no further chemical degradation of the cellulose. The COD and BOD levels of the wastewater that is generated are far lower due to the fact that the quantity of impurities extracted and/or degraded is far lower.

The treatment bath may often be reused in later treatment.

If a biodegradable detergent is used, the wastewater may be reused for the washing of the dyed fabric.

Field of application

This new process is applicable in new and existing plants that already perform scouring processes.

Production benefits

Process times are shorter. The weight losses of scoured products are lower and the general quality of the scoured material is higher than traditionally scoured material.

Environmental benefits

In a particular case, the environmental benefits may be summed up as:

COD of conventional scouring with NaOH ....3,690 mg/l
COD of bioscouring ....1,760 mg/l

In the case of the bioscouring and bleaching of cotton fabric, data concerning the consumption of water and chemical products and the degree of pollution of wastewater calculated on a production of 1,000 t/year are summarised in the following table:

Table 30

CHEMICAL PRODUCTS, WATER AND WASTEWATER POLLUTANT LOAD	TRADITIONAL ALKALINE PROCESS	THE BIOSCOURING PROCESS
NaOH	500 t	100 t
Organic acids	500 t	75 t
Surfactants	30 t	30 t
Chelating agents	15 t	15 t
Stabilisers	30 t	15 t
H_2O_2	250 t	200 t
Rinse water	>100 Mill m^3	<40 Mill m^3
BOD	>1,000 mg/l	<350 mg/l
COD	>1,500 mg/l	<500 mg/l
Total of soluble solids	>2,500 mg/l	<1,000 mg/l

Therefore, the enzyme scouring process allows for energy saving, a decrease in the consumption of chemical products, a considerable saving in water and an important reduction in the pollutant load of the wastewater generated in the process.

Economic parameters

Although the enzymes are more expensive than the conventional scouring products, the economic interest in this new technique depends on the costs of treatment, the costs of water supply and the cost of the chemical products used in the industrial processes, which vary with time in accordance with environmental legislation which is getting stricter and stricter.

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"Biopreparación del algodón- un nuevo concepto enzimático".
Revista de Química Textil, issue 145 (1999), pp. 66-75.

6.1.2.10. Pretreatment of cotton with cationic agents

Traditional problem

In the way in which this technique is currently being used, there are no reference points referring to traditional techniques.

Description of the technique

The pretreatment of cotton fabric with cationic agents produces a fibre that can be dyed with direct dyes at pH 7, in the absence of electrolyte and with high dye exhaustion onto the fibre.

The cationic agents may be biopolymers like chitosan, and products which react with the cellulose such as:

- Epoxy quaternary ammonium compounds
- Poly epichlorohydrin-dimethylamine
- Mono and bi-reactive haloheterocyclic agents

Field of application

Cotton fabrics and blends with chemical fibres which are to be used in aged finishing processes and certain fashion effects.

There is a growing interest among companies that dye ready-made garments in this process.

Depending on the final conditions of the fabric to be manufactured, this pretreatment may or may not be carried out.

Production benefits

The dyeing-finishing process of ready-made garments is made considerably easier.

Environmental benefits

With this pretreatment, fewer chemical products are consumed, and less conductivity to and dyeing of wastewater is achieved.

Economic parameters

This Pretreatment is more expensive than the usual way of carrying out dyeing but it means that new effects can be achieved on the dyed fabric.

Bibliography

- *Y. A. Youssef, JSDC, Vol. 116, Oct. 2000, pp. 316-322.*

6.1.2.11. Samples by digital printing

Traditional problem

The process, from the buying of a design, which is generally on paper, until the printed products reach the market, is extraordinarily long and costly.

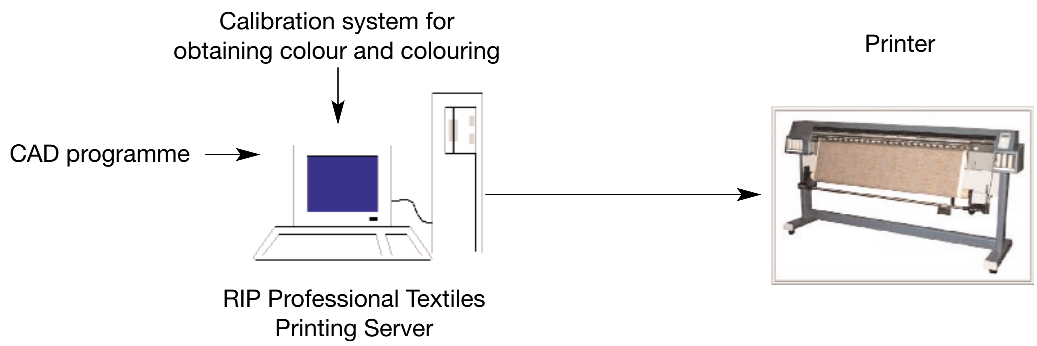
Habitually, the manufacturer of printed fabric must provide his clients with fabric samples in the colour combinations that have been proposed and, on occasion, even ready to wear garments. This involves a highly complicated process of printing of small yardages, garment-by-garment dressmaking, etc., which cause the consumption of resources and the generation of effluents and proportionally higher quantities of waste than are generated with larger consignments.

Furthermore, cylinders must be engraved, which are sometimes only used for the preparation of the aforementioned samples with the consequent expense to the company.

Alternative technique

Thanks to the new technique of digital stamping, samples of the designs created for printing can be made on the fabric without the need to engrave and create cylinders, and with no need to carry out the physical process of printing, as it will be done later in the factory.

By connecting one or several CAD (computer aided design) systems to a digital printer printing on fabric, it is possible to carry out samples with different types of dyes: reactive, acid, disperse and pigment dyes. This means that it is possible to later obtain a reproducibility with the results that are going to be obtained with the traditional method. The digital printer is controlled by a printing server (RIP) which allows the storage of the work and the optimisation of its functioning.



Each type of combination of fibres in the fabric (knit or open weave) requires a different process for the preparation of the fabric and a suitable set of dyes with affinity to the fabric.

In most cases, the fabric which has been dyed must be dried and then the dyes must be fixed on the fibre in a suitable machine. Later, the fabric must be washed and finished.

Field of application

The printing of cotton, polyester, silk and wool fabrics (prepared for printing).

The possibility of creating exclusive combinations of small yardages.

This technique may be applied on a small or large scale by simply increasing the number of digital printers. Depending on the sample volume more than one unit shall be necessary. The required space for the installation will depend on the number of printers (size 210 cm wide approx.)

More and more companies are implementing this technique on a level of sample production. In Italy, there are several plants in which several in-line printers work on silk in order to do high-resolution prints.

Process benefits

This technique allows the rapid response to market demands given that it permits a faster visualisation of the design created on different fabrics. Moreover, it makes small productions possible, without going through traditional production channels.

Nevertheless, digital printing machines produce between 100 and 200 m^2 per hour, which is a significantly lower production than that which may be obtained using the traditional system. However, certain operations are avoided compared to the traditional printing process.

The maintenance of the ink injectors is a critical parameter.

Environmental benefits

A reduction in the generation of printing paste remains, in water consumption in cleaning operations of the aforementioned remains and of the wastewater pollutant load.

Economic parameters

Depending on the printer to be installed, the price range of the investment varies, and amortisation is fast for the user since all expenses incurred in the engraving of cylinders and moulds are saved.

The cost of the machine may be offset by the increased availability for the production of samples.

References: Ferraz Pinto, SIVT, Zenith, STOF, Grupo Perrin

6.1.2.12. Transfer printing technology

Traditional problem

Polyester is traditionally printed with disperse dyes. The conventional printing system involves:

1. The preparation of the printing paste
2. Printing on the polyester fabric
3. Drying
4. Steaming
5. Washing
6. Finishing

This whole set of operations requires a specific machine and involves an important production time and great difficulty in case short series of printing were required. Moreover, the paste remains must be cleaned from the printing machines, which implies time, water and energy consumption and the generation of wastewater. The washing of the printed fabric also involves the consumption of considerable amounts of water and energy and significantly contributes to the wastewater pollutant load.

Alternative technique

The technology of printing by transfer implies the use of a paper printed with special disperse dye inks which is brought into contact with the polyester or polyamide fabric (knit or open weave) for 10-35 seconds. At temperatures of 160 - 200ºC, the paper's disperse dye sublimates, condenses on the fabric and diffuses towards the interior of the fibre.

The printed paper may be acquired from specialised companies in the field of printing on paper for printing by transfer.

At the end of the process, the fabric contains the same design as the paper and is already calendered and ready to be made up.

The application of the transfer paper containing the design onto the fabric may be done either in continuous or discontinuous mode:

- In discontinuous: it is done on a hot, flat board
- In continuous: the transfer paper and the fabric are simultaneously fed into a thermoprinting calender

Once printed, the original feel of the fabric remains unchanged. There are no undesirable waste products to be washed off and the product is washable and hardwearing.

Field of application

Knitted and open weave polyester, polyamide and acrylic fabrics, each material with its own, specially selected dyes. Also applicable to garments made with these chemical fibres, using suitable presses.

Production benefits

- There is no limitation as to the number of printed colours
- It provides a rapid response to changing market demands
- It is suitable for printing both long and short yardages

Environmental benefits

This new technology offers several advantages:

- Water is not consumed, and so no wastewater is generated
- The paper which is used for transfer can be used later for packing

Economic parameters

Overall, it is a highly competitive technique.

A calender must be available for thermoprinting, suitable to the required widths.

Bibliography

- *J. Barton, International Dyer, vol 186, issue 5, p. 15.*

6.1.2.13. Systems of minimum finish application

Traditional problem

The application of finishes to bleached, dyed or printed fabrics is usually done by the full bath system, that is to say, that the fabric remains submerged for a certain time in a bath that contains the finishing product which is to be applied.

Having finished the application, the fabric must be subjected to hydroextraction and drying, which, in addition to the generation of wastewater and the energy used for drying, generally, implies slow production.

Alternative technique

There are several possible alternative techniques to achieve the necessary quantity of finishing product, but applying a minimal bath quantity on the fabric.

The main ones are:

1. The application of unstable foams on the fabric: the finishing products are applied in a foaming machine which speads the foam onto the fabric. With this, the fabric is impregnated to less than 30% (on 100 g of fabric, 30 g of the foamed finishing solution is distributed).

2. Minimum bath application cylinder. This is an automatic machine which is based on an inductor cylinder that transports the bath from a trough to the fabric, while two bolsters determine the weight per square metre before and after the impregnation process. Impregnation in the region of 30% is also achieved.

Field of application

This technology may be applied to all types of open-width fabric. Generally speaking, following the application, the fabric can be dried in a stenter.

Production benefits

Since the fabric contains far less water, it can dry at a much higher speed in the stenter that the company already possesses. This means that production speed can be increased in the order of 40 to 60%.

Environmental benefits

Lower water consumption in the preparation of the finishing baths and a lower generation of wastewater.

Energy savings in the drying of the fabric.

Economic parameters

The implementation of this new technology requires purchasing the equipment and investing in the training of the company staff.

6.1.3. Good housekeeping practices

6.1.3.1. Substitution of traditional paraffin with synthetic paraffin in the formula for the sizing of cellulose warp threads and its blends with chemical fibres

Traditional problem

For many companies, a change in the formulation of the sizing products is a most difficult process. The yield of the weaving facilities depends to a great extent on the sizing of the warp threads.

The sizing must be eliminated in the desizing process, which is one of the first operations of the textiles ennobling sector and, without doubt, is the operation that contributes the most to the wastewater pollutant load as far as COD and BOD levels are concerned.

Alternative technique

When it is still technically not considered possible to substitute the so-called chemically modified starch and starch-based semi-synthetic sizes (which are also mixed with 6 or 7 products, among which are the lubricating agents such as paraffin) with the new hydrosoluble sizes, it is highly recommended to substitute conventional paraffin with the new synthetic paraffin which, being itself easily emulsifiable in water, when it is incorporated into a desizing formula, will facilitate this operation globally.

The synthetic paraffin incorporates fatty acids with emulsifying products to the sizing formulation, which gives rise to highly efficient sizing agents in the production of a fabric with a low metal/fibre friction-coefficient, at the same time as facilitating the later desizing process.

Field of application

These products can be incorporated into many current sizing formulations.

Several Spanish companies have carried out the above-mentioned substitution for reasons of quality in production.

Production benefits

The production benefits should be considered globally.

Although the weaving efficiency is not necessarily reduced, where significant benefits can be obtained is in the later desizing process.

Environmental benefits

The environmental benefits of this technique are obtained in two ways. On the one hand, a certain decrease in the wastewater pollutant load is achieved.

Nevertheless, the principal factor is the improvement in the quality of desizing, which leads to a higher final quality of the fabric, thus reducing the number of reoperations and additions to the dye.

Economic parameters

The difference in cost between the conventional paraffins and the synthetic ones is not significant and so benefits are obtained thanks to the reduction of the number of re-operations and additions used to achieve the desired end quality.

6.1.3.2. Demineralisation and desizing of woven cotton fabric by the pad-batch system

Traditional problem

The processes of preparation (desizing-scouring) and bleaching are the object of continuous innovations since they affect almost the whole of textiles production.

Alternative technique

The traditional steps for the preparation and bleaching of woven cotton fabric may be innovated on the basis of the extraction of the cations of di- and trivalent metals that are contained in the cotton fibre, using formulations of easily biodegradable products with high complexing power of the di- and trivalent cations and high power to disperse the impurities.

For woven fabric, enzymatic desizing may be used to perform simultaneous demineralisation in such a way that following rinsing, the fabric can be directly subjected to peroxide bleaching, thus reducing the number of stages in the preparation and bleaching stages:

Pad-batch enzymatic desizing

Beixol T 2090 .... 5 ml/l (optimum pH for the enzyme: 6-6.5)
Felosan Jet .... 5 ml/l (biodegradable detergent)
Beixion NE .... 1-5 ml/l

Impregnation, digestion for 4h at 70ºC, and washed at 90ºC.

This process allows the preparation of cotton for later bleaching with hydrogen peroxide.

Pad-steam bleaching (padding-steaming)

Contavan GAL .... 6 ml/l (stabiliser of the decomposition of the peroxide)
Felosan JET .... 3 ml/l (biodegradable detergent)
NaOH 50% .... 20 ml/l
H_2O_2 50% .... 30 ml/l

With an impregnation of 100% over the weight of the fabric, steamed at 102ºC for 20 min.

Field of application

The companies that can adopt the new system are all those that have Pad-Batch facilities (padding and cold rest, beaming on large beams).

Production benefits

As for benefits for the fabric, with this system, greater fibre resistance to future treatments is obtained and, generally, the degree of whiteness of the cotton is better than after traditional desizing with NaOH.

Environmental benefits

There is a reduction in the levels of AOX and COD in wastewater.

Economic parameters

Given the variations between the new and the traditional processes, it is quite difficult to make direct comparisons. The economic analysis must take into account all of the production process globally, including the environmental costs.

Bibliography

- *Technical information supplied by Cresa (CHT).*

6.1.3.3. Washing and dyeing of knitted polyester fabrics in a single bath

Traditional problem

Traditionally, the dyeing of polyester fabrics has needed a washing stage prior to dyeing given that although it is an essentially hydrophobic fibre, uniform hydrophility and absorbency must be achieved in all of the fabric to be dyed. Consequently, a polyester dyeing process requires:

1. Prefixing in stenter (heat setting)
2. Washing
3. Dyeing
4. Reductive clearing
5. Rinsing

This large number of stages implies a high consumption of water and energy and the generation of wastewater of different characteristics at each stage.

Alternative technique

Currently, by using special surfactants, it is possible to perform the washing and dyeing simultaneously in just one bath. Therefore, the stages of the process would be as follows:

1. Prefixing in stenter (heat setting)
2. Washing-dyeing
3. Reductive clearing
4. Rinsing

This is operated as follows: add 3-5% of Dispergal PCS during the cold filling of the machine. Once the pH has been adjusted to 4.5-5.5, the selected disperse dyes are introduced. At this point, the dyeing process may be started.

Field of application

All factories that dye polyester fabric may apply this technique.

Production benefits

Naturally, the productivity of the dyeing facilities is increased since a washing and a dyeing operation are grouped together.

Environmental benefits

By reducing the number of baths, 25% of water is saved, as well as energy.

Economic parameters

Depending on the machinery used for dyeing, greater or lesser savings will be made on the process costs.

6.1.3.4. Single stage desizing, scouring and bleaching of cotton fabric

Traditional problem

For woven cotton fabric and blends with synthetic fibres, a pretreatment routine consisting of three stages has for many years been the standard procedure, and includes:

1. Desizing
2. Scouring
3. Chemical bleaching

The fact that three stages are needed implies a high level of water and energy consumption and the generation of wastewater of different characteristics at each stage.

Alternative technique

New formulations of new auxiliaries, combined with automatic dosage systems and steamers make this new process possible.

The Flash Steam procedure unifies desizing, alkaline treatment (scouring) and pad-steam bleaching (padding - steaming) with hydrogen peroxide in a single stage, and so the efficiency of the process is increased.

The operational data corresponding to this new process are as follows:

At an interval of 2 to 4 minutes, when the fabric is impregnated with the attached formula, a suitable degree of bleaching for dyeing is achieved. This is a great advantage, especially for the processing of fabrics that are susceptible to form creases.

Bleaching with Flash Steam peroxide

15-30 ml/kg Ciba Tinoclarite FS*
30-50 g/kg NaOH 100%
45-90 ml/kg H_2O_2 35%

Steaming for 2-4 minutes (saturated steam)
Hot wash

Field of application

All those cotton and cotton-polyester fabrics that technically can be processed open-width and in continuous mode, or those for which this is advisable.

Production benefits

- An important increase in production speed.
- Since the formula contains few components, it may be used in most automatic facilities for the preparation of solutions.

Environmental benefits

This procedure allows for very important water savings and the use of a smaller amount of chemical products and so the wastewater pollutant load is reduced.

Economic parameters

Overall, they favour the new process. There is a reduction in the number of products in stock in the company with all the associated consequences.

Nevertheless, machinery is needed that allows the automatic dosage of products and so, if this is not available, it will have to be acquired, which involves investment cost.

Bibliography

- *International Dyer, October (2000), p. 10.*

* Ciba Tinoclarite FS is a phosphorous free combination, with a bleaching stabiliser, a dispersing agent, a wetting agent and a detergent.

6.1.3.5. Printing with pigments

Traditional problem

The direct printing of fabrics requires, for each type of fibre, the use of the suitable dyes.

A conventional direct printing process involves:

1. The preparation of the printing paste
2. The printing onto the fabric
3. Drying
4. Steaming
5. Washing
6. Finishing

All of these operations require specific machinery and involve significant production time as well as water and energy consumption and the generation of wastewater in the wet processes and equipment cleaning operations.

On the other hand, each type of fibre requires a specific dye for it to diffuse and fix in it. This complicates the printing formulas and processes in the frequent case of fibre mixtures.

Alternative technique

Printing with pigments is the most important printing technology in the world. It is estimated that over 60% of all printed fabrics are made using this technique.

The traditional dyes and printing systems may be replaced by printing with pigments given that with the right chemical means, pigments may be fixed onto all sorts of fibres.

The main steps are:

1. Printing (on a flat machine, with a microperforated or garment cylinder)
2. Drying
3. Polymerisation (with hot air at 160ºC for 4 min)

In many cases, the printed fabric is already ready to be made up.

Field of application

The technique is applied to the printing of knitted and open weave fabrics.

The printing of fabrics is becoming increasingly important. With special binders, printing can be done on elastic fabrics.

Production benefits

It has the advantage of being a suitable process for knitted and woven fabrics and for ready-to-wear garments, with any type of fibres and mixtures of fibres since the pigments are to be retained by the binder and the cross-linking agent, regardless of the type of fibre onto which they are applied.

The modern printing thickeners have been developed on an aqueous base, and so the use of solvents has decreased.

Environmental benefits

This process allows considerable water and energy saving since water is not consumed for the washing of the printed fabric and neither is energy used to dry the printed-washed fabric.

With the new product ranges, prints free from formaldehyde can be produced (in the order of 20 ppm in fabric), and emissions of volatile organic compounds are in the order of some 0.7 kg of VOC/ tonne of printing paste generated. The new pigments are below the limits of heavy metal contents required by the ecolabel.

Economic parameters

The greater cost of printing paste containing pigments compared to other pastes is compensated by the savings it generates through lower water and energy consumption, less wastewater generation and a lower emission of volatile organic compounds.

6.1.3.6. Other good housekeeping practices

In addition to the previous good housekeeping practices which are strictly related to the manufacturing processes of the companies in the dyeing, finishing and printing subsectors, other, more generic ones exist which can also contribute to an improvement in company environmental management and, therefore, to the prevention of the pollution it generates. Some of them are mentioned below:

Control of the number of re-operations and additions

The decrease in the number of re-operations and additions and, therefore, the achievement of a high degree of reproducibility in the dyeing process has a great impact on the reduction of water and energy consumption, in the reduction of waste flows that are generated and in the reduction of costs.

It may be considered that the average number of re-operations in the sector is between 6 and 10%, while that of additions is between 2 and 4%.

Nevertheless, as some of the practical cases included here indicate, there is room for their reduction.

The following can be done to achieve the reduction of the index of re-operations and additions:

- Identify the possible factors that influence the indices of re-operations and additions through the analysis, during a certain period of time, of the registry of process parameters that are made up of parts of production or other types of registers which the company may have, and their comparison with the data on the evolution of re-operations and additions indices.

- Control the parameters that have been identified as possible causes. Some of these may be:

  - Process water quality
  - Characteristics of the fabric to be processed: dyeing capacity, weight, moisture content
  - Errors in the weighing of dyes and chemical products
  - Dosage methods for the dyes and chemical products
  - Moisture content in dyes
  - Bath ratios
  - pH of dye bath
  - Time/temperature profiles in the dyeing process

- On occasion, what must be done is to request as much information as possible from clients and suppliers concerning the characteristics of the raw materials to be processed, of dyes, auxiliaries and chemical products, in order to adjust the recipes to be used, as far as possible, to the weight of the fabric and its characteristics.

Preparation of the mother printing pastes

- Use reusable recipients with a minimum moist area ratio to prepare the pastes.

- Weigh the products that are needed to prepare the paste exactly and precisely.

- The dyes being sensitive to moisture and temperature, the control of the environmental conditions has to be carried out in the storage area of the containers that have been “started” and the paste preparation area.

A reduction in the number of containers and their returnability

In the companies of the subsectors studied, there usually exists a great variety of dyes, chemical and auxiliary products, which means that they must be acquired in relatively small containers which, once empty, become waste products which must be suitably managed.

Nevertheless, some of the products used are consumed in quantities that allow them to be bought in larger, returnable containers, or even in bulk, in cistern lorries.

In each case, it is useful to adjust the volume of the containers to the degree of consumption of each product.

Nonetheless, it should be borne in mind that the plants where the availability of space is limited, the acquisition of containers or the installation of tanks for the reception of products from cisterns is, necessarily, very limited.

A reduction in water consumption

- Check that the taps, stopcocks and other devices to regulate the flow of water are not open unnecessarily or broken. Establish periodical inspection protocols.

- Clean equipment and utensils immediately after use to avoid formation of hardened deposits that require a greater consumption of water for cleaning.

Prevention of leaks and accidental spillage

- Store dangerous materials in areas where the probability of leakage is low.

- Store containers in such a way that the possibility of their breaking is minimal and the visual detection of leaks and spillage is facilitated.

- Install retention troughs to contain possible leakage from containers or tanks.

- Avoid, as far as possible, the positioning of buckets full of chemical products, finishes, printing pastes, etc. on the ground, in thoroughfares, given that it is easy to trip over them by mistake.

- Establish procedures for prevention, control and the action of the operatives in the event of an accidental spillage or leak. These procedures should include the preference of dry-collecting the spilled materials, whenever possible, rather than cleaning with water. Whenever possible, the collected product should be reused. Otherwise, it should be suitably treated as a waste product.

- Draft reports on all leaks and their associated costs.

A reduction in emissions into the atmosphere

- Keep recipients, baths, containers and equipment that contain substances with volatile organic compounds covered or closed, when they are not in use.

Product storage

- Use and store containers in accordance with the supplier's recommendations.

- Use suitable containers for the products they contain: they must be stable, easy to handle, closed, and it may be useful for them to have a dispenser device, etc.

- Separate from the ground all products by means of shelves or pallets and label them clearly and visibly.

- Visually inspect, on a regular basis, the physical state of the shelves, recipients, taps, dosage conduits, shut-offs, etc.
- Do not store liquid products above solid products.
- Separate alkaline products from acid products.
- Avoid contact between oxidising products and inflammable materials.
- Keep containers and drums tightly closed to avoid spillage and emissions into the atmosphere.
- Install level indicators on storage tanks for liquids and check their correct functioning regularly.

Control of inventories

- Use computerised systems to follow up raw materials and finished products and perform the control of stocks on a regular basis.
- Apply the "FIFO" philosophy (first in first out) in the use of dyes and auxiliary products in order to reduce as far as possible the generation of out-of-date products which should be treated as waste products.

6.2. OPPORTUNITIES FOR RECYCLING AT SOURCE

6.2.1. Recycling at source

6.2.1.1. Substitution of starch-type sizing products with synthetic, hydrosoluble sizes in the sizing of warps for manufacturing woven fabric

Traditional problem

Sizing is an essential operation in order to allow the high-speed production of woven fabric. The traditional sizing formulas involve the mixing of a high number of components (often starch-type components) which, once applied on the warp threads, are not dissolved by the wash water and so they must be eliminated from the fabric in the enzymatic desizing process, which is a long, costly process that pollutes wastewater.

Alternative technique

The substitution of starch-type sizing products with synthetic, hydrosoluble sizing products of the ethyl-vinyl-acetate or carboxymethyl-starch types, allows the substitution of enzymatic biotechnology with a simple wash to eliminate sizing products. Thus, quicker, more economical desizing processes are achieved. With the correct training of personnel on the quality control of these new sizing products, the aforementioned substitution may be carried out to allow:

- The reuse of sizing products by extraction, filtration and concentration in the case of a weaving company that has sizing and desizing sections.

- Getting right to the process of scouring/bleaching in a single stage.

- Making the enzymatic scouring process unnecessary.

Field of application

Conventional sizing machines are suitable for sizing with the new products.

Production benefits

The greatest benefits are obtained as long as it is the company that applies the glue that later performs the desizing and the processing of the desizing bath for the concentration and reuse of the size.

The substitution of enzymatic desizing with a simple wash process means that a reduction in the consumption of chemical products and process time can be achieved.

Environmental benefits

If the size is recycled at source, the environmental benefits are clear given that both the flow of wastewater generated and pollutant load are reduced.

When desizing is carried out by the textiles ennobling company and not at the weaving company (which besides, is the most common), the substitution of enzymatic desizing with a simple wash means that there is a reduction in the consumption of chemical products, the use of enzymes is eliminated and therefore, there is a reduction in the wastewater pollutant load.

Economic parameters

The new products have a higher cost than the traditional ones but, if they are reused, they end up being more economical.

6.2.1.2. Membrane technology for recycling wastewater

Traditional problem

Traditionally, wastewater is not usually recycled, not even once treated, and is dumped, either into public riverbeds or into the drainage network.

Alternative technique

The membrane filtering system means that wastewater can be recycled, that is to say, it can be reused in approximately the same processes in which it had previously been used.

The technology of the membranes used is based on microfiltering, ultrafiltering and nanofiltering. The membranes used are porous and act as filters, selecting the diameter of the particles that can be transferred from one side of the membrane to the other upon applying pressure.

As an example, the bibliography indicates the reduction percentages of COD and of colour, depending on the type of membrane used:

Table 31

TECHNOLOGY	COD REDUCTION (%)	REDUCTION IN COLOUR (%)
Microfiltering	20	14
Ultrafiltering	85	90
Nanofiltering	95	99

Any of the three technologies produces a permeate (filtered water) which is what, if there is compliance with the quality requirements, can be reused, and a concentrate (rejected water from the filtering operation that contains the material that has not been able to pass through the membrane).

Example of operational data:

Wastewater flow: 20 m^3/hour
Mean wastewater COD: 2,200 mg/l

Mean COD after biological treatment: 180 mg/l

Mean COD after filtering with membranes: 45 mg/l
Surfactant content: 0.5-1%
Colour: < 50 units

The filtered water presents characteristics of pollutant load and colour that make it suitable for its reuse in dyeing or in the washing operations after dyeing.

Field of application

Companies in the textiles ennobling sector that have primary and secondary treatments for their wastewater.

Production benefits

They have not been described.

Environmental benefits

The reuse of filtered water allows an important reduction in the consumption of water through its recycling. However, the concentrate that results from filtering must be adequately managed.

Economic parameters

This technology requires the availability of expensive facilities and machinery, but the highest cost of recycled water compared to water from the grid is compensated by a reduction in water consumption.

In a company that has been studied, with data corresponding to the year 2001, the following results were obtained:

- Mean cost of water entering the plant: 1.29 €/m^3

- Mean cost of treating 330,000 m^3/year: 1.33 €/m^3

Despite the cost of the recycled water being slightly higher than the incoming water, the environmental benefits it offers in saving large amounts of water and therefore, a reduction in emissions, are strong arguments in favour of the implementation of this technique.

Bibliography:

- *J. Porta "Membranas: proceso alternativo para reciclar agua residual" Revista de Química Textil issue 153, (2001), pp. 30-46.*

6.3. OPPORTUNITIES FOR WASTE RECOVERY

The industries in the dyeing, printing and finishing sectors generate waste textiles (fabric or lint) which, in some cases, may be reused in other industrial sectors. However, the existing options and the viability of each of them depend on large variety of factors such as the existing industrial structure in each geographical area or the environmental legislation that is in force.

As far as the recovery of energy is concerned, some waste products, such as used lubricating oils, used solvents or printing pastes, possess high calorific power and may be incinerated in order to recover energy.

Nevertheless, this is waste that may be regenerated or recycled, either at the same facilities where it has been generated or at specialised facilities. Recycling is considered as being the most environmentally correct option in waste manegement and has thus, priority over other options.

6.4. SUMMARY TABLE OF THE ENVIRONMENTAL BENEFITS OF THE POLLUTION PREVENTION OPPORTUNITIES

As stated in the introduction, some of the opportunities for the alternatives described in order to achieve pollution prevention could be classified in different sections and, in turn, could have positive repercussions on more than one environmental vector. Below is a summary table whose aim is to illustrate these synergies:

Table 32

	REDUCTION AT SOURCE			RECYCLING AT SOURCE
	SUBSTITUTION OF RAW MATERIALS	NEW TECHNOLOGIES	GOOD HOUSEKEEPING PRACTICES	
REDUCTION IN WATER CONSUMPTION	6.1.1.2 6.1.1.5 6.1.1.7	6.1.2.1 6.1.2.2 6.1.2.3 6.1.2.4 6.1.2.5 6.1.2.7 6.1.2.9 6.1.2.11 6.1.2.12 6.1.2.13	6.1.3.1 6.1.3.2 6.1.3.3 6.1.3.4 6.1.3.5 6.1.3.6	6.2.1.1 6.2.1.2 6.1.2.3
REDUCTION IN ENERGY CONSUMPTION	6.1.1.1 6.1.1.2	6.1.2.1 6.1.2.2 6.1.2.3 6.1.2.4 6.1.2.5 6.1.2.6 6.1.2.8 6.1.2.9 6.1.2.13	6.1.3.1 6.1.3.2 6.1.3.3 6.1.3.4 6.1.3.5 6.1.3.6	6.1.2.3
REDUCTION IN THE ONSUMPTION OF RAW MATERIALS	6.1.1.1 6.1.1.5 6.2.1.1	6.1.2.1 6.1.2.2 6.1.2.3 6.1.2.6 6.1.2.10	6.1.3.1 6.1.3.4	6.2.1.1 6.1.2.3
REDUCTION IN WASTEWATER POLLUTANT LOAD	6.1.1.1 6.1.1.3 6.1.1.4 6.1.1.5 6.1.1.6 6.1.1.7 6.2.1.1	6.1.2.1 6.1.2.2 6.1.2.3 6.1.2.4 6.1.2.6 6.1.2.9 6.1.2.10 6.1.2.11 6.1.2.12 6.1.2.13	6.1.3.1 6.1.3.2 6.1.3.4 6.1.3.5 6.1.3.6	6.2.1.1 6.2.1.2 6.1.2.3
REDUCTION IN EMISSIONS INTO THE ATMOSPHERE	6.1.1.5	6.1.2.2 6.1.2.7 6.1.2.8	6.1.3.5 6.1.3.6	—
REDUCTION IN THE AMOUNT OF WASTE GENERATED	—	6.1.2.2 6.1.2.3 6.1.2.11	6.1.3.6	6.1.2.3
IMPROVEMENTS FOR THE TREATMENT SYSTEM	6.1.1.1 6.1.1.3	6.1.2.2 6.1.2.3	—	6.1.2.3
INCREASE IN PRODUCTIVITY	6.1.1.1 6.1.1.2 6.1.1.4	6.1.2.1 6.1.2.2 6.1.2.4 6.1.2.6 6.1.2.7 6.1.2.9	6.1.3.3 6.1.3.4	—
OTHER BENEFITS	—	6.1.2.8	—	—

7. CASE STUDIES

7.1. CASE STUDY 1

COUNTRY: SPAIN
COMPANY: Fibracolor, S. A.

Improvement made: Wastewater treatment system by neutralisation with steam generator gases
Description: The company carries out the dyeing, finishing and printing of textiles. Most wastewater generated comes from the emptying of equipment, following the dyeing and bleaching operations. This water is characterised by its high basicity and must be subjected to a process of neutralisation prior to being treated biologically by the company's plant. Before implementing the improvement described below, 96% sulphuric acid was used for the neutralisation process. This meant a risk of temporary over-acidification and the presence of sulphates in the treated wastewater. The new acidification system that has been implemented uses the gases generated by the two cogeneration boilers, which are used to obtain steam for the production process. The fuels used are fuel oil and natural gas, and specifically, the acid nature of two gases that are generated in the normal burning of these fuels is taken advantage of: carbon dioxide and sulphur dioxide. As a consequence, at the same time as lower emissions of sulphur dioxide and carbon dioxide which come from the boiler burners is achieved, the consumption of sulphuric acid is also decreased, the risk of temporary over acidification is avoided and, thus, so is the risk in the biological WWTP operation. The concentration of sulphates in wastewater is considerably reduced, which increases the possibility of its reuse in processes. Furthermore, the handling and transport risks associated with the consumption of sulphuric acid is reduced, as well as possible accidental pollution. The economic advantages are also considerable since zero cost carbon dioxide is used and the consumption of sulphuric acid is reduced.
Investment: 210,354 €

Below is a table showing the main consumption and costs involved in the neutralisation operation, before and after the implementation of the aforementioned improvement:

	SITUATION PRIOR TO THE IMPLEMENTATION OF THE IMPROVEMENT	SITUATION AFTER THE IMPLEMENTATION OF THE IMPROVEMENT
Consumption of sulphuric acid	2,100 t/year	1,040 t/year
Consumption of used carbon dioxide	0 t/year	476 t/year
Presence of sulphates in wastewater	2,057 t/year	1,017 t/year
Energy consumption	Not significant	1,080 kWh/d
Annual cost of energy (0.051 €/kWh)		**20,138 €/year**
Annual savings in sulphuric acid (0.062 €/kg)		**68,515 €/year**

	€/YEAR
ANNUAL SAVINGS:	48,377

	YEARS
ESTIMATED PAYBACK PERIOD:	4.4

7.2. CASE STUDY 2

COUNTRY: SPAIN
COMPANY: Herederos de Salvador Segura, S. A.

Improvement made:

Development of a dyeing process with low environmental repercussions

Description:

The company carries out the dyeing of textile materials in general and, specifically, textile ennobling (wool, polyester, viscose, etc.). Fabric dyeing is done in autoclaves. Dosage of raw materials was done, prior to the implementation of the improvement described hereunder, manually, leading to the excessive consumption of chemical products and water, which, later, was transformed into wastewater characterised by high concentrations of BOD and suspended solids, colour and temperature.

The company has installed an integrated computer system which controls all stages in the dyeing process, consisting of:

- A central computer and processor, to elaborate the exact formulation and the activities programme
- Microprocessors, which control the opening of valves, the temperature curve and bath duration, quantities of water, dyes and other products
- Flowmeter to introduce the exact quantity of water
- Measurers, to weigh and dose the dyeing products

The company has managed to reduce the bath ratio used in the dyeing of thread and combed yarn from 1:20 to 1:6, which translates into a significant saving of water and raw materials. Moreover, an estimated reduction has been achieved of 30% of the carbon monoxide and carbon dioxide, nitrogen oxides and sulphur dioxide emissions as a direct consequence of the lower consumption of fuels in the boilers and the cogeneration engine.

Also noteworthy is the fact that this improvement in the quality of the wastewater has allowed the downgrading of the parameters included in treatment taxes, in turn leading to a shorter payback period for the initial investment.

Investment:

327,626 €

SITUATION PRIOR TO THE IMPLEMENT. IMPROVEMENT	QUANTITY	UNITS/YEAR
Energy consumption	1,893,375	TE/year
Water consumption	36,000	m³/year
Consumption of raw materials (dyes and chemical additives)	245	t/year
COD discharged (base 100)	100	
Suspended solids (base 100)	100	
Cost of energy consumption	25,035	€/year
Cost of water consumption	23,800	€/year
Cost of consumption of raw materials (dyes and chemical additives)	57,237	€/year
Cost of wastewater treatment	7,465	€/year

SITUATION AFTER THE IMPLEMENT. IMPROVEMENT	QUANTITY	UNITS/YEAR
Energy consumption	538,312	TE/year
Water consumption	10,800	m³/year
Consumption of raw materials (dyes and chemical additives)	198,17	t/year
COD discharged (base 100)	20.5	
Suspended solids (base 100)	18	
Cost of energy consumption	8,666	€/year
Cost of water consumption	7,140	€/year
Cost of consumption of raw materials (dyes and chemical additives)	46,144	€/year
Cost of wastewater treatment	2,239	€/year

	€/YEAR
ANNUAL SAVINGS:	49,348

	YEARS
ESTIMATED PAYBACK PERIOD:	6.6

7.3. CASE STUDY 3

COUNTRY: SPAIN
COMPANY: Acabats Barberá, S.L.

Improvement made:

Recycling at source of an enzyme desizing bath

Description:

The company belongs to the garment-ennobling sector for third parties, specifically denim.

All cotton finishing processes require prior desizing so that the processes to which the garment is later subjected have an effect. When the size used is starch, the simplest desizing process and through which the best results may be obtained is that carried out by means of enzymes, specifically amylases and cellulases.

Enzymes are expensive organic substances, basically formed of carbon, hydrogen and oxygen, which lead to an increase in the COD and BOD levels of wastewater. A process that allows its recycling at source in turn allows the significant reduction in the process cost and the wastewater pollutant load and, as a consequence, the treatment cost.

The company combined the effect of amylases and cellulases at the desizing stage in order to improve the result. It specifically used an 800 l bath of water to which 800 ml of amylases and 2 kg of cellulases were added. The cost of the bath was high and its COD, at the end of the desizing process, could reach 9,000 mg O_2 / l.

The company built a system that would send the desizing bath to a storage tank once the process had finished. The desizing baths from the different operational machines are accumulated in this tank. Automatically, the necessary bath volume for the next machine to become operative is measured and sent. When reaching the machine which starts the new desizing process, 30% of the enzymes that would have been used if the bath had been prepared again are added, and 100% of the auxiliaries. This process may be repeated up to 20 times per day, five days per week. Once per week, all desizing baths are renewed and are poured into the company's treatment system.

Investment:

57,276 €

	FORMER PROCESS	CURRENT PROCESS
Production (kg of fabric/year)	736,000 kg/year	736,000 kg/year
Consumption in the desizing process - Cellulases (kg) - Amylases (l) - Water - Other bath components	 10,284 kg/year 4,114 l/year 4,113,600 l/year 5,142 l/year	 3,285 kg/year 1,394 l/year 600,000 l/year 5,142 l/year
COD effluent	37,022 kg O_2/year	5,400 kg O_2/year
Desizing process cost - Enzymes - Water - Other bath components	124,463 €/year 116,365 €/year 3,807 €/year 4,291 €/year	42,443 €/year 37,596 €/year 555 €/year 4,291 €/year
Treatment cost	3,708 €/year	541 €/year
TOTAL COST	**128,172 €/year**	**42,984 €/year**
SAVINGS	**85,188 €/year**	

	MONTHS
ESTIMATED PAYBACK PERIOD:	8.4

7.4. CASE STUDY 4

COUNTRY: TURKEY
Location of the company: Istanbul, european side

Improvement made: Reduction in dyeing reoperations from 5% to 1%
Description: Crucial in dyeing operations is the achievement of the desired shade and colourfastness of the fabric being processed. Fluctuations in the quality of the fabric, as well as production volumes handled require the adjustment of operational parameters (reaction time, concentration of dye and chemical auxiliaries, etc.) in order to ensure the desired quality. If this adjustment is not achieved, errors arise in dyeing which require the reprocessing of fabrics, consuming chemical products and additional resources. Consequently, the percentage of fabrics that require reprocessing is an important parameter, which influences the consumption of water, energy and chemical products used in dyeing and the later washing operations. Furthermore, the reduction of this parameter is a good indicator of the potential for improvement. Below is a summary of the results obtained with the implementation of this improvement: • Reduction in water consumption: 1.1 % • Reduction in thermal energy consumption: 0.8% • Reduction in the consumption of chemical products: 1.7% • Reduction in overall cost: 1.0% • Total annual savings: 24,568 €
Investment: Not significant.

SITUATION PRIOR TO THE IMPLEMENT. IMPROVEMENT	QUANTITY	UNITS/YEAR
Energy consumption	102,742,422	MJ/year
Water consumption	381,696	m^3/year
Consumption of raw materials	3,549	t/year
Generation of wastewater	316,808	m^3/year
Generation of waste	72,832	Kg/year
Cost of energy consumption	963,624	€/year
Cost of water consumption	238,047	€/year
Cost of consumption of raw materials	1,036,646	€/year
Cost of wastewater treatment	112,416	€/year
Cost of waste management	3,763	€/year
Other costs	—	—

SITUATION AFTER THE IMPLEMENT. IMPROVEMENT	QUANTITY	UNITS/YEAR
Energy consumption	101,952,869	MJ/year
Water consumption	377,395	m^3/year
Consumption of raw materials	3,487	t/year
Generation of wastewater	313,238	m^3/year
Generation of waste	72,832	Kg/year
Cost of energy consumption	956,218	€/year
Cost of water consumption	235,364	€/year
Cost of consumption of raw materials	1,023,433	€/year
Cost of wastewater treatment	111,148	€/year
Cost of waste management	3,763	€/year
Other costs	—	—

	MONTHS
ESTIMATED PAYBACK PERIOD:	Immediate

Referencie: Mirata, M., "Use of Environmental Performance Indicators to Promote Cleaner Production Technologies in Small and Medium Sized Cotton Textile Wet Processing Industry", MSc Thesis, Middle East Technical University, Department of Environmental Engineering, Sep 2000, Ankara, Turkey.

7.5. CASE STUDY 5

COUNTRY: TURKEY
Location of the company: Denizli

Improvement made:

A reduction in the bath ratio of certain machines, from 1:9 to 1:4

Description:

The “bath ratio” parameter is of great importance given that it directly influences the consumption of water, energy and chemicals that are used in each of the stages of the textiles process in discontinuous mode. The bath ratio value is a good indicator of the existing potential for improvement, from both the economic and the environmental points of view. This improvement may be achieved thanks to the adaptation of cleaner technologies. The “bath ratio” parameter, furthermore, has a great value since it allows the monitoring of the improvements achieved.

The reduction in the bath ratio from 1:9 to 1:7 can be achieved by changing the conditions in which the processes are performed. Nevertheless, to achieve a reduction from 1:7 to 1:4, new machinery must be acquired.

The company has overflow machines with a total capacity of 2,900 kg. Replacing these machines by ULLR-type jets (ultra low bath ratio) (3 of 600 kg, 2 of 300 kg and 3 of 150 kg capacity) meant an investment of 1,026,882 €.

The reduction in the bath ratio from 1:9 to 1:4 could imply a water savings of up to 55%. The annual savings, in this case, are 618,220 €, which means 4.4% of the overall cost, which is considered as being the sum of the cost of the water, energy and the chemical products consumed in the wet processes.

Below is a summary of the results obtained with the implementation of this improvement:

- Reduction in water consumption: 55%
- Reduction in thermal energy consumption: 41.25%
- Reduction in the consumption of chemical products: 55%
- Reduction in the overall cost: 46.8%
- Total annual savings: 618,220 €

Investment:

1,026,882 €

SITUATION PRIOR TO THE IMPLEMENT. IMPROVEMENT	QUANTITY	UNITS/YEAR
Energy consumption	71,692,991	MJ/year
Water consumption	239,526	m^3/year
Consumption of raw materials	1,589	t/year
Generation of wastewater	198,806	m^3/year
Generation of waste	42,493	Kg/year
Cost of energy consumption	711,963	€/year
Cost of water consumption	149,382	€/year
Cost of consumption of raw materials	364,582	€/year
Cost of wastewater treatment	70,544	€/year
Cost of waste management	3,763	€/year
Other costs	—	—

SITUATION AFTER THE IMPLEMENT. IMPROVEMENT	QUANTITY	UNITS/YEAR
Energy consumption	42,116,218	MJ/year
Water consumption	106,456	m^3/year
Consumption of raw materials	706	t/year
Generation of wastewater	88,358	m^3/year
Generation of waste	42,493	Kg/year
Cost of energy consumption	418,244	€/year
Cost of water consumption	66,391	€/year
Cost of consumption of raw materials	162,262	€/year
Cost of wastewater treatment	31,353	€/year
Cost of waste management	3,763	€/year
Other costs	—	—

	MONTHS
ESTIMATED PAYBACK PERIOD:	20

Reference: Mirata, M., “Use of Environmental Performance Indicators to Promote Cleaner Production Technologies in Small and Medium Sized Cotton Textile Wet Processing Industry”, MSc Thesis, Middle East Technical University, Department of Environmental Engineering, Sep 2000, Ankara, Turkey.

7.6. CASE STUDY 6

COUNTRY: TURKEY
Location of the company: Denizli

Improvement made: Installation of a heat exchanger for energy recovery
Description: Heat recovery from the discharge of hot baths was achieved with total efficiency in the thermal energy recovery cost of 17.57%. The cost of a heat exchanger for a capacity of 1 t/h, was 430 €. This cost increases arithmetically as capacity increases. The company needed a capacity of 26 t/h for the recovery of heat and so, including other additional elements for heat recovery, the cost of the equipment totalled 11,183 €. The annual savings reached through heat recovery were 205,458 €, and hence the payback period was less than a month. Below is a summary of the results obtained with the implementation of this improvement: • Reduction in water consumption: - % • Reduction in thermal energy consumption: 29.4% • Reduction in the consumption of chemical products: -% • Reduction in overall costs: 17.8% • Total annual savings: 205,458 €
Investment: 11,183 €

SITUATION PRIOR TO THE IMPLEMENT. IMPROVEMENT	QUANTITY	UNITS/YEAR
Energy consumption	71,692,991	MJ/year
Water consumption	239,526	m^3/year
Consumption of raw materials	1,589	t/year
Generation of wastewater	198,806	m^3/year
Generation of waste	42,493	Kg/year
Cost of energy consumption	711,963	€/year
Cost of water consumption	149,382	€/year
Cost of consumption of raw materials	364,582	€/year
Cost of wastewater treatment	70,544	€/year
Cost of waste management	3,763	€/year
Other costs	—	—

SITUATION AFTER THE IMPLEMENT. IMPROVEMENT	QUANTITY	UNITS/YEAR
Energy consumption	51,003,884	MJ/year
Water consumption	239,526	m^3/year
Consumption of raw materials	1,589	t/year
Generation of wastewater	198,806	m^3/year
Generation of waste	4,493	Kg/year
Cost of energy consumption	506,505	€/year
Cost of water consumption	149,382	€/year
Cost of consumption of raw materials	364,582	€/year
Cost of wastewater treatment	70,544	€/year
Cost of waste management	3,763	€/year
Other costs	—	—

	MONTHS
ESTIMATED PAYBACK PERIOD:	1

Reference: Mirata, M., “Use of Environmental Performance Indicators to Promote Cleaner Production Technologies in Small and Medium Sized Cotton Textile Wet Processing Industry”, MSc Thesis, Middle East Technical University, Department of Environmental Engineering, Sep 2000, Ankara, Turkey.

7.7. CASE STUDY 7

COUNTRY: TUNISIA
COMPANY: Société Industrielle de Textile – SITEX (Production of Denim- and Indigo-type fabrics)
(Taken from MEDCLEAN No. 10)

Improvement made:

Implementation of a cleaner production programme

Description:

Aware of the importance of cleaner production as a useful tool in the protection of the environment, the Centre International des Technologie de l'Environnement de Tunis (CITET), National Focal Point of the RAC/CP in Tunisia, has carried out a pilot project on the methods of production rationalisation, optimisation of processes and minimisation of waste with the aim of reducing production costs, the impact of industrial activities on the environment and increasing the competitiveness of companies. This project was carried out in several different sectors and, in the case of the textiles industry, was carried out at the company SITEX.

The main objectives that were pursued with the implementation of the cleaner production programme at SITEX were:

1. To reduce water consumption in the fabric finishing process
2. To reduce the impacts produced by the fabric dyeing process on the environment

Three options were identified for the prevention of pollution:

1. To reduce water consumption in the rinsing process and to eliminate the vat and rinsing bath No. 5. A saving of 6 m^3/h of clean water is achieved. This reduction was only possible after establishing total control of the water flow in the rinsing process.

2. To recover the cooling water from the singeing process from the Goller machine and send it to the Frigotol refrigeration tank. A saving of 3.3 m^3/h of clean water is achieved.

3. To recover the cooling water from the yarn singeing process from the Dénimrange machine and send it to the Frigotol refrigeration tank. A saving of 4 m^3/h of clean water is achieved.

Investment:

4,972 €

	OPTION 1	OPTION 2	OPTION 3	PROJECT OVERALL
Annual reduction in water consumption	18,000 m³/year	10,000 m³/year	12,000 m³/year	
Annual economic savings	28,837.6 €/year	15,910.4 €/year	18,893.6 €/year	63,641.6 €/year
Annual reduction in energy consumption	843,000 th/year			
Annual economic savings	12,927.2 €/year			12,927.2 €/year
Annual reduction in the consumption of chemical products	32.8 t/year	18 t/year	22 t/year	
Annual economic savings	10,938.4 €/year	5,966.4 €/year	6,960.8 €/year	23,865.6 €/year
Annual reduction in the consumption of spare parts and maintenance				
Annual economic savings	8,949.6 €/year			8,949.6 €/year
Total economic-savings	61,652.8 €/year	21,876.8 €/year	25,854.4 €/year	109,384 €/year
Investment	994.4 €/year	1,988.8 €/year	1,988.8 €/year	4,972 €/year
Payback period	immediate	1 month	1 month	17 days

1 $ = 0,9944 €

7.8. CASE STUDY 8

COUNTRY: TURKEY
COMPANY: First Textile
(Taken from MEDCLEAN No.13)

Improvement made: Implementation of a cleaner production programme
Description: The company First Textile produces knitwear fabrics, yarn, dyed fabrics (cotton, polyester and polyester/cotton) and printed fabrics. Its production capacity is approximately 1,600 t/year of knitwear fabrics, 4,500 t/year of dyed fabrics, 800 t/year of dyed yarn and fibres and 940 t/year of printed fabrics. This company has been awarded the EKO-TEX-100 standard. The company carried out an assessment of its processes and identified several opportunities for minimisation. Some of the possibilities identified are summarised below: 1. Recovery of heat from the stenter frames of the looms and wastewater. 2. Decrease in the bath ratio in the bleaching and dyeing processes, which was at 1:10. 3. Water savings and the elimination of the use of some raw materials from the processes of the bleaching and dyeing of cotton fabrics. 4. Water savings in the regeneration processes of the conditioning resins for the process water, which are washed in countercurrent fashion with a sodium chloride solution. Following the feasibility study, some of the possibilities identified were implemented. Specifically they were: 1. The company incorporated air-water heat exchangers at the stenter frame output to thus supply hot water to certain parts of the dyeing process. 2. The bath ratio was reduced in the bleaching and dyeing processes to 1:8. 3. The formulation used in the bleaching and dyeing processes for cotton fabrics was modified. Some washes were eliminated as well as some of the neutralisation processes and the amount of detergent used was reduced. 4. The regeneration process for the resins that soften the input process water was optimised.

OPTION	ENVIRONMENTAL BENEFITS	COST (investment + operational)	ANNUAL SAVINGS	PAYBACK PERIOD
1	• Reduction in steam and energy consumption • Control of emissions	326,978.6 €	510,127.2 €	1 year
2, 3	• Reduction in the consumption of water, energy and chemicals	0 €	32,188.73 € - 58,013.3 €	immediate
4	• Reduction in water consumption and salts	19,888 €	57,356.99 €	3 months

7.9. CASE STUDY 9

COUNTRY: EGYPT
COMPANY: El Nasr Spinning and Weaving Co
Dakahleya Spinning and Weaving Co
Amir Tex Co
(Taken from MEDCLEAN No. 20)

Improvement made:

Prevention of pollution in the process of sulphur black dyeing

Description:

El Nasr Spinning and Weaving Co, Dakahleya Spinning and Weaving Co, and Amir Tex Co are three textiles companies where an industrial audit was carried out with the aim of determining the possibilities of preventing pollution in the sulphur black dyeing process.

Sulphur black dyes are used to achieve a jet black on cotton fibres; this is done by converting it into a substance that is soluble in water thanks to the addition of a reductive agent, normally sodium sulphide, and hence the fibre absorbs the dye. After dyeing, the dye returns to its insoluble state due to the addition of an oxidising agent, often acid dichromates. Both substances, the sodium sulphide and the acid dichromate, are toxic and their use may leave harmful waste on the fabric once finished, and generate effluents that are difficult to manage.

The audit carried out at the companies detected cleaner production opportunities by substituting chemicals. Thus analyses were carried out in order to determine the feasibility, costs and the quality of using several potential substitutes for the sodium sulphide and the acid dichromate; likewise, pilot tests were carried out in order to ascertain their application on an industrial scale. Furthermore, opportunities for the optimisation of the process were identified in order to improve productivity and obtain economic savings.

The following measures were adopted:

1. *Substitution of sodium sulphide and acid dichromate.*
   Through this the treatment of effluents was improved and savings were obtained in wastewater treatment.
   - Substitution of sodium sulphide: it was replaced in the three factories with glucose which, when used with sodium hydroxide, gives very dark shades, and has a lower cost than other possible replacement substances. On the other hand, the elimination of the free sulphur avoids the previously existing problem of softening during storage.

   - Substitution of dichromate: at *El Nasr Spinning and Weaving Co.,* dichromate was substituted by sodium perborate as an acceptable substitute, cheaper than others and, at *Dakahleya Spinning and Weaving Co. and Amir Tex Co.,* hydrogen peroxide was preferred, given that it is particularly suitable for knitwear (one of the main products at both companies).

2. *Optimisation of the process:*
   - At El Nasr Spinning and Weaving Co. the soaping bath temperature was reduced. The results were savings in steam (16%) and electricity (22%) and a 2- hour reduction in process time.
   - At *Dakahleya Spinning and Weaving Co.* the cold washes were situated between the dyeing and oxidation stages, and two baths were removed: one cold bath after oxidation, and the other hot after soaping. The results were the reduction in the cost of steam, water and electricity of between 38 and 39%, and the process time was reduced from 13 to 8 hours, with the consequent increase in production capacity.
   - At *Amir Tex Co.* Two cold washing stages were omitted (after overflow washing), which cut water consumption by 15% and also the temperature and duration of the oxidation bath. Likewise, savings were made in electricity (18%), steam (21%), water (15%), time and work.

OPTION	**ENVIRONMENTAL BENEFITS**	**ADDITIONAL COSTS (increase in cost of chemical substances used —glusose—) (€/t of processed fabric)**	**SAVINGS (€/t of processed fabric)**	**PAYBACK PERIOD**
Substitution of sodium sulphite and dichromate	• Reduction in toxic waste in wastewater • Elimination of toxic materials from the working area	• El Nasr Spinning and Weaving Co: 23.82 • Dakahleya Spinning and Weaving Co: 3.57 • Amir Tex Co	• El Nasr Spinning and Weaving Co: 91.23 • Dakahleya Spinning and Weaving Co: 118 • Amir Tex Co: 61.26	Immediate
Optimisation of the process	• Reduction in water and steam consumption • Savings in electricity			

7.10. CASE STUDY 10

COUNTRY: TURKEY
COMPANY: Pisa Tekstil ve Boya A. S.

(Taken from MEDCLEAN No. 21)

Improvement made:
Pollution prevention at a company in the cotton subsector

Description:
The environmental diagnosis performed at this company assessed the factory's water consumption and identified opportunities for pollution prevention and reduction in water and energy consumption that did not require large investments. These opportunities are summarised below:

- Heat recovery by means of steam-liquid heat exchangers
- Reduction of the bath ratio in the dyeing process
- Reuse of treated wastewater
- Possibilities of energy recovery
- Reduction in water consumption in the regeneration process of process water-conditioning resins

Following a feasibility study which took into account technical, environmental and economic aspects, the following opportunities were chosen:

1. Reduction in the bath ratio in the dyeing process from 1:7 to 1:4
2. Reuse of wastewater for the pre-washing of filters
3. Optimisation of the resin regeneration process by controlling water hardness. The company carries out a regeneration process that takes 62 minutes, although after 43 minutes water hardness is negligible. If the regeneration process is done in 43 minutes, not only is there a reduction in operation time of 19 minutes, but also savings of 3 m^3 of regeneration water are made. Given that two resin regeneration processes are performed daily, the daily regeneration water saving is 6 m^3. Economic savings are also made, since the cost of 1 m^3 of water for the process, including the cost of the water, its prior treatment, the treatment of the wastewater and discharge costs is 0.64 €/m^3.

		FORMER PROCESS	NEW PROCESS	SAVINGS
Input	Energy consumption (kWh/d)	880.2	877.2	3
	Consumption of chemicals (kg/d)	1,924	1,916	8
	Consumption of chemicals (€/d)	149	143.3	5.7
	Water consumption (m^3/d)	1,800	1,794	6
	Water consumption (€/d)	929.6	925.5	4.1
Output	Chemicals (kg/d)	1,163	1,156	7
	Chemicals (€/d)	82.3	81.3	1
	Wastewater (€/d)	602.2	599.1	3.1
Environmental benefits			• Lower energy consumption • Lower water consumption • Lower consumption of chemicals for wastewater treatment • Less wastewater generated	
Cost			The investment and operational cost is negligible	
Annual savings			**2,007.5 €**	
Payback period			**Immediate**	

7.11. CASE STUDY 11

COUNTRY: EGYPT
COMPANY: El-Nasr
(Taken from MEDCLEAN No. 27)

Improvement made:

Conservation of water and energy in the textiles sector

Description:

The main activities of El-Nasr company (Mahalla El-Kobra, Egypt) are: yarn, fabric and wet processing. Annual production figures are, approximately, 8,000 tonnes of net material, of which 20% corresponds to cotton yarn, 12% yarn with polyester blends and 68% raw fabric.

Within the framework of a SEAM project, an industrial audit was performed on the company and several opportunities for pollution prevention were identified. Below is a description of the most important ones:

1. Incorrect storage of end dyes and fabrics reduced the expiry dates of the dyes, producing stains on the fabrics.
2. Inadequate insulation of the steam and hot water pipes meant considerable heat loss.
3. Condensation of steam from all departments was directly deposited in the drainage system instead of being recirculated as feed water, producing an unnecessary water loss.
4. Huge quantities of thermal energy were lost in the combustible boiler gases emitted to the atmosphere.
5. Discharge into the sewerage system of considerable amounts of hot effluents in the pre-treatment and dyeing departments caused considerable energy losses.
6. Huge quantities of end wash water from the bleaching process were directly discharged without its being utilized.

Special attention was paid to those improvements that could be put into practice at low or nil cost, given their simple implementation and since they often involved significant savings.

It was found that the pre-treatment and dyeing stages had great potential for savings, mainly concentrating on water and energy savings. The following action was taken concerning these:

1. Collection and use of condensed steam
2. Improvement in the insulation of the steam and hot water networks
3. Countercurrent flow of the Kyoto line
4. Installation of automatic shut-off valves in the bleaching lines
5. Utilization of the water from the end wash in the bleaching process
6. Recovery of thermal energy and use of wash water used from the scrubbing of the yarn and dye liquids
7. Improvements in storage (dyes and fabrics)
8. Optimisation of the use of chemicals by replacing some of them.

What was achieved:

- A 20% reduction in water consumption
- A 20% reduction in wastewater generation
- A 5% reduction in energy consumption
- A 5% reduction in the consumption of chemicals
- A 5% reduction in fuel consumption

FACTORY DEPARTMENT	ACTION	CAPITAL & EXPLOI-TATION COSTS (€)	ANNUAL SAVINGS (€)	PAYBACK PERIOD (months)
Measures already implemented				
All	Recovery of condensed steam	13,203.0	39,638.3	<4
	Improvement in the insulation of steam and hot water networks	14,083.2	39,646.0	<5
	Improvement in storage facilities	0	6,689.5	Immediate
	Optimisation of the use of chemicals	0	10,269.0	Immediate
Pretreatment fabrics	Countercurrent flow in the Kyoto line	12,909.6	65,064.4	<3
Subtotal		**40,195.8**	**161,307.2**	**<3**
Additional measures to be implemented				
Pretreatment fabrics	Installation of automatic shut-off valves, Gaston County line	10,709.1	13,159.0	<10
	Recycling of the end wash water	8,802.0	41,442.8	<3
Yarn dyeing	Thermal recovery from hot liquors	23,472.0	31,443.7	<9
Subtotal		**42,983.1**	**86,045.4**	**<6**
COST / OVERALL BENEFIT RATIO		**83,178.9**	**247,352.6**	**4**

8. PROPOSALS AND FINAL CONCLUSIONS

The textiles sector can be considered an important input to the economy of most of the Mediterranean countries, as may be seen in the data received on their contribution to the GDP, which varies between 1%, in the case of Israel, and 23%, in the case of Syria. Nevertheless, the textiles sector presents differentiated structures in the Mediterranean countries. This, together with the heterogeneity of the information received, with regard to the subsectors that are the object of this study: dyeing, finishing and printing, makes comparison among countries difficult. In some countries, these subsectors are not dealt with separately, and so it has not been possible to obtain data that refer to them exclusively.

Based on the information received, it can be seen that most companies in the dyeing, finishing and printing subsectors may be considered as being SMEs, although large companies also exist, sometimes in the public sector, in countries such as Egypt and Libya.

Regarding types of raw materials, the great importance of the cotton industry in countries such as Egypt, Turkey and Syria should be highlighted; and for wool, in countries such as Libya, Syria, Tunisia and Turkey.

The situation of the textiles sector concerning environmental management is diverse, specifically in the dyeing, finishing and printing subsectors, given that both legal obligations and the infrastructures available in the different countries are also diverse. With regard to costs relating to environmental management, it can be concluded that the main costs concern the supply of water, the cost of treating wastewater and the taxes that are applicable as well as the cost of waste management. Other costs, such as taxes on water consumption, generation of waste or emissions into the atmosphere, or the cost of treating these emissions are of less importance or are non-existent.

As we have seen in previous chapters, the subsectors dealing with dyeing, finishing and printing present a series of characteristics that determine and condition their environmental effects. These characteristics are:

- Raw materials (fibres and fabrics) from other companies, even from other countries and, often, with no knowledge of the chemical products that may have been used at previous stages of their manufacture and may affect the later stages of ennoblement.
- A great variety of processes (one establishment often processes different types of fibre and fabric with the same equipment or with different equipment in order to achieve a wide variety of finishes).
- Processes that quickly change with time (one establishment often varies the fabric or fibre it uses as a raw material as well as the processes of ennoblement to which they are subject according to the demand of the market and the fashion at the time, and so these processes may be significantly different from one season to another. Moreover, the size of consignments to be processed may also change from one season to the next).

- The processes can be continuous, semi-continuous or batch but they always constitute different processing stages.
- The "re-operation" or "additions" of the same consignment until the desired quality is achieved is possible in bleaching and dyeing. It is not the case of some printing and sizing processes.
- Many of the stages (dyeing and finishing) are done wet and at a high temperature, which implies important water and energy consumption.
- Many of the wet stages need water of a certain quality and so processes are needed to adapt the water such as electrodialysis or reverse osmosis.
- The great variety of processes that exist in any one establishment requires the handling of a large number of colouring agents, auxiliary products and chemical products.

Given these basic characteristics, the following environmental effects are generated:

- High water and energy consumption.
- Greater or lesser consumption of colouring agents, auxiliary and chemical products depending on the available technology.
- Large volume of wastewater with a significant pollutional load. (Although the pollutant load of wastewater generated depends on the processes carried out, the parameters that are usually most significant are COD, BOD, total solids, AOX, toxicity, and sometimes nitrogen).
- Generation of colouring agents, auxiliary and out-of-date chemical products due to the great variety that an establishment must handle and the changes in their level of consumption from one season to another.
- Generation of a large number of empty containers, corresponding to colouring agents, auxiliary and chemical products used in the process.
- Emission into the atmosphere of volatile organic compounds, if colouring agents and/or auxiliary products that contain such compounds have been used in formulating them.

However, as we have explained previously in chapter 6 and indicated in the chapter that deals with case studies, this situation allows the implementation of a large number of improvements in order to achieve pollution prevention and savings of natural resources. Broadly speaking, bearing in mind the diversity of the sector, and in order to maintain competitiveness among companies, the solution lies in the introduction, in each particular case, of the improvement or improvements that are considered as being most suitable from among all those possible.

A brief list of such improvements would be:

- Insulation of all pipes and equipment that use steam or hot water, in order to minimise energy loss.
- Assessment of possibilities for heat recovery, whether by means of hot gases, steam or hot water.

- Identification of the possibility for reducing the number of stages carried out wet, by carrying out two or more stages in the same bath. In this way, usually, water and energy consumption as well as auxiliary and chemical product consumption is reduced.

- Optimisation of processes and equipment in order to reduce the number of baths used and thus minimise water consumption.

- To implement the automatic control of the critical variables of the process in order to minimise the indices of “re-operation” and “additions”, with which not only are water, energy colouring agents, auxiliary and chemical products saved, but also the company’s productivity can be increased.

- Automation of the preparation of dye baths, pastes for printing and additives, by means of automatic colour laboratories and the automatic dosage of auxiliaries in order to minimise potential errors which would have repercussions on a higher incidence of “re-operation” and “additions”.

- Identification of the possibilities for wastewater reuse in specific processes such as, preliminary rinsing

- Assessment of the possibility for recycling at source some of the baths, some additives and remains of printing pastes.

- Optimisation of machine and utensil cleaning operations.

- Reduction, as far as possible, of the variety of colouring agents, auxiliary and chemical products that are used; and correct storage and control of stocks of all of these in order to reduce the generation of out-of-date products or products that are in a bad state that need to be managed as waste.

- Adaptation of the volume of the containers in which colouring agents, auxiliary and chemical products are acquired to the degree of consumption of each product. In the cases in which consumption is high, it would be interesting to have facilities for the bulk receipt of the product, given that in this way, the generation of empty containers would be avoided.

However, in order to carry out some of these possibilities, it is necessary to substitute certain raw materials, acquire certain facilities and/or the introduction of certain new technology (as indicated in chapter 6) which, although they may be interesting targets in themselves due to the environmental benefits they bring, they may also be requirements for achieving more global targets.

Analysis of the economic feasibility of the different alternatives should be made in each particular case, given that the investments that are required will depend on each company’s pre-existing technology.

In any case, the introduction of any of the previously mentioned cleaner production options and, especially when dealing with the substitution of raw materials or modifications in the processes, should be accompanied by information and training of the employees so that the desired environmental benefits may be obtained and maintained without affecting either the quality of the product or the company’s productivity.

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