BAT Guide for textile industry

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0 INTRODUCTION

This guide forms part of the work done by the Ministry of Environment and Urbanism of Turkey (MoEU) to align the environmental policies to the standards of the European Union. Within this context, one of the key targets is the alignment with the specifications stated in Chapters I and II of the Industrial Emissions Directive 2010/75/EU which establish an integrated environmental permits system. According to these Chapters of the Directive, the environmental conditions established in the new integrated environmental permits must be based on the so-called Best Available Techniques (BATs) and the associated Emission Levels (AELs), which are described in a series of BATs Reference Documents (BREFs).

Work has been performed by the MoEU to transpose those two Chapters, in order to start the implementation of the new integrated environmental permits system, and as the associated environmental standards requested to the industries falling within the scope of this system will be substantially changed, there is a need of awareness and tools that may help them and the environmental authorities to start taking some measures in order to soften this transition.

The first step taken by the MoEU to foster the use of BATs in the textile sector has been the publication of the “Communication 28142 on integrated pollution prevention and control in the textile sector” in December of 2011. In this communication several obligations for the operators were established, and among them “ensuring the control of all kinds of emissions, discharges and wastes by applying the best available techniques”, listing in Annexes I, II and III a set of BATs selected from the BREF for the textile sector.

Nevertheless it has been considered necessary and useful to take a second step through the preparation of this guide. The excessive length and wide scope of the BREF for the textile sector, the need to provide information about some pollution abatement techniques which are either not enough explained in the BREF or not even appearing in it due to the evolution in the technologies since the publication of the BREF (2002), plus the importance of this sector in Turkey were the reasons to prepare a BAT National Guide for the Textile Industry, focussed just on this kind of installations, more understandable and adapted to the characteristics of the sector in Turkey. It includes in addition other information practical for both this industry and the staff of the MoEU. Moreover, it may serve as well to communicate to a broader audience the main characteristics of the sector and its main pollution abatement techniques, given its simple and concise style.

The objectives of this guide are the following:

- Present an overview of the sector in Turkey, and its current position in terms of environmental performance, with reference to the currently applicable environmental legislation (Chapters 1 & 3).
- Describe the processes, technologies and techniques particular of this kind of industry (Chapter 2).

- Discuss the BATs and some emerging techniques to increase the environmental performance, and present the ranges of AELs associated to them whenever this is possible (Chapters 4 & 6).
- Discuss the available tools and methods to monitor and control the environmental impacts of the installations (Chapter 5).
- Provide in some annexes useful reference tools, such as a check list of the contents that an integrated environmental permit for a textile installation should have.

In this manner, this guide should constitute a reference for both the staff of the MoEU responsible for the issuance of environmental permits for this sector, and for the textile industry representatives. This guide is not a law stating some emission limit values (ELVs) for certain parameters which have to be respected, but rather a reference on which the environmental authority should base its decisions on the contents of environmental permits issued to installations of this sector, taking of course as well into consideration the relevant applicable environmental legislation in the process of issuance of the new permits.

1 GENERAL INFORMATION ON THE TEXTILE INDUSTRY IN TURKEY.

1.1 IMPLEMENTATION OF THE DIRECTIVE ON INDUSTRIAL EMISSIONS IN THE TEXTILE SECTOR

1.1.1 National Legislation transposing the permitting requirements of the Directive on Industrial Emissions. Other sectoral legislation applicable to the sector.

The Ministry of Environment and Urbanism is drafting the By-Law on Integrated Environmental Permits, that will transpose the permitting requirements stated in chapters 1 and 2 of the Directive on Industrial Emissions 2010/75/EU. Explanations about how to implement in practice this new By-Law are provided in the guidance document “Integrated Environmental Permits: Supporting guideline for the Applicants” .

The list of current national environmental legislation of relevance for the environmental permitting of textile installations is provided in Annex VI.

1.1.2 Installations regulated under this legislation and covered by this guidance

The installations covered by this guidance which are subject to the legislation mentioned in section 1.1.1 are the ones fulfilling both of the following conditions:

- Installations for pre-treatment (operations such as washing, bleaching, mercerisation) or dyeing of natural and synthetic fibres, as well as textile products and fibres requiring dying and other finishing treatments,
- with a nominal treatment capacity exceeding 10 tonnes per day.

1.1.3 Administrative procedure to apply for the Integrated Environmental Permit.

The administrative procedure is explained in detail in chapter 5 of the guidance document “Integrated Environmental Permits: Supporting guideline for the Applicants” .

1.1.4 Preliminary comments about the textile industry in Turkey

Textile industry is one of the longest and most complex industrial chains in manufacturing industry in general. Having demands from three main final area of use as clothing, home textile and industrial use, this industry is a heterogeneous sector dominated by SMEs and separated into sub-sectors. (Textile BREF)

Textile and ready-made clothing industry are evaluated together in Turkey, and these sectors are traditional branches of industry that are indispensable due to their success at export. Textile and apparel sectors are still the sectors that have the largest foreign trade surplus. Additionally, they contribute significantly to decrease unemployment and welfare of the society via the employment opportunity they create. These sectors have an important role in the world with their reputation of high technology and with designs possessing the power to determine quality of product, fashion and trends. While yarn production is intensely carried out in the provinces like Istanbul, Adiyaman, Gaziantep, Bursa; Denizli stands out with the production of towel, bathrobe and home textiles; Usak with yarn and blanket; Corlu and Cerkezkoy with textile finishing; Adana with cotton weaving and finishing; Gaziantep with polypropylene, spunlace and machine carpets; Istanbul with apparel and knitting. (Sector report of textile, ready-made, leather and leather products, Min. of Industry, April 2012)

The number and location of the installations for textile finishing is given at the following table: (TTTSD, data of 2011)

Number of installations for textile finishing:
599
Location of the installations:
Marmara Region : 419 Aegean Region: 86 Mediterranean Region: 46 Southeast Anatolian Region: 29 Other: 19

The main purpose of the Turkish Textile Industry is to maintain and increase international competitive power and market share in spite of the major changes progressively taking place in the World Textile Markets (at the production, at the foreign trade) and in the expectations from textile products. (9th development plan, DPT,2007-2013)

1.2 TECHNOLOGICAL STATUS OF THE TURKISH TEXTILE SECTOR.

1.2.1 Yarn production

Depending on spinning technology and the characteristics of the raw material used at the yarn production, different processes have been developed. Operation steps at these processes are so numerous that each step includes complicated machines and systems. Short fibre yarn production has three yarn spinning systems which have already proved their success in commercial use: Ring spinning, open-end (rotor) spinning and air-jet spinning. Ring spinning is the most widespread yarn spinning system worldwide.

In Turkey, ring and open-end spinning are the dominant systems at the short fibre yarn production. Yarn production is the operation of opening, cleaning, mixing, then giving the shape of cheesecloth and strap, spinning at the requested number, and winding of natural fibre such as cotton and man-made fiber such as polyester, viscose, acrylic. While ring spinning perfoms this operation with more processing, open-end and air-jet spinning use less processing for this operation.

Although ring yarn spinning system has higher investment and operational cost, it enables variety of numbers and types. It can work on various fibres such as thick yarns for denim yarn, thin yarn for shirt fabrics, cotton, polyester, viscon, acrylic, linen and polyamide.(9th development plan, DPT,2007-2013)

The yarn production capacity of Turkey is 3.500.000 tonnes in total, divided into 2.300.00 tonnes for short fibre (cotton etc.) yarn, 400.000 tonnes for long fibre (wool etc.) yarn, 800.000 tonnes for filament (continuous) yarn. (Textile, apparel, leather and leather products sectors, Min. Of Industry, March 2010)

1.2.2 Fabrics production

It is estimated that total established weaving capacity of Turkey is around 1.350.000 tonnes. Knitting has the capacity of 2.250.000 tonnes. Furthermore, over 200.000 tonnes of non-woven production capacity is present in Turkey. (Textile, apparel, leather and leather products sectors, Min. Of Industry, March 2010)

1.2.3 Textile finishing sector:

Turkish textile finishing industry has the biggest textile finishing capacity in Europe. Turkish finishing industry is widely experienced at the production of mid-quality products. Also, Turkey has a closer location to European countries than China, which makes Turkey more advantageous in goods delivery. Companies involving in export to USA and EU countries for long times have sufficient sensitivity to eco-friendly production. However, in order to form a market, it is required that high technology is followed closely; a structure which enables to produce trending, high-quality and high performance special products instead of cheap and regular goods. (9th development plan, DPT,2007-2013)

1.2.4 Carpet production

22,4% of our total carpet export is handmade carpet export and 77,6% is machine-made carpet export. Our total carpet export has the share of 0,8% in total export of Turkey.

Turkey makes great investment in machine-made carpet sector. Machine-made carpet export has continously increased since 1990s and this increase is expected to continue. State-of-the-art technology is available at the production of machine carpets in Turkey.

Turkish carpet sector has some advantages in the aspect of raw material and production as follows:

- Turkey is a textile country. Significant amount of yarn is produced. It is a plus that Turkey produces both wool yarn and synthetic yarn for carpet yarn.
- It is close to Middle East countries, European countries and former Soviet Union countries which have main markets.
- It has qualified labour force especially in handmade carpet sector. Accumulation of knowledge is available in machine-made carpet sector.
- It has liberal trade policies.
- It is flexible in production.
- It gives importance to quality, environment, human health and working conditions of workers.
- Turkey has a Customs Union Treaty with EU and free trade agreements with some other countries.

Over 900 companies are present in Turkey which produces carpet for exporting. (General Secretariat of Istanbul Textile and Apparel Exporter Associations – ITKIB)

1.3 MAIN ENVIRONMENTAL ISSUES

The main environmental concerns in the textile industry is about the emissions into air and water and energy consumption.

The primary environmental problems of the sector are waste water discharge and water consumption. In textile industry, water is used in the removal of pollutants, application of coloring and chemical finishing agents, and in the generation of steam. In the production process, the quantity of the water which is held by the product and evaporates during drying is at a negligible level and the large part of the water that is used is discharged as waste water. The important environmental problems for this sector are the quantity of the waste water and the pollutant load it carries.

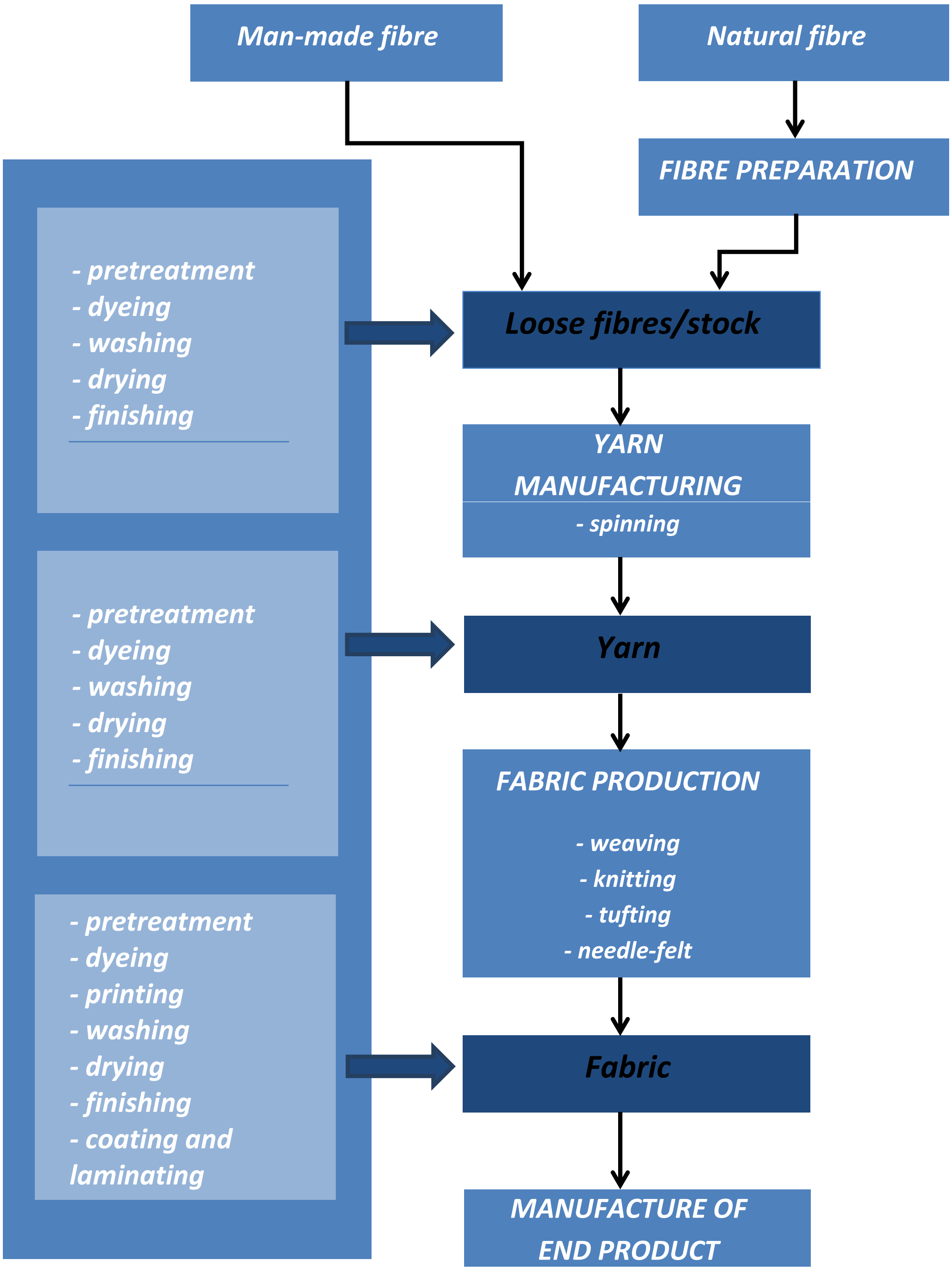
Air emissions are usually collected at their point of origin. Because they have long been controlled in different countries, there are good historical data on air emissions from specific processes. This is not the case with emissions to water. The various streams coming from the different processes are mixed together to produce a final effluent whose characteristics are the result of a complex combination of factors such as the types of fibres and make-ups processed, the techniques applied and the types of chemicals and auxiliaries used.

In our country, the standards for discharge of the waste water from textile industry to the receiving media are laid down in the Water Pollution and Control Regulations. Among the parameters that are monitored, there are COD (Chemical Oxygen Demand), pH, suspended solids, ammonium nitrogen, free chlorine, total chrome, sulphur, sulphite, toxicity dilution factor, fats and grease and phenol. One of the other studies carried out aimed at the control and reduction of water pollution is the Communique on Integrated Pollution and Prevention Control in Textile Sector, which was published on the date of 14 December 2011. In this context, the existing installations are required to prepare their clean production plans and present them to the competent authority before 31/12/2012.

More detailed information on environmental issues caused by the raw materials and processes of textile industry can be found in Chapters 2 and 3.

2 APPLIED PROCESSES AND TECHNIQUES. DESCRIPTION OF TEXTILE CHAIN TECHNOLOGICAL PROCESSES

The textile chain begins with the production or harvest of raw fibre. The basic steps in this chain are schematically represented in the following.



The main part of this chapter will describe those treatments that are broadly referred to as "finishing processes" (that is pretreatment, dyeing, printing, finishing and coating, including washing and drying). As the diagram shows, they can take place at different stages of the production process.

"Finishing" cannot be defined as a standard sequence of treatments, but rather is a combination of unit processes that can be applied within the production of a textile product, depending on the requirements of the final user. For this reason finishing treatments will be described as unit processes without considering the possible sequences in which they can be applied.

As well as fibres, the raw materials of the textile industry include a wide range of chemicals and auxiliaries. These chemicals and auxiliaries are often not process-specific and can be found in different steps within the process cycle. This chapter, because of the complexity of the above problem, will give only general information about textile raw materials, including common procedures for storage and handling.

Raw materials

Two general categories of fibres are used in the textile industry: natural and man-made. Man-made fibres encompass both purely synthetic materials of petrochemical origin, and regenerative cellulosic materials manufactured from wood fibres. A more detailed classification of fibres is shown in table below:

Natural fibers	**Animal origin**		*Wool* *Hair* *Silk*
	Plant origin		*Cotton* *Hemp* *Linen* *Ramie* *Jute*
	Mineral		*Asbestos*
Synthetic fibers	**Natural polymer fibers**		*Acetate* *Cupro* *Lyocell* *Triacetate* *Viscose*
	Synthetic polymer fibers	***Inorganic Polymers***	*Metal (Metal Fiber)* *Glass (GRP)*
		Organic polymers	*Acrylic (PAC)* *Elastane (EL)* *Polyamide (PA)* *Polyester (PES)* *Polypropylene (PP)*

Table 1.1. classification of fibres

Some most popular fibres included in this document are described in more detail below, highlighting in particular the typical impurities present on them. Part of these impurities will enter the textile process and will influence the associated emissions.

Natural fibers – animal origin

Wool

Wool is an animal hair from the body of sheep. This hair is normally sheared once, or sometimes twice, a year and its quality and quantity varies widely, depending on the breed of sheep and its environment. Wool is a member of a group of proteins known as keratin, also found in horns, nails, etc.

In addition to wool fibre, raw wool contains:

Natural impurities like wool grease, suint (dried perspiration) and dirt.

Residues of insecticides (organochlorine (OCs) andorganophosphorous(Ops)), acaricides or insect growth regulators used as veterinary medicines to protect sheep.

The percentage of the above-mentioned components may vary widely depending on the origin of wool. The clean fibre content of raw wool usually lies within the 60 to 80 % range, but may vary from 40 to 90 %.

The organochlorines are hazardous due to their persistence and bioaccumulability. They are thus likely to have long-range effects (in terms of both distance from the source and time after release). The synthetic pyrethroid insecticides show high aquatic toxicity. Organophosphates have lower aquatic toxicity than synthetic pyrethroids and are less persistent than organochlorines. All major grower countries have banned the use of organochlorine pesticides for sheep treatment. Wool from the majority of grower nations contains residual sheep treatment medicines which are used legally. These materials may be organophosphates, synthetic pyrethroids and insect growth regulators. The incidence of these materials on wool is variable and depends on the permitted legal use pattern in each country.

Silk

Silk accounts for only 0.2 % of the total fibre production. Nevertheless, this fibre is very important for specific "niche" articles such as ladies' shirts, jackets and scarves.

Silk is derived from the silk worm, which spins a cocoon around itself. It is a protein fibre like wool and it is the only natural filament fibre to be used with success in the textile industry (the length of the thread is in the range of 700 to 1500m).The silk fibre is composed of fibroin filaments wrapped with sericine (silk gum), which has to be removed during the pretreatment.

Natural fibers – plant origin

Cotton and flax

Cotton fibre consists mainly of cellulose (88 – 96%) and some other components like: pectin substances, wax, proteins, ash and other organic components.

Cotton production may use chemicals such as pesticides, herbicides and defoliants and these may remain as a residue on raw cotton fibres that reach the textile mill. However, this is of little concern for the textile industry (the problem is rather with the growers).

Flax is a bast fibre. Many economic factors have contributed to this fibre losing much of its previous importance. Nevertheless flax remains a noble fibre with a wide range of applications.

Synthetic fibres - natural polymer fibres

Viscose (CV)

The starting material is the cellulose that is extracted from coniferous timber and supplied to the fibre manufacture in sheets about 1cm thick. The wood contains ca. 40 - 50 % cellulose that is useable to make viscose. The cellulose is first allowed to swell in a NaOH solution. The white flakes obtained are then treated with carbon disulphide until the sodium cellulose xantogenate is formed. The xantogenate is soluble in diluted sodium hydroxide and the formed solution (pulp) is already called viscose. The pulp then needs to be spun. Spinning consists in coagulating the xantogenate solution at the outlet of the spinneret in an acid bath containing sulphuric acid, sodium sulphate and zinc sulphate.

Cupro(CU)

Cellulose (wood pulp) can also be dissolved in an aqueous solution of ammonia and copper sulphate. Cupro fibres are produced by wet spinning.

Acetate fibres

The cellulose molecule contains 3 alcohol groups. When between 2 and 2.5 of the 3 groups are esterified with acetic acid, the polymer is called diacetate. When all the three alcohol groups are esterified then the polymer is called triacetate. The acetate fibres contain less that 92 % of cellulose acetate, but at least 74 *%* of the hydroxilic groups must be acetylated.

Synthetic polymer fibers – organic polymers

Polyester fibres (PES)

Polyester fibres (PES) are made of linear macromolecules containing at least 85 % of an ester in the chain. To date three polyester polymers are commercially available:
- poly(ethylene terephthalate) (PET), which is based on ethylene glycol
- poly(butylene terephthalate) (PBT), which is based on butyl glycol
- and polytrimethylene terephthalate (PTT), which is based on trimethylene glycol.

However, only one of these three polymers, poly(ethylene terephthalate), also known as PET, has so far been widely applied in the textile industry.

PET fibres have a very high degree of crystallinity, which allows for excellent heat-resistance and other mechanical properties. On the other hand, this compact structure inhibits the diffusion of the colourants into the fibre during dyeing. As a result, PET fibres cannot be dyed below 100 °C, unless dyeing accelerants (so-called carriers) are used. Carriers are harmful for the environment and in many cases are toxic for humans.

Carrier-free dyeable PES fibres are now available on the market. Thanks to physical and chemical alterations made to the structure of the fibre during the manufacturing process, they show lower crystallinity, which makes them easier to dye without need for carriers. Because of their high cost, however, these fibres are applied only in specific segments of the market.

Polyamide fibres (PA)

The starting polymer comes from the polycondensation reaction between a diamine and a dicarboxylic acid. According to the number of carbon atoms of the end-product one can speak of PA 6,6 or PA 6.

Acrylic fibres (PAC)

The polymer is obtained by radical polymerisation of acrylonitrile in aqueous emulsion or in solvent. The obtained polymer, made of 100 % acrylonitrile (also called PAN), gives fibres with insufficient dye-binding capability, due to the high glass transition temperature (above 100 °C). For this reason this polymer in pure form is no longer used in the textile industry. Acrylic fibres (PAC), commonly found on the market today, are anionic copolymers containing 85 - 89 % of acrylonitrile, 4 - 10 % of a non-ionic comonomer (vinyl chloride, vinyl acetate, methyl acrylate) and 0.5 - 1 % of ionic comonomers containing sulphonic or sulphate groups.

Dry and wet-spinning techniques can be used for the production of the fibre. When dry spinning is used the polymer is dissolved in dimethylformamide (DMF). If the fibre is manufactured through wet spinning, besides DMF, dimethylacetamide, dimethylsulphoxide, ethyl carbonate and aqueous solutions of inorganic salts or acids are also used. Residues of these solvents (0.2 - 2 % of the weight of the fibre) are found in the waste water from pretreatment.

Polypropylene fibres (PP)

The isotactic polymer is used for fibre production. Due to the tertiary carbon atom, PP is very sensitive to high temperature and oxidation. Alkylated phenols or p-xylols, together with sulphides or thio-derivatives are used as stabilizers. Substances with benzotriazol groups, Ni complexes, anthrachinon derivatives and steric hindered diamines are used as UV-absorbents. These low molecular weight substances remain in the PP fibres and are considered as possible emission-relevant substances.

Elastane (EL)

Elastane fibres are made out of an elastomer containing at least 85 % of polyurethane (PU). For the production of the fibre (dry spinning) the polymer is dissolved in dimethylacetamide. Residues of this solvent remain in the fibre (<1 % on the weight of the fibre) and are found in the waste water from pretreatment.

To reduce the high adhesive characteristics and to guarantee sufficient gliding properties during processing, preparation agents are applied to the fibre (approximately *6 - 1 %* add-on). These auxiliaries contain 95 % silicone oils and 5 % surfactants. The high percentage of silicone oils will cause environmental concerns during pretreatment of the textile material, when these substances have to be removed.

Chemicals and auxiliaries

In the textile industry applies a large number of dyes, pigments and auxiliaries. Can basically be classified into:

- Dyes and pigments
- basic reagents include all inorganic chemicals and organic reducing agents or oxidizing and organic acids, aliphatic
- auxiliary products containing mainly organic compounds, except for those considered in the previous section. Also known as a specialty and its exact composition is unknown.

Currently, there are over 7,000 markets for commercial products and auxiliary chemicals (based on about 600 active ingredients).

2.1 Fibres manufacturing and preparation.

2.1.1 Materials handling and storage

Basic fibrous raw materials arrive on site in press-packed bales and are stored in covered warehousing, which may also be used to store and dispatch finished goods to customers.

Basic chemical intermediates, acids, alkalis and bulk auxiliary chemicals are normally held within a bound or contained storage area. Large bulk containers may be situated in the open. High value and moisture- or environmentally-sensitive materials are normally transferred directly to the preparation area from where they are dispensed.

Some synthetic organic colourants are regarded as a potential health hazard. Therefore colour kitchens are normally equipped with air extraction and filter systems to suppress dust levels in the workplace during dispensing.

The chemicals (dyestuffs, pigments, basic chemicals and auxiliaries) are metered out either in powder form or as solutions. This operation can be done manually or with computer-aided metering devices.

The required measured amounts of products must in general be dispersed, diluted or mixed before being fed to the finishing machinery. Various systems are found in the industry, ranging from completely manual procedures to fully automatic ones. In the case of manual systems the prepared chemicals are added directly into the machine or in a storage container near the equipment, from which they are then pumped into the machine. In larger companies the chemicals are usually mixed in a central mixing station, from which they are supplied to the various machines through a network of pipes. The quantities and the addition of chemicals and auxiliaries are normally called up automatically according to predetermined programmes.

2.1.2 Chemical (man-made) fibres

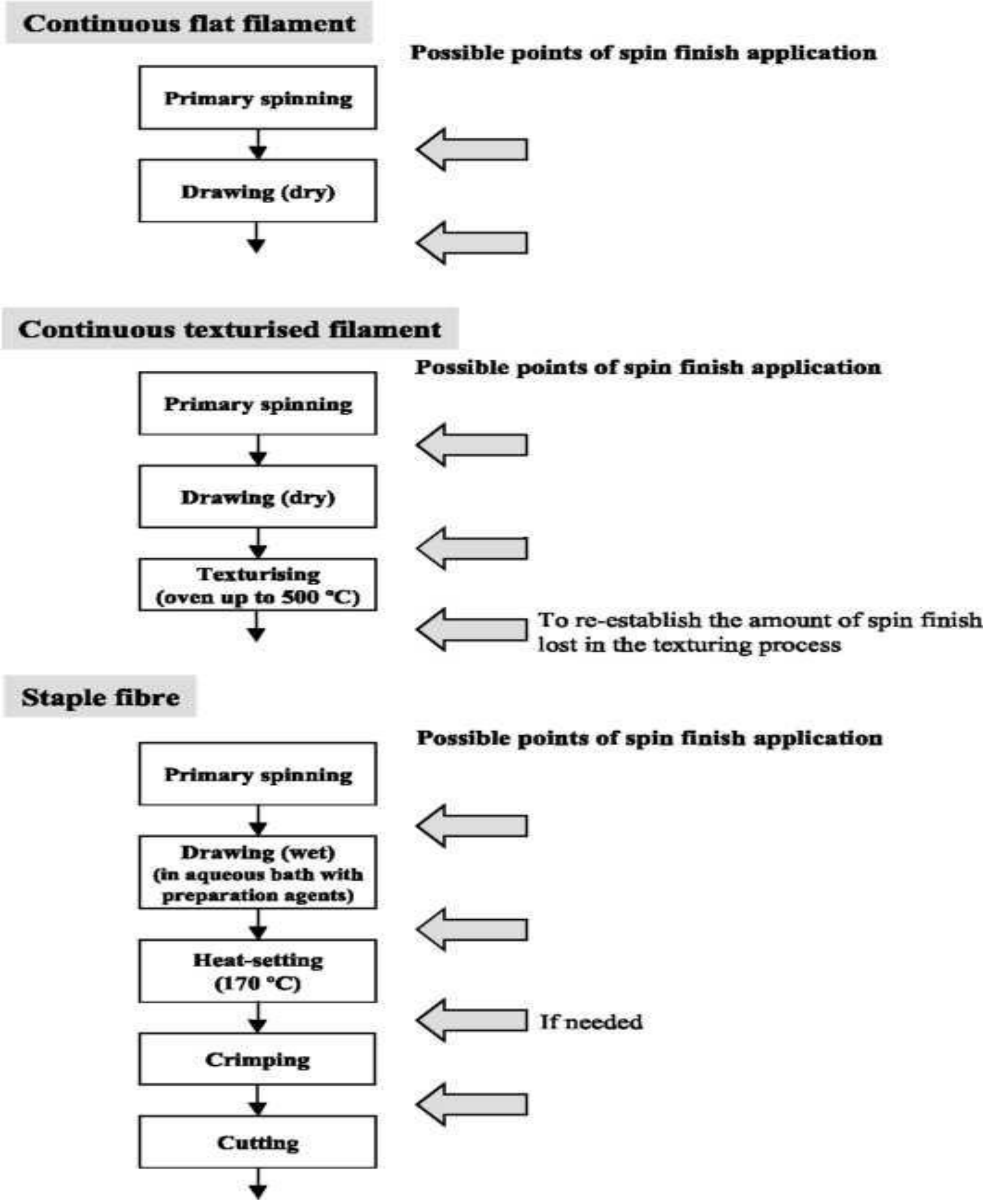
Man-made fibres are typically extruded into continuous filaments. Three main methods are used to produce the continuous filaments (primary spinning):

- *Melt spinning :*The polymer is melted in a melt-extruder. The liquid is forced through the spinner opening under pressure and cooled by a jet of air to form the filament. A spinning preparation (spin finish) is generally applied at the bottom of the spinning duct. The melting process is suitable for thermoplastic fibres such as polyester, polyamide, polyolefins (e.g. polypropylene) and glass fibre.,

- *Dry spinning:* The polymer is dissolved in a solvent. The dissolved polymer is extruded through a spinneret into a chamber of heated air or gas where the solvents evaporates and the filament forms. This filament is further after-treated with a spin finish. The dry spinning process is principally used for acetate, triacetate and polyacrylonitrile.
- *Wet spinning:* The polymer is dissolved in solution. The solution is forced under pressure through an opening into a liquid bath in which the polymer is insoluble. As the solvent is dissipated the fibre forms. The solvent can be dissipated through extraction or by means of a chemical reaction between the polymer solution and a reagent in the spinning bath (reactive spinning). The residual solvent can be extracted by simple washing. After the thread is formed and the solvent is washed out, a spin finish can be applied. Wet spinning produces viscose, acrylic fibres.

Following primary spinning, the applied treatments vary, depending on the final product and the processed fibre. Two simplified process sequences can be identified for this stage:

- process for the manufacturing of continuous filament in flat or texturised form,
- process for the manufacturing of staple fibres.



Preparation agents can be applied at various stages during the manufacture of the chemical fibres. Application of preparation agents in primary spinning (fibre manufacturing) is usually followed by further additions during secondary spinning, when the yarn is manufactured.

The preparation agents need to be removed to ensure uniform penetration of dyes and finishing agents and to avoid reaction or precipitation with them. Due to their high organic content and their often-low bioeliminability, these substances are responsible for waste water pollution and air emission in the subsequent fibre pretreatment. Particularly relevant in this respect is the production of continuous filaments destined for the production of knitted fabric and the manufacturing of elastomeric fibres, because in this case the amount of preparation agents applied is higher.

2.1.3 Preparation of natural fibres

2.1.3.1 Wool

Wool is usually opened and de-dusted before it is fed to the scour. This is a mechanical process designed to shake out dirt from the wool and to open the fleeces in order to improve the efficiency of the scour in removing contaminants. The process also roughly blends the wool and produces a layer of fibres suitable for presentation to the scour. The process produces a solid waste comprising dirt, sand, fibre fragments and vegetable matter.

The object of subsequent raw wool scouring processes is to remove contaminants from the wool fibre and to make it suitable for further processing.Almost all of the scouring plants are based upon aqueous washing. Solvent scouring is much less widely practised.

A **conventional wool scouring by mean of water** is carried out by passing the wool through a series of 4 - 8 wash bowls, each followed by a mangle or squeeze press which removes excess scouring liquor from the wool and returns it to the bowl. Clean water is added at the last bowl and passes via a counter-flow system from bowl to bowl with final disharge from the first bowl in a controlled manner to drain.In the scouring bowls, suint is removed from the wool by dissolution, grease by emulsification and dirt by suspension.

In order to achieve grease emulsification, the scouring bowls are charged with detergent and often with sodium carbonate, or other alkali, which acts as a detergent builder. Concentrations of detergent and builder are usually highest in the first scour bowl and they decrease in subsequent bowls.

Finally, the wool is rinsed by passing it through bowls containing water only.

In coarse wool scouring plants the final bowl of the scouring train is sometimes used for chemical treatments. In this case, it is isolated from the countercurrent liquor flow system and may also be isolated from the drain if the chemical treatment uses ecotoxic chemicals. The most commonly used treatment is bleaching, in which hydrogen peroxide and formic or acetic acid are added to the bowl. Other treatments sometimes applied include mothproofing, using a synthetic pyrethroid insecticide and acetic or formic acid, and sterilisation (of goat hairs) using formaldehyde.

After leaving the final squeeze roller the wool will contain 40 to 60 % moisture. It is therefore dried by convection in a hot-air drier. The drier is usually heated either by closed steam pipes or by direct gas firing. The heat supply to the drier may be controlled by a signal from a device which senses the humidity of the drier atmosphere or the moisture content of the wool at the output end, thus saving energy and avoiding overdrying the wool.

The dirt tends to settle at the bottom of the bowl and modern scour bowls usually have hoppershaped bottoms from which the sludge is removed by gravity through a valve. The discharge from the scour bowl hopper bottoms is led to a heavy solids settling tank where it is gravity-settled. Flocculant may be added to the heavy solids settling tank to assist the separation of dirt, or a decanter centrifuge or hydrocyclone may be used in preference to gravity settling for dirt removal.

For grease recovery, modern scour bowls have a side tank in which the grease-rich liquors removed from the wool by the squeeze press are collected. The following centrifuge separates the liquor into three phases. The top phase, referred to as the cream, is rich in grease and passes to secondary and possibly tertiary centrifuges for further dewatering, finally producing anhydrous grease; the bottom phase is rich in dirt and goes to the heavy solids settling tank; the middle phase is impoverished in both grease and dirt compared with the input and this is split.

In a commonly used variation of the above recycling arrangements, the dirt and grease removal and recycling loops may be combined. In this case, scouring liquor may be removed from the bottoms of the bowls only, or from top and bottom, and passed first through the dirt removal equipment, then through the primary grease centrifuge.

The dirt removal and grease recovery loops described above serve several purposes. They save water, by recycling effluent to the scour, and they act as a process-integrated partial effluent treatment. The recovered wool grease can be sold, although the market for this by-product has been variable in most recent years. Finally, since the discharges from the loops are the only points at which heavily contaminated scour liquors are discharged, valves and meters at these points can be used to control the rate of water usage in the scouring section.

It is necessary to mention **wool scouring by mean of organic solvent**, like trichloroethylene (TCE). In this process wool is also fed through a series of wash bowls and washed in the countercurrent flow of solvent. Clean, solvent saturated wool is taken to a centrifuge, to remove most of the solvent saturated liquor, and then to the dryer. The processing area from the wash bowls through to the centrifuge and the dryer is all fully enclosed and is kept under a slight negative pressure by evacuating air to a vapour recovery system.

Solvent from the first washing bowl is processed through high-speed centrifuge equipment to remove solid particles and recycled back to bowl.

Dirt slurry is sent to an indirect heated dirt dryer to evaporate and recover solvent, leaving dry, solvent free dirt.

Solvent used in the process is recycled in the multistage solvent evaporation system. Usually 3 stages are used to recover 99,98% of solvent.

Solvent is also recovered on every stage of the process where the air saturated with solvent is extracted. Air/solvent stream is sent to vapour recovery unit consisting of a refrigerated primary collection system followed by activated carbon adsorption recovery system.

Solvent wool cleaning system does not use any water in the washing process, but there is however a small flow of water due to moisture in the wool, moisture in the air as well as small flow of water into the solvent system. Solvent is separated from the water by gravity and later, on the second step, by heating the water and stripping it in the solvent air stripping unit. Traces of solvent are removed from water by oxidizing/de-halogenating, thereby destroying the solvent molecules.

There is also a small stream of contaminated liquids from maintenance activities. They are treated in a very similar manned to process water.

2.1.3.1.1 Environmental aspects

Wool washing with waters

The main environmental problems associated with **washing wool with water**is water pollution. However, solid waste and atmospheric emissions must also be considered.

Potential water pollution

The removal of contaminants from raw fiber can lead to the discharge of an effluent with high concentrations of organic matter, dirt and other pollutants. Detergents can also be found, whose presence depends on the effectiveness of recovery and recycling processes. The latter have a lower contribution to the contamination of sewage washing, except when using surfactants harmful to the environment.

These substances must be purified wastewater in order to be discharged without posing a potential danger to the environment.

With a high concentration of scouring activity, there is a risk of high concentration levels of pesticides in the receiving water. In this case, it is preferable to define discharge limits on the basis of risk assessment models.

Potential soil contamination

In the process of washing wool are produced mainly two types of waste: grease and sludge.

Grease should be considered as a byproduct and that can be marketed to refineries lanolin and subsequent use in cosmetics. It may be possible to recover from 20 to 40 % of the grease initially present on the raw wool.

The resulting sludge from the treatment of wastewater containsgrease, dirt and pesticides associated with grease. The sludge must be managed as hazardous waste. There are several methods to treat sludge, the most popular are:

- incineration (with heat recovery),
- pyrolisys/gasification,
- brick manufacturing,
- composting or co-composting with other organic material,
- landfill.

Potential air pollution

Air pollution is not important in the process of washing wool with water. However, certain contaminants can be generated depending on the sludge treatment system used, especially dust and odours.

Solvent wool scouring

Solvent wool scouring systems, like the Wooltech system, uses trichloroethylene as solvent. Trichlorethylene is a non-biodegradable and persistent substance. Unaccounted losses of this solvent arising from spills, residues on the fibre, etc., if not adequately treated to destroy the solvent, may lead to diffuse emissions resulting in serious problems of soil and groundwater pollution.

As far as water and energy consumptions are concerned, solvent wool scouring system shows lower consumption levels compared to a typical scouring process using water.

To learn more about Wooltech system please refer to chapter 2.3.1.3 of BREF (pages 30-33).

2.1.3.2 Cotton and flax

Raw cotton is a much cleaner raw fibre than wool and initial operations are mainly dry. The fibres are supplied to the spinning mill in compressed bales. They are sorted by grade, cleaned to remove particles of dirt and blended with fibres from different bales to improve the consistency of the fibre mix. Sorting and cleaning is performed in machines known as openers.

With flax, the isolation of the fibre from the flax stem is done in different steps. After crop (plucking) the flax is retted (dew retting, water retting, enzymatic, microbiotic, steam or chemical retting). Retting is a wet process that can result in waste water with high contents of COD and BOD: pectinic and hemicellulosis substances are degraded in this step. Rovings are produced by further mechanical treatment before spinning.

2.1.3.2.1 Environmental aspects

The main environmental problem is associated with wool opening. This is a mechanical, dry process wherethe remains of seeds after opening are the only solid waste, which is easy to manage. For flax the environmental problems depend on the process used for the isolation of the fibre. Generally it can in some cases result in waste water discharges with high content of COD and BOD.

2.1.3.3 Silk

For silk production the silk worm is killed with steam and the filament is unwound directly from the cocoon. The filament is submitted to pretreatment processes to remove the silk gum and other organic impurities.

2.1.3.3.1 Environmental aspects

No relevant specific environmental issues arise in silk preparation.

2.2 Yarn manufacturing and fabric production.

Almost all textile apparel products are made from spun yarn of 100 % natural fibres, 100 % man-made staple fibres or blends. Only a few apparel products, for instance smooth sportswear, are made exclusively of filament yarns.

Secondary spinning is the process by which staple fibres are transformed into yarn suitable for the textile industry. There are two main spinning processes:

- the wool spinning process,
- the cotton spinning process.

2.2.1 The wool spinning process

The wool spinning process is mainly used to produce wool and wool-blend yarns. A distinction is made between the worsted and woollen process. In worsted spinning, higher-quality and longer fibres are processed (paralleled in a combing machine and are then drawn and spun)and the result is a fine yarn which is used to produce worsted fabric. In the woollen spinning system, shorter fibres are processed(carded and then spun).

The resulting yarn is then twisted (if required) and finally prepared for the subsequent treatments (dyeing, weaving, tufting, etc) through an operation called winding.

In both the woollen and worsted systems the various fibres are combined during the blending operation. In order to allow efficient mechanical processing in the subsequent operations, spinning lubricants are applied to the fibres at this.

2.2.2 The cotton spinning process

The cotton spinning process is generally used for cotton and man-made fibres. Cotton fibres are first submitted to opening and cleaning operations. The following steps, which are the same for cotton and man-made fibres, are:

- carding,
- combing,
- drawing,
- roving,
- spinning,
- twisting (if required),
- winding.

2.2.3 Environmental aspectsregarding spinning processes

The preparation agents (conditioning agents and spinning lubricants) applied to the fibre during the spinning process have significant environmental implications for the subsequent finishing steps of the textile chain and must be completely removed before dyeing. They are found either in the ***exhaust air*** from the high-temperature processes or ***in the water*** from wet treatments. In the first case they give rise to air pollution, whereas in the second they contribute to the organic load of the final effluent.

Spinning lubricants may be responsible for the emission not only of hard-to-biodegrade organic substances such as mineral oils, but also of hazardous compounds such as polyaromatic hydrocarbons, APEO and biocides, depending on the type and amount of the lubricant applied to the fibre. The amount of the lubricant ranges from 2% (for wool worsted spinning) up to 7% (for elastomeric fibres) of the weight of the fibre.

2.2.4 Cloth production

Raw materials for cloth production are spun yarns and filament yarns. These raw materials can then be converted into:

- woven textiles,
- knitted textiles,
- floor-coverings and non-woven fabrics.

2.2.4.1 Woven textiles

Warping

Before weaving, warp yarns are wound onto beams in a process called warping. During this operation there is no consumption of auxiliary agents that could have a negative influence on the emissions from the subsequent finishing processes.

Sizing

In order to lubricate and protect the warp yarn during weaving, sizing agents (in the form of water solutions or water dispersions) are applied after warping. In some cases (wool mills) the warp yarn is not sized, but treated with liquid paraffin.

The main sizing agents can be grouped into two classes:

- Sizing agents based on native polysaccharides (starch; starch derivates such as carboximethyl starch or hydroxiethyl starch ether; cellulose derivates, especially carboximethyl cellulose (CMC); galactomannans; protein derivates).
- Fully synthetic polymers (polyvinyl alcohols (PVA); polyacrylates; polyvinyl acetate; polyester).

It is important to bear in mind that:

- the type of sizing agent applied varies according to the fibres to be processed, the weaving technique adopted and the demands of any system used for recycling the sizing agents,
- sizing agent formulations are usually mixtures of the substances mentioned above.

With cotton, additional auxiliaries are present in the sizing mixtures. These are mainly:viscosity regulators, sizing fats, wetting agents and preservatives.

Sizing agents used for synthetic fibres do not contain these auxiliaries, except for the preservatives.

Sizing agents are introduced by the weaving firm, but have to be removed by the finisher (during the operation called desizing). This desizing process results in high waste water loads. In the case of woven fabric, sizing agents can represent 30 - 70 % of the total COD load in waste water.

Weaving

Weaving is the process by which yarns are assembled together on a loom and a woven fabric is obtained. The process only requires electricity. Lubricants and oils are used to lubricate the loom, but in particular cases they may contaminate the fabric.

2.2.4.2 Knitted textiles

Waxing

The yarn specially made for the knitting industry is lubricated or waxed (generally with paraffin wax) to allow knitting at higher speed and protect the yarn from mechanical stresses. Waxing may be done while re-winding the yarn onto bobbins, in which case the process is normally called “preparation for knitting”.

Knitting

Like weaving, knitting is a mechanical process and involves knitting yarn together with a series of needles. Mineral oils are widely used to lubricate the needles and other parts of the knitting machinery. The quantity of oils used depends on the technology of the machine and on the speed of the needles. The value ranges between 4 and 8 % of the weight of the fabric.

The oil and the wax that remain on the final fabric will be washed out during the finishing treatments. Their contribution to the total pollution load coming from finishing mills may be significant.

2.2.4.3 Textile floor-coverings

Textile floor-covering is a collective noun for articles having a usable surface of textile material. This particular class of cloths can be schematically described as composite substrates made up of several layers, such as:

- ***a carrier layer***- is mainly made of polypropylene strips of fabric (75 %), PP or PES webs (16 % and 8 %, respectively) and less commonly of jute fabric (1 %);
- ***a pile yarn*** *(or more generically a face fibre)*- can equally well be made from filament or staple fibre yarns (mainly polypropylene, polyamide, polyester, wool, acrylic fibres);
- ***a pre-coating layer***- typical of tufted carpet and whose function is to anchor the pile onto the carrier layer. This coating layer is made from synthetic rubber or an artificial dispersion based on carboxylated styrene-butadiene rubber latex;
- ***a coating layer***- an additional layer applied to the bottom side of the carpet. It is possible to distinguish between foam coating, textile back coating and heavy coating methods. The purposes of this final layer are various. Mainly, it is intended to

strengthen the attachement of the pile, improve dimensional stability of the carpet and provide the carpet with properties such as anti-slip, heat insulation, stepping elasticity, or even flame retardancy.

The characteristics of the end-product and the applied manufacturing techniques can vary significantly. The principal methods of manufacturing carpet/floor-coverings are tufting, weaving and needling (other methods are knotting, bonding, knitting, etc.). Using this techniques you get different types of carpets.

2.2.4.3.1 Tufted carpet

Tufted carpets are made up of the following different components:

- the face yarn (pile), which can be made from either staple fibres (PA, PP, PES, PAC, wool and cotton) or synthetic filaments,
- the primary backing (carrier layer),
- the pre-coating layer,
- the back-coating layer (which can consist of a textile back-coating or of a foam coating.

In the tufting process, pile yarns (face) are inserted by needles into a woven or non-woven carrier material (primary backing), made of polypropylene, polyester or jute, across the entire width of the substrate (up to 5m). During subsequent manufacturing processes the base of the pile yarn is anchored in the back of the carpet by means of an applied coating.Through variations of the tufting technique, different three-dimensional pile structure can be produced as well as patterned carpets (e.g. level loop pile, multi-level loop pile, cut and loop, velvet and velour etc.).

2.2.4.3.2 Needle felt carpet

The fibres lie criss-cross to each other and are compressed with needles. This compression is fixed with binding agents. Needle-pile carpets can consist of one or several layers, with or without a carrier layer. They may be equipped with various types of backings (textile backing, foam, heavy coating). For lasting binding of the fibres, the needled substrate is subsequently subjected to further thermal or chemical treatment (chemical reinforcement). Almost all fibres may be used for the production of needle felts; however, man-made fibres are mostly used (PP, PA, PES, PAC, wool, jute/sisal, viscose).

2.2.4.3.3 Woven carpet

The manufacturing process for woven carpets is similar to the manufacturing of any other woven good. Since coarse types of yams are used for woven carpets, the warp is normally not sized.As a rule, woven carpets are provided with a stabilising back-coating. Only in rare cases is an additional heavy coating (e.g. PVC or bitumen) applied.

2.2.4.4 Non-woven textiles

Textiles manufactured without an intermediate yarn-processing step are called non-wovens. The application of these textiles is quite broad ranging from backings for coatings, filters, geo-textiles and other technical textiles to dishcloths, etc.

In the fabrication of non-woven textiles the only significant environmental impact is normally associated with the off-gases emitted during the thermal and chemical bonding steps. The volatile compounds mainly originate from fibre inherent monomers (especially caprolactame), monomers in the bonding polymers, etc.

2.2.4.5 Environmental aspects

For cloth production environmental impact, depending on textile and product, vary from none to significant.During **sizing** process special agents are used that have to be removed later in a process called desizing. This process results in high waste water loads with 30-70% load in waste water. For **knitting** mineral oils and wax are widely used and during washing the final fabric their contribution to the total pollution load from the finishing mills may be significant. In production of **non-woven textiles** the only significant environmental impact is assiociated with the off-gases emitted during thermal and chemical bonding steps.

According textile floor coverings their environmental impact is not clearly defined and described in BREF but because they are composite of several different layers their contribution to the total environmental load may vary from none to significant depending on the material used.

2.3 Finishing processes.

This chapter describes the finishing processes used in textile production process. Usually “finishing” is a combination of unit processes that can be applied within the production of a textile product, depending on the requirements of the final user. Because of that finishing processes are described as unit processes without considering the possible sequences in which they can be applied.

2.3.1 Pretreatment

Pretreatment processes should ensure:

- the removal of foreign materials from the fibres in order to improve their uniformity, hydrophilic characteristics and affinity for dyestuffs and finishing treatments,
- the improvement of the ability to absorb dyes uniformly (which is the case in mercerising),
- the relaxation of tensions in synthetic fibres (without this relaxation of tension, unevenness and dimension instabilities can occur).

The position of pretreatment within the production scheme is closely related to the position of dyeing in the sequence. The point is that pretreatment comes immediately before dyeing (and printing).

Pretreatment processes and techniques strictly depend on:

- the kind of fibre to be treated,
- the form of the fibre (flock, yam, woven or knitted fabrics),
- the amount of material to be treated.

Pretreatment operations are often carried out in the same type of equipment used for dyeing.

2.3.1.1 Pretreatment of cotton & cellulose fibres

Cotton pretreatment includes number of various wet operations:

- ***Singeing*** - can be carried out both on yarns and woven fabrics, but it is more common on fabrics, especially on cotton, cotton/PES and cotton /PA substrates.Protruding fibre ends at the fabric surface disturb the surface appearance and produce an effect known as "frosting" when dyed. It is therefore necessary to remove the surface fibres by passing the fabric through a gas flame. The fabric is passed over a row of gas flames and then immediately into a quench bath to extinguish the sparks and cool the fabric. The quench bath often contains a desizing solution, in which case the final step in singeing becomes a combined singeing and desizing operation.Singeing has no effect on the effluents because only cooling water is necessary. During singeing relatively strong odours and emissions of dust and organic compounds are observed. Odorous substances can be destroyed using catalytic oxidation techniques.
- ***Desizing*** - is used for removing from woven fabric sizing compounds previously applied to warp. depending on the kind of sizing agent to be removed. Thus it can be categorised as follows:
    - *Techniques for the removal of starch-based sizing agents (water-insoluble sizes)* - require either catalytic action of an enzyme (catalytic degradation) or other chemical treatment in order to be converted into a washable form. This chemical degradation is mainly achieved by either enzymatic or oxidative desizing.
    - *Techniques for the removal of water-soluble sizes* - theoretically to remove water-soluble sizes such as PVA, CMC and polyacrylates only requires washing with hot water and sodium carbonate. The washing efficiency can be increased by adding suitable auxiliaries (wetting agents). Process is carried out in normal washing machines.
    - *Techniques for the removal of water soluble and insoluble sizes* – the process called *"oxidative desizing"* I used. The fabric is impregnated in a bath containing hydrogen peroxide and caustic soda, together with hydrogen peroxide stabilisers and complexing agents.
- ***Scouring*** - is aimed at the extraction of impurities present on the raw fibre or picked up at a later stage such as: pectins; fat and waxes; proteins; inorganic substances, such

as alkali metal salts, calcium and magnesium phosphates, aluminium and iron oxides; sizes. Can be carried out as a separate step of the process or in combination with other treatments (usually bleaching or desizing) on all kind of substrates: woven fabric (sized or desized), knitted fabric and yarn. For yarn and knitted fabric, scouring is usually a batch process which is carried out in the same equipment that will subsequently be used for dyeing. Woven fabric is scoured in continuous mode using the pad-steam process.

- The action of scouring is performed by the alkali (sodium hydroxide or sodium carbonate) together with different auxiliaries.
- ***Mercerising (and caustification)*** - is carried out in order to improve tensile strength, dimensional stability and lustre of cotton.Mercerising can be carried out on yarn in hanks, woven and knitted fabric through one of the following different treatments:
    - *Mercerising with tension* – is the most commonly applied mercerising technique (it is not applied to flax). Cotton is treated under tension in a solution of concentrated caustic soda for approximately 40 - 50 seconds. During this process the solution temperature is adjusted at low values (5-18°C) but, rarely, there is also *“hot mercerizing technique used”* with the solution temperature close to 100°C.
    - *Caustification (without tension)* – the material is treated at 20 - 30°C with caustic soda solution without applying tension. The material is allowed to shrink, thus improving the dye absorption.
    - *Ammonia mercerizing* – used for treating cotton yarn and fabric with anhydrous liquid ammonia as an alternative to caustic soda. Effects similar to mercerising are obtained, although the lustre grade is inferior to caustic soda mercerising. Traces of ammonia have to be removed, preferably with dry heat treatment followed by steaming.
- ***Bleaching*** - is an obligatory step when the fibre has to be dyed in pastel colours or when it will need to be subsequently printed. When the material has to be dyed in dark colours it can be directly dyed without need of bleaching. Bleaching can be performed on all kinds of make-ups (yarn, woven and knitted fabric). Most frequently bleaching agents used are: oxidative bleaches, namely: hydrogen peroxide (H_20_2), sodium hypochlorite (NaClO), sodium chlorite ($NaC10_2$) and peracetic acid.

Some of these treatments are obligatory steps only for certain make-ups (e.g. desizing is carried out only on woven fabric).Moreover some of these treatments are often combined together in one single step in order to respond to the need to reduce production time and space as much as possible.

2.3.1.1.1 Environmental aspects

The main environmental issues associated with cotton pretreatment arise from emissions to water.The characteristics of the emissions vary according to a number of factors: the make-up, the sequence adopted, the fact that some treatments are often combined in a single step, etc.

Desizing represents the main emission source in the overall process. Washing water from desizing may contain up to 70 % of the total COD load in the final effluent, especially in the case of native sizing agents.

Mercerising is responsible for a large amount of strong alkali that is discharged in waste water and needs to be neutralised. The corresponding salt is formed after neutralisation. Mercerising baths are usually recovered and re-used. When this is not possible, they are used as alkali in other preparation treatments.

Bleaching, depending on the agent used, can cause different discharges of different substances in the waste water. The decomposition of hydrogen peroxide during bleaching forms only water and oxygene. Use of sodium hypochlorite as well as sodium chlorite leads to secondary reactions that form organic halogen compounds.

2.3.1.2 Wool preparation before colouring

Typical preparation wet treatments applied on wool fibre before dyeing are:

- ***Carbonising*** – is the process of vegetable inpurities removal by mean of sulphuric acid. Can be carried out on:
  - *Loose fibre* - performed only on fibres that are later used to produce fine fabric for garments (worsted fabrics) and usually takes place at the scouring mill. Still damp scoured wool is soaked in a solution containing mineral acid. Excess acid and water are removed by pressing or by centrifugation. The fibres are then dried at 65 - 90 °C to concentrate the acid and baked at 105 - 130 °C (carbonising).
  - *Fabric* – typical for woolen fabrics. onventional procedure is substantially similar to that used for loose fibre.
- ***Washing (scouring)*** – performed to remove certain amount of spinning oils and sizing agents. Can be provided by:
  - *Water washing* - carried out in neutral or weakly alkaline conditions in the presence of detergents. This is normally a batch operation which is carried out in the equipment in which the textile material will be subsequently dyed.
  - *Dry cleaning*- is less common and is applied when the fabric is heavily soiled and stained with oils from the weaving or knitting process. The most widely used solvent is perchloroethylene. In some cases water and surfactants are added to the solvent to provide a softening effect.
  - *Solvent washing*- can be carried out either in discontinuous mode in a tumbler (generally for knitted fabric) or in continuous mode in open-width (for woven and knitted fabric). Impurities are carried away by the solvent, which is continuously purified and recycled in a closed loop.
- ***Fulling*** - this treatment takes advantage of the felting tendency typical of wool fibre when it is submitted to friction under hot humid conditions and is a typical pretreatment for woollen fabric. It is usually carried out after carbonising, but in some cases it can be done directly on raw fabric. The material is kept in circulation in a bath containing fulling auxiliaries. After fulling, the fabric is washed.

- ***Bleaching*** - wool is bleached with hydrogen peroxide.For achieving high levels of whiteness an additional reductive bleaching is added. A typical reductive bleaching agent is sodium dithionite (hydrosulfite), which is often used in combination with optical brighteners to enhance its effect.

Other possible treatments are those that go under the definition of anti-felt and stabilisation treatments. Although they are often carried out before dyeing, they are not obligatory preparation steps.

2.3.1.2.1 Environmental aspects

Wool pretreatment gives rise mainly to water emissions, although there are also specific operations where halogenated solvents are employed. The use of halogenated organic solvents can produce not only emissions to air, but also contamination of soil and groundwater if their handling and storage is not done using the necessary precautions. Due to the predominantly batch nature of wool pretreatment operations for all types of makeups, the resulting emissions will be discontinuous and with concentration levels largely influenced by the liquor ratios used. The pollutants that can be found in the waste water, originate in part from the impurities that are already present on the fibre (pesticides, spinning lubricants, knitting oils and other preparation agents) when it enters the process sequence and in part from the chemicals and auxiliaries used in the process (detergents, wetting agents, reducing agents, complexing agents etc.).

2.3.1.3 Pretreatment of silk

Typical pretreatments applied on silk are:

- ***Washing (scouring)*** – used to remove sericin, natural oils and other organic inpurities. The scouring treatment can be carried out in a neutral, acid or alkaline solution, depending on the desired results.Scouring baths present a high total organic charge; the concentration of nitrogen organic components in particular is high. Due to the percentage of sericin removed during scouring the end-product is defined as:
    - *"Unscored" silk* - all residual substances from previous operations, with a minimal elimination of sericin, are removed. The operation is carried out in a slightly alkaline soap bath at low temperature.
    - *"Souple" silk* – to get this product process is carried out on weft yarns under acid conditions. The loss of weight is approximately 10 %.
    - *Degummed silk* –silk yarn and/or as silk fabric are treated by mean of ***soap baths***, ***synthetic detergents baths*** and ***high temperature bath under pressure***. The goal is complete elimination of sericin, as well as substances added in previous operations, without modifying the fibroin.
- ***Weighting*** – performed to promote recovery of the weight loss after the removal of the sericin. The treatment consists in the deposition of tin salts or in grafting polymer chains to the functional groups of the fibroin protein chain.Depending on the weighting agent can be presented as:

- *Wieghting with minerals* - the silk yarn undergoes a treatment using tin tetrachloride in baths at different concentrations (strong or weak baths) in an acid medium. In a strong bath, silk can increase its weight by about 10 % simply by absorbing the salt. The procedure is followed by accurate washing cycles to eliminate unfixed salt and to hydrolyse the salt present on the fibre. Such operations can be repeated to further increase the silk weight. To ensure fixation of tin salts, weighting is completed with a treatment in a sodium phosphate bi-basic solution, followed by a second treatment in sodium silicate. Disadvantages of this procedure are the long processing time and the high water and energy consumption. The high amount of tin in the waste water is an environmentally undesirable effect of this process.
- *Weighing with vinyl monomers* - grafting vinyl monomers onto silk represents an alternative to the traditional mineral weighting. Such a method not only allows the desired weight increase to be achieved, but also improves silk characteristics and performance. Co-polymerization with vinyl monomers is carried out using radical activation methods.
- *Mix weighting*– the most frequently applied weighting procedure. Is a mix of the above methods.

2.3.1.3.1 Environmental aspects

Scouring of silk results in waste water with load of high total organic charge; the concentration of nitrogen organic components in particular is high. For weighing the high amount of tin in waste water may be the most important uderisable effect of this process.

2.3.1.4 Pretreatment of synthetic material

Typical operations before colouring:

- ***Washing*** - is necessary to remove from the yam the preparation agents that have been applied to its surface in the previous treatments.Most preparation agents (about 95 %) are removed at this stage. Removal of sizing agents froma woven fabric is a crucial step. The extraction of these substances is achieved thanks to the synergistic action of: surfactants, complexing agents and alkali.
- ***Thermofixing (heat-setting)*** - is another important operation in synthetic fibres pretreatment. Its position within the process can be different, depending on the make-up and the fibre.

2.3.1.4.1 Environmental aspects

Potentially harmful impurities and additives are already present on synthetic fibres before they are processed at the finishing mill and they account for a large fraction of the pollution load coming from pretreatment.

Some of these impurities like unreacted monomers, low-molecular-weight oligomers and residual catalysts are produced during the manufacture of the fibre. They are emitted to air during thermal treatments.

Other substances are intentionally added to the fibre to improve subsequent processing. These are the preparation agents used in fibre and yarn manufacturing and the sizing agents.

The average amount of preparation agents applied on man-made fibres (except for elastomeric, where the load can be much higher) ranges between 2 and 4 % of the weight of the fibre.When the textile is washed, about 80 % of these substances are released to the waste water and the remaining 20 % can be emitted to exhaust air in the subsequent high temperature treatments (drying and thermofixation).

2.3.2 Dyeing

Dyeing is a method for colouring a textile material in which a dye is applied to the substrate in a uniform manner to obtain an even shade with a performance and fastness appropriate to its final use. Textile dyeing involves the use of a number of different chemicals and auxiliaries to assist the dyeing process.

Various dyeing techniques can be identified:

- mass dyeing/gel dyeing - dye is incorporated in the synthetic fibre during its production (this technique is the most commonly applied process for PP fibres and is of interest also for PAC),
- pigment dyeing - insoluble pigment, without affinity for the fibre, is deposited onto the textile substrate and then fixed with a binder,
- dyeing processes which involve the diffusion of a dissolved or at least partially dissolved dye into the fibre.

This last group of processes is the one that will be discussed in more detail in the following sections. From a molecular point of view, four different steps are involved:

1. The dye, previously dissolved or dispersed in the dye liquor, diffuses from the liquor to the substrate.
2. Accumulation of the dye on the surface of the textile material occurs. This process is controlled by the affinity (substantivity) of the colourant for the fibre.
3. The dye diffuses/migrates into the interior of the fibre until this is uniformly dyed. The penetration of the dye into the fibre requires that the fibre itself is accessible. In the case of hydrophilic fibres the dye penetrates through the available micro-pores, while in hydrophobic fibres, whose molecular structure does not allow a continuous water phase, cavities need to be developed in order to make the penetration of the dye possible. Access to the fibre is enhanced by the higher dye temperature above 100 °C. In some cases large amounts of salt have to be added to the dyeing bath in order to reduce the electrostatic forces on the surface of the fibre and promote an even penetration of the dye.
4. The dye must be anchored (fixation) to suitable places within the substrate. Different mechanisms of fixation are known, ranging from chemical reaction of the dye with the fibre to form a covalent bond (reactive dyes) to formation of Van der Waals and other short range forces between the fibre and the dye (direct dyes).

Textiles can be coloured at any of several stages of the manufacturing process so that the following colouring processes are possible:

- flock or stock dyeing,
- top dyeing - fibres are shaped in lightly twisted roving before dyeing,
- tow dyeing - it consists in dyeing the mono-filament material (called tow) produced during the manufacture of synthetic fibres,
- yarn dyeing,
- piece (e.g. woven, knitted and tufted cloths) dyeing,
- ready-made goods (finished garments, carpet mgs, bathroom-sets, etc.) dyeing.

Dyeing can be carried out in batch or in continuous/semi-continuous mode. The choice between the two processes depends on the type of make-up, the chosen class of dye, the equipment available and the cost involved. Both continuous and discontinuous dyeing involve the following steps:

- preparation of the dye,
- dyeing,
- fixation,
- washing and drying.

In **batch dyeing** (also called exhaustion dyeing) a certain amount of textile material is loaded into a dyeing machine and brought to equilibrium with a solution containing the dye and the auxiliaries over a period of minutes to hours.

The dyeing process starts with the absorption of the colourant onto the external surface of the fibre, then the diffusion and migration of the colourant through the fibre takes place. The use of chemicals and controlled temperatures accelerates and optimises exhaustion and fixation (rate/level) of the dye. When the dyeing is judged to be the right shade, the spent dye bath is drained and the textile material is washed to remove unfixed dyes and chemicals. Washing is usually carried out in the same equipment. However, separate washing machines can also be used in the case of fabric.

All these operations can be carried out manually or with different degrees of automatisation.

Dyeings which are “overshade” can be corrected by stripping dyestuff from the fibre using an excess of levelling agent or reducing conditions, and then adding further colour to achieve the correct shade. This is a very costly and polluting practice and is only used as a last resort in most dyehouses.

An important parameter in **discontinuous dyeing** is the *liquor ratio* of the equipment. This is the weight ratio between the total dry material and the total liquor. This parameter not only influences the amount of water and energy consumed in the dyeing process, but also plays an important role in the level of exhaustion of the dye and in the consumption of chemicals and auxiliaries.

Because dyeing machines vary greatly in their liquor ratios, depending also on the type of substrate to be dyed and its hydrophilicity, equipment manufacturers provide a range of nominal liquor ratios for each type of machine. This is defined as the range of liquor ratios at which the machine can be operated when it is loaded at its optimum/ maximum capacity. Below you will find a table with liquor ratio ranges for different equipment, different processes and different textiles.

Make-up		Process	Equipment	Liquor ratio
Loose/stock fibre (also card sliver and tow)		Loose stock dyeing	Autoclave (loose stock dyeing)	1:4-1:12 ^{w}
Yarn	Bobbins/ cones	Yarn dyeing	Autoclave (package dyeing)	1:8-1:15 ^{w}
	Hank	Hank dyeing	Hank dyeing machines	1:12-1:25 ^{w}
Woven and knitted fabric, tufted carpet	Rope	Piece dyeing in rope form	Winch beck	1:0
			Overflow	1:12-1:20 ^{w}
			Jet - for fabric for carpet	1:4-1:10 ^{w} 1:6-1:20$^{(4)}$
			Airflow	1:2-1:5 $^{(5)}$
	Open-width	Piece dyeing in open-width form	Winch (only for carpet)	1:15-1:30$^{(4)}$
			Beam dyeing Beam + washing machine	1:8-1:10 ^{w} 1:10-1:15 $^{(7)}$
			Jig dyeing Jigger + washing machine	1:3 -1:6 ^{w} 1:10$^{(7)}$
Ready-made goods (e.g. garments, rugs, bathroom-sets, etc.)		Piece dyeing	Paddle	1:60 (not exceptional)
			Drum	Very variable

Table 2.1. liquor ratio ranges for different equipment, different processes and different textiles

In **continuous and semi-continuous dyeing** processes, the dye liquor is applied to the textile either by impregnation (by means of foulards) or by using other application systems. Most commonly, textiles are fed continuously in open width through a dip trough filled with dye liquor. The substrate absorbs an amount of dye solution before leaving the dip trough through rollers that control the pick-up of the dye. Surplus stripped dye flows back into the dye bath. In the carpet industry (and for open goods that must pick-up and retain large volumes of liquor), thickening agents are added to the pad liquor to prevent dye migration. Dye fixation is usually achieved in a subsequent stage using chemicals or heat (steam or dry heat). The final operation is washing, which is usually carried out in washing machinery at the end of the same line.

The only difference between continuous and semi-continuous processes is the fact that in semi- continuous dyeing the application of the dye is performed continuously by padding, while fixation and washing are discontinuous.

In continuous and semi-continuous processes the liquor ratio is not of practical importance and it is not used as a parameter. In these processes the factor to be taken into account is the *wet pick-up %* (grams of liquor picked up by 100 grams of substrate) and the concentration of the dye.

An overview of the most common techniques and machinery utilised in continuous and semi-continuous processes is given in the table below.

Make-up		Process		Equipment
Woven & knitted fabric,	Rope	Continuous		Padding machine for piece in rope form + J-box or conveyor + washing machine
Tufted carpet	Open-width	Semi-continuous	Pad-batch (or Carp-O-Roll for carpet)	Padding machine + washing machine
			Pad-roll (or Carp-O-Roll for carpet)	Padding machine + washing machine
			Pad-jig	Padding machine + jigger + washing machine
		Continuous	Pad-steam	Padding machine + steamer + washing machine
			Pad-dry	Padding machine + stenter frame + washing machine
			Thermosol	

Table 2.2. Most common techniques and machinery utilised in continuous and semi- continuous processes

2.3.2.1 Cellulose fibres dyeing

Cellulose fibres can be dyed with a wide range of dyestuffs:

- ***Reactive dyes*** – In Turkey, all cellulose fibres are dyed with reactive dyes.. Mostly applied according to the pad-batch and continuous processes for woven fabric, while batch processes are the most common for knitted fabric, loose stock and yarn.
    - *Batch dyeing* – dye, alkali (sodium hydroxide or sodium carbonate or bicarbonate) and salt are added to the dye bath in one step, at the start of the process, or stepwise, where alkali is added only after the dye has absorbed to the fibre.Alkali amount is determined by the reactivity of the system and the desired depth of shade. Salt is added to improve bath exhaustion: the concentration employed depends on the substantivity of the dye and on the intensity of the shade.After dyeing, the liquor is drained off and the material is rinsed and then washed off with the addition of auxiliaries.
    - *Pad dyeing* - dye and alkali can be added together to the dye liquor or in separate steps into two separate padders. When all the chemicals are applied in one step, the stability of the pad liquor is important. With increasing reactivity of the dye there is a risk that the dye is hydrolysed by the alkali, before reacting with the fibre. For this reason dye and alkali are commonly metered separately into the padder. Among ***semi-continuous processes*** the cold pad-batch is by far the most important one for reactive dyes. After the textile has been padded with dye and alkali, it is rolled up into batches. Fixing takes place during storage. In ***continuous processes,*** padding, fixing, washing-off and drying are carried out in the same process line. Fixation is commonly achieved either by dry-heating or by steaming.
- ***Direct dyes*** - is used commonly to dye cotton or viscose substrates. Direct dyes are applied directly from the dye bath together with salt (sodium chloride or sodium sulphate) and auxiliary agents, which ensure a thorough wetting and dispersing effect. Mixtures of non-ionic and anionic surfactants are used for this purpose.

  - *Batch dyeing* - dye is made into paste, then dissolved in hot water and added to the dye bath. The electrolyte is then added to the dye bath. After the dye bath is drained, the fabric is washed with cold water and generally subjected to after-treatment.
  - *Pad dyeing* - encompass the following techniques: pad-steam, pad-roll, cold pad-batch and pad-jig process (the material is padded with the dye and then passed through a salt liquor in a jigger). In all processes the material is rinsed at the end with cold water. With increasing depth of colour the wet fastness can decrease to such an extent that after- treatment must generally be carried out. It can be done by: removing the unfixed dye by washing with complexing agents or surfactants with a dispersing effect or; reducing the solubility of the dye by blocking the hydrophilic groups ("enlargement of the molecule"). This is done by treating the textile by different agents: fixative cationic agents, metal salts, agents based on formaldehyde condensation products with amines, diazotised bases. Environmental concerns arise when after-treating with formaldehyde condensation products or metal salts.
- ***<u>Vat dyes</u>*** - are often used for fabrics that will be subjected to severe washing and bleaching conditions. Vat dyes are normally insoluble in water, but they become water-soluble and substantive for the fibre after reduction in alkaline conditions (vatting). They are then converted again to the original insoluble form by oxidation and in this way they remain fixed into the fibre.The following chemicals and auxiliaries are applied in vat dyeing: reducing agents, oxidising agents; alkali (caustic soda); salt; dispersing agents; levelling agents.
  - *Batch dyes* - textile is dyed very rapidly and unevenly due to the high affinity of the dye. Level dyeing can be achieved by: adding levelling agents; increase of the temperature under a controlled profile ("High Temperature" process and "Semi-pigmention" method); impregnation of the textile with the dye as water-insoluble dispersion, followed by addition of the reductive agent in a subsequent step (pre-pigmentation process). In all cases, oxidation and after-treatment follow. After-treatment consists in washing the material in a weakly alkaline bath with a detergent at boiling temperature.
  - *Continuous processes* - used almost exclusively for dyeing woven fabrics and to only a small extent for knitwear. The most commonly applied continuous process is the ***pad-steam*** process. The textile is padded with the aqueous dye dispersion in the presence of anti-migrant (polyacrylates, alginates, etc.) and dispersing/wetting agents, if required. After drying, the fabric is passed through a chemical padder, which contains the required amount of alkali and reducing agent and is fed immediately to a steamer. The material is finally rinsed, oxidised and soaped in an open-width washing machine. Voluminous open fabrics can be dyed according to a ***wet-steam process***. Unlike the pad-steam process, this process does not require intermediate drying before steaming.
- ***<u>Sulphur dyes</u>*** - used in piece dyeing (cellulose and cellulose-polyester blends), yarn dyeing (sewing thread, warp yarn for denim fabric, yarn for coloured woven goods),

dyeing of flock, card sliver (wool-man-made fibres blends). Sulphur dyes are insoluble in water, and, under alkaline conditions, are converted into the leuco-form, which is water-soluble and has a high affinity for the fibre. After adsorption into the fibre the colourant is oxidised and converted to the original insoluble state. The reducing agent, salts, alkali and unfixed dye are finally removed from the fibre by rinsing and washing. Number of chemicals and auxiliaries are applied to the substrate: reducing agents; alkali (caustic soda); salt; dispersing agents; complexing agents and oxidising agents.Mostly ***continuous dyeing*** methods are applied, although batch dyeing (in jigger, jet, and winch beck) is also possible. Material is impregnated with dye, reducing agent and wetting agent through a one-bath or a two-bath procedure. With the one-bath procedure (*pad-steam process*) the reducing agent and the dye are added at the same time. With the two-bath procedure (*pad- dry/pad-steam*) the material is padded in the liquor containing the dye and the wetting agent, while the reducing agent is applied, if necessary, in a second step, after intermediate drying. The material is then submitted to air-free steaming. After that, rinsing, oxidation and re-rinsing are carried out. Because the exhaustion is not too high, it is possible to re-use dyeing baths.

- ***Azoic (naphtol) dyes*** - allow colours with outstanding fastness.Dyeing is a complex process which involves a number of following steps:
  - preparation of the naphtholate solution by the hot solution process (the naphthol is dissolved by boiling with caustic soda) or by the cold solution process (the naphthol is solubilised with alcohol or cellosolve, caustic soda and cold water);
  - application of the naphtholate to the fibre by batch or padding techniques;
  - preparation of the diazotized base by reaction with sodium nitrite and hydrochloric acid (this step can be avoided when using fast colour salts);
  - formation of the azoic dye into the fibre, by passing the textile, previously impregnated with the naphtholate solution, through a bath containing the diazotized base or the fast colour salt;
  - after-treatment by rinsing the material to remove the excess naphthol from the fibre.

In the table below most common dyestuffs and dyeing techniques applied for cellulose fibres are presented.

Dyestuff	Chemicals and auxiliaries/ typical application conditions	Technique
Reactive	pH 9.5 -11.5 by addition of sodium carbonate and/or sodium hydroxide Salt is used to increase dye bath exhaustion: higher concentrations are used for low-affinity dyes and for deep shades. Application temperatures vary from 40 °C to 80 °C depending on the class of the dyestuff. In padding processes urea or cyanoguanidine is usually added to the pad liquor (the Econtrol® process described in Section 4.6.13 does not need urea). After dyeing, the material is soaped and then washed off with addition of surfactants to remove unfixed dye.	**Batch** **Pad-batch** **Pad-steam** **Pad-dry**
Direct	Salt is used to increase bath exhaustion. Mixtures of non-ionic and anionic surfactants are used as wetting/dispersing agents. After-treatment is usually necessary to improve wet-fastness (possible use of fixative cationic agents, formaldehyde condensation products).	**Batch** **Pad-batch** **Pad-jig** **Pad-steam**
Vat	Alkali and reducing agents (sodium dithionite, sulphoxylic acidderivatives, thiourea dioxide, and other organic reducing agents) areapplied to convert the dye to the sodium leuco form. Poorly degradable dispersants are present in the dye formulation and arefurther added in other steps of the process. Levelling agents are sometimes necessary. Temperature and the amount of salt and alkali required vary according to the nature of the dye (IK, IW, IN). Dye is fixed to the fibre by oxidation, generally using hydrogen peroxide, but halogen-containing oxidising agents can also be used After-treatment takes place in a weakly alkaline detergent liquor at boiling temperature. In continuous processes, anti-migration and wetting agents are used.	**Batch** **Pad-steam**
Sulphur	Reducing agents (Na_2S, NaHS, glucose-based combination of reducing agents) and alkali are applied to convert the dye into soluble form, unless ready-for-use dyes are used. Dispersants and complexing agents are used in batch dyeing In batch dyeing, the dye generally absorbs at 60 - 110 °C, while in the pad-steam process the material is padded at 20 - 30 °C and then subjected to steaming at 102 - 105 °C. Oxidation is carried out mainly with hydrogen peroxide, bromate and iodate.	**Batch** **Pad-steam** **Pad-dry/ pad-steam**
Azoic	Preparation of the naphtholate (caustic soda and, in some cases, addition of formaldehyde is required to stabilise the naphthol on the fibre) Impregnation of the naphtholate by exhaustion or padding processes Preparation of the diazotised base (with $NaN0_2$ and HCl). Developing stage (the textile is passed through the cold developing bath or the developing solution is circulated through the stationary textile in the dyeing machine).	**Batch** **Padding methods**

Table 2.3. Most common dyestuffs and dyeing techniques applied for cellulose fibres

2.3.2.2 Wool dyeing

Wool can be dyed with the following dyestuffs:

- ***Acid (metal-free)*** - typically applied in acidic conditions, but the pH range used varies depending on the type of acid dye.Levelling agents play an important role in acid dyeing.
    - *Level-dyeing colourants* are applied under strongly acidic conditions (1 - 3 % formic acid) in the presence of sulphate ions (5 - 10 % sodium sulphate) to assist migration and levelling.
    - *Acid milling dyes* have good affinity for the fibre and do not migrate well at the boil. They are therefore applied at more neutral pH (5 - 7.5 with acetic acid) in the presence of sodium acetate or ammonium sulphate and levelling agent.
    - *Fast acid dyes* (also known as half-milling dyes or perspiration-fast dyes) exhibit superior fastness properties to level-dyeing acid dyes, while retaining some of the migration properties. Application is from a moderately acidic dye bath (1 - 3 % acetic acid) in the presence of sodium sulphate (5 - 10 %) and levelling agent to assist migration.
- ***Chrome*** - Dye application takes place from a moderately acid dye bath (1 % acetic acid) often with an addition of formic acid towards the end of the boiling period to promote exhaustion of the dye. The dye bath is then cooled back from the boil to approx. 80 °C, the pH is lowered to approx. 3.5 with formic acid and the pre-dissolved chromium salt added. The dye bath is then returned to the boil. Chromium is added to the dye bath as either sodium or potassium dichromate. Most popular application methods of dye are:
    - *Chrome mordant* process relies on chroming the fibre prior to dyeing with a chromable dye;
    - *Metachrome* process applies both dye and chromium salt simultaneously;
    - *Afterchrome* process where dye is applied first and the fibre is then chromed in a separate step, utilising the exhausted dye bath and thus conserving water.
- ***Metal complex*** - use of levelling agents is very common when dyeing with metal-complex dyes. The groups of substances used for acid dyes also apply in this case. There are 2 methods of dye application:
    - *1:1 metal-complex dyes* is carried out at pH 1.8 - 2.5 with sulphuric acid or at pH 3-4 with formic acid, in the presence of sodium sulphate and other organic levelling agents.
    - *1:2 metal-complex dyes* is carried ot in the presence of ammonium acetate and may be divided into two sub-groups: weakly polar at pH range 4-7 and strongly polar at pH range 5-6.
- ***Reactive*** - are generally applied at pH values of between 5 and 6, depending on the depth of shade, in the presence of ammonium sulphate and specialised leveling The dyeing method may include a temperature hold step at 65-70 °C, during which the dye bath is maintained at this temperature for 30 minutes in order to allow the dye to migrate without fibre reaction. When dyeing of the very highest fastness is required,

the fibre is rinsed under alkali conditions (pH 8-9 with ammonia) to remove unreacted dyestuff..

Summary of the most common dyestuffs and techniques is presented below.

Dyestuff	Chemicals and auxiliaries/ typical application conditions	Technique
Acid dyes (metal-free)	Strongly acidic conditions for equalising dyes (by formic acid). Moderately acidic conditions for half-milling dyes (by acetic acid). More neutral conditions for milling dyes (by acetic acid and sodium acetate or ammonium sulphate). Salt: sodium sulphate or ammonium sulphate. Levelling agents other than sulphate and formic acid are notnecessary for level-dyeing colourants.	**Batch dyeing**
Chrome dyes (mordant)	pH 3 - 4.5 sodium sulphate. Organic acids: acetic and formic acid (tartaric and lactic acids can also be used). Reducing agent: sodium thiosulphate after-chrome with Na or K dichromate.	**Batch dyeing (After-chrome method)**
1:1 metal-complex dyes	pH 1.8 - 2.5 (pH 2.5 in the presence of auxiliary agents such as alkanolethoxylates). Sulphuric or formic acid. Salt: sodium sulphate. Ammonia or sodium acetate can be added to the last rinsing bath	**Batch dyeing**
1:2 metal-complex dyes	pH 4.5 - 7 Ammonium sulphate or acetate. Levelling agents (non-ionic, ionic and amphoteric surfactants).	**Batch dyeing**
Reactive dyes	pH 4.5 - 7 Formic or acetic acid levelling agent. After-treatment with ammonia for highest fastness.	**Batch dyeing**

Table 2.4. Most common dyestuffs and techniques.

2.3.2.3 Silk dyeing

Silk is dyed with the same dyes as wool, excluding 1:1 metal complex dyes. In addition, direct dyes can be used. The dyeing pH is slightly higher than with wool.For more detailed description, please refer to the "Wool dyeing" section.

2.3.2.4 Synthetic fibres dyeing

Polyamide (PA) fibres

Before dyeing, fabrics must generally be pre-fixed to compensate for material-related differences in affinity and to reduce the sensitivity to creasing during the dyeing process. Pre-fixing can be performed in a stenter frame.

Polyamide fibres (PA 6 and PA 6,6) are easily dyed with various types of dyes. Due to their hydrophobic characteristics, they can be dyed with disperse (non-ionic), acid, basic, reactive and 1:2 metal-complex dyes (ionic) can also be used. In practice acid levelling dyes are most commonly used. Dyes used are:

- ***Disperse dyes*** - are used for polyamide fibres. They are applied especially for lighter shades. The material is dyed in acidic conditions (pH 5) by acetic acid. A dispersing agent is always added to the liquor.
- ***Acid dyes*** - for high-affinity dyes the liquor must be sufficiently alkaline at the start and then slowly decreased to optimise exhaustion. Optimal exhaustion and uniform dyeing can also be achieved by controlling the temperature profile. Auxiliary agents (anionic, cationic, non-ionic surfactants) are normally used to improve the levelling effect. After-treatment with syntans (synthetic tanning agents) is often necessary. The material is treated at 70 - 80 °C and is then rinsed.
- ***Metal-complex dyes -*** dyeing conditions vary from weakly acidic by addition of ammonium sulphate and acetic acid to neutral or moderately alkaline for high-affinity dyes. For high-affinity dyes amphoteric or non-ionic levelling agents are usually added.
- ***Reactive dyes*** - the same dyes used for wool are also suitable for polyamide. The dyeing process is carried out in weakly acidic conditions (pH 4.5 - 5). The process is started at 20 - 45 °C and then temperature is increased near to boiling. Non-ionic surfactants and sodium bicarbonate or ammonia are used in the after-treatment step.

Summary of the most common dyestuffs and dyeing techniques for polyamide is presented in the following table.

Dyestuff	Chemicals and auxiliaries/ typical application conditions	Technique
Disperse	PH 5 by acetic acid. Dispersing agents (sulphoaromatic condensation products or nonionic surfactants). Dyeing is conducted at near-boiling temperature.	**Batch**
Acid dyes	pH conditions from acid to neutral depending on the affinity of the dye optimal bath exhaustion and level dyeing are achieved by either pH or temperature control methods (levelling agents are also used) in the acidic range, electrolytes retard the exhaustion with levelling dyes, wet-fastness is often unsatisfactory and after- treatment with synthanes can be necessary.	**Batch**
1:2 metal-complex dyes	Dyes containing sulphonic groups are preferred because they are more water-soluble and produce better wet-fastness to improve absorption of low-affinity dyes (especially for disulphonic) dyeing is carried out in weakly acidic conditions using acetic acid. High-affinity dyes are applied in neutral or weakly alkaline medium using amphoteric or non-ionic levelling agents.	**Batch**
Reactive dyes	In principle the reactive dyes used for wool are also suitable for PA dyeing is conducted at near-boiling temperature in weakly acidic conditions after-treatment is performed at 95 °C, using a non-ionic surfactant and sodium bicarbonate or ammonia.	**Batch**

Table 2.5. Most common dyestuffs and dyeing techniques for polyamide.

Polyester (PES) fibres

Articles made of pure PES are dyed almost exclusively using batch dyeing techniques and among these, dyeing under high-temperature conditions is the most commonly applied. The high temperature dyeing process is usually carried out in acidic conditions (pH 4-5) with addition of acetic acid under pressure at 125-135°C. In these conditions levelling agents are necessary to prevent excessively rapid absorption.

The thermosol process is another applied technique, although it is primarily used for PES/cellulose blends. The dye is padded on the textile together with an anti-migration agent. A drying step at 100-140 °C is carried out. Then the dye is fixed (200-225 °C for- 25 seconds).

For light shades, the material needs only to be rinsed or soaped after dyeing. For dark shades, in order to ensure high light fastness, an after-clearing step is normally necessary.

PES fibres can be dyed with cationic dyestuffs, provided that acidic components are used as co-monomers during the manufacturing of the fibre (creation of anionic sites).

Summary of the most common dyestuffs and dyeing techniques for polyester fibres is presented in the following table.

Dyestuff	Chemicals and auxiliaries/ typical application conditions	Technique
Disperse	pH 4 - 5 by acetic acid. Levelling agents (aliphatic carboxylic esters, ethoxylated products, combinations of alcohols, esters or ketones with emulsifying agents). Possible addition of complexing agents (EDTA) for dyes sensitive to heavy metals.	**Batch dyeing at 125 - 135 °C under pressure (HT)**
	This techniques requires the use of carriers unless modified polyester fibres are employed	**Batch dyeing below 100 °C**
	pH 4 - 5 by acetic acid. Thickeners such as polyacrylates and alginates are added to the padding liquor in order to prevent migration of the dye during drying. After-treatment with a solution containing sodium hydrosulphite and sodium hydroxide (dispersing agents are added to the last washing bath).	**Thermosol process**

Table 2.6. Most common dyestuffs and dyeing techniques for polyester fibres.

Acrylic (PAC) fibres

PAC fibres are hydrophobic and contain anionic groups in the molecule. As a result, they can be dyed with disperse and cationic dyes. With the introduction of cationic comonomers in the polymer, the fibre can also be dyed with acid dyes.

Batch dyeing is commonly applied for cable or stock (package dyeing), yarn in hank form or packages and for fabric. Piece dyeing can be performed on beam, overflow, paddle (for knitwear, ready-made bath sets), or drum (socks).

Stock, cable and top can be also dyed on special machine, using the pad-steam process, preferably with pressurised steam to obtain short fixing times. Piece goods, especially upholstery material (velour), are also dyed according to the pad-steam process, but in this case fixing is carried out with saturated steam. This implies longer fixing times, which means that rapidly diffusing cationic dyes and dye solvents are required.

Generally the following dyes are used:

- ***Disperse dyes*** **-** used to produce light to medium-deep shades. The dyeing techniques correspond to those used on polyester fibres. However, dyeing can be performed at temperatures <100 °C without carriers. Due to the good migration properties of disperse dyes, levelling agents are not required.
- ***Cationic dyes*** - include an electrolyte, acetic acid, a non-ionic dispersant and a retarding agent. *Batch dyeing* is conducted by controlling the temperature in the optimum range for the treated fibre. Finally the bath is cooled down and the material is rinsed and submitted to after-treatment.

Continuous processes commonly applied are:

- ***Pad-steam process with pressurised steam at more than 100 °C*** - this process has the advantage of reducing fixing time. Pad liquor typically contains a steam-resistant cationic dye, acetic acid and a dye solvent.
- ***Pad-steam process with saturated steam at 100 - 102 °C*** - this process requires a longer fixing time. Rapidly diffusing cationic dyes and dye solvents, which exhibit a carrier effect, are required.

When dyeing with basic dyes, special levelling agents (also called retarding agents) are widely used to control the absorption rate of the colourant on the fibre, thus improving level dyeing.

Summary of the most common dyestuffs and dyeing techniques for acrylic fibres is presented in the following table.

Dyestuff	Chemicals and auxiliaries/ typical application conditions	Technique
Disperse	Dyeing conditions correspond to those used for polyester. Addition of carriers is not required.	
Cationic	Acetic acid (pH 3.6 - 4.5). Salt (sodium sulphate or sodium acetate). Retardant auxiliaries (usually cationic agents). Non-ionic dispersing agents.	**Batch**
	Acetic acid (pH 4.5). Dye solvent. Steam-resistant, readily-soluble dyes (usually liquid) are required.	**Pad-steam process with pressurised steam**
	Dye solvent. Rapidly diffusing dyes are required.	**Pad-steam process with saturated steam**

Table 2.7. Most common dyestuffs and dyeing techniques for acrylic fibres.

Cellulose acetate (CA) and cellulose triacetate (CT)

CA and CT are hydrophobic and therefore they can be dyed with disperse dyes under conditions which are very similar to those applying to PES fibres.

Cellulose acetate is dyed by the exhaustion method with disperse dyes in the presence of non-ionic or anionic dispersing agents in weakly acidic conditions (pH 5 - 6). Dyeing is normally done at 80 - 85 °C.

Cellulose triacetate dyeing and finishing characteristics are more similar to purely synthetic fibres. CT, like CA, is dyed with disperse dyes in a weakly acidic medium in the presence of levelling auxiliaries. Applied dyeing techniques for CT are:

- ***Batch dyeing process*** - usually at 120 °C, but if these conditions are not possible a dyeing accelerant (based on butyl benzoate or butyl salicylate) is required.
- ***Thermosol process***.

Fibre blends dyeing

Natural/synthetic fibre blends are becoming more and more important in the textile industry because this allows combining the favourable technological properties of synthetic fibres with the pleasant feel of natural fibres.

Fibre blends can be produced according to three different methods:

- fibres of different types in the form of staple fibres are mixed at the yarn manufacturing stage, during spinning;
- fibres of different types are separately spun and the resulting yarns are wound together to give a mixed yarn;
- fibres of different types are separately spun and combined together only at the weaving stage, where one or more fibre yarns are used as warp and the other ones as weft.

Dyeing of blend fibres is always longer and more difficult as an operation compared to pure fibre dyeing. Despite these disadvantages, dyeing tends to be placed as close as possible towards the end of the finishing process.

When dyeing blend fibres, the following methods can be applied:

- the two fibres are dyed in the same tone ("tone on tone") or in two different shades using the same dyes,
- only one fibre is dyed (the colourant is not absorbed by the other ones),
- the different fibres are dyed in different tones.

Blend fibres dyeing can be done in batch, semi-continuous and continuous processes.

The most common fibre blends will be presented in the following sections.

Polyester-cellulose blends

A large part of the entire production of PES (ca. 45 %) is used to make this mixture. Polyester-cellulose blends are used for all types of clothing and for bed linen. The cellulose component is usually cotton, but viscose staple fibres and occasionally linen are also used.

In dyeing PES-cellulose mixtures, disperse dyes are used for the polyester component, while the cellulose portion is usually dyed with reactive, vat and direct dyes. Pigment dyeing is also commonly used for light shades.Disperse dyes stain cellulose fibres only slightly and they can easily be removed by subsequent washing or, if necessary, by reductive aftertreatment. Most of the dyes used for cellulose stain PES only slightly or not at all.

In *batch dyeing,*most common method, the application of dyes can be done in one or two steps in one bath or in two different baths in subsequent stages. The disperse dye is generally applied at high-temperature conditions without the use of carriers.

In *continuous processes* the dyes are usually applied in one bath. The fabric is subsequently dried and disperse dye is fixed to the PES component by the thermosol process. Afterwards, the second dye is developed according to the procedure typical of each class, using in general pad- steam, pad-jig or pad-batch processes.

Polyester-wool blends

Polyester-wool blends are widely used, especially for woven goods and knitwear. The most frequently found ratio is 55:45 PES: wool.

Wool cannot be dyed at the high temperatures typical of the high temperature dyeing process for PES fibres and PES-cellulose blends. The dyeing time should also be as short as possible so that the wool is not damaged. For large productions it is therefore preferable to dye wool and PES separately in top, blending the two fibres at the yarn manufacturing stage.

When dyeing polyester-wool blends, disperse dyes are used for polyester and anionic (acid and metal-complex dyes) for wool.

PES-wool blends are typically dyed according to the following batch processes:

- at boiling temperature with carriers,
- at 103 - 106 °C with little carrier,
- at 110 - 120 °C with the addition of formaldehyde as a wool protective agent and with low amounts of carriers or none at all (HT conditions).

The *one-bath process* method is preferred in practice; the *two-bath process* is applied when deep shades and high fastness are required. The material is first dyed with disperse dyes. A reductive intermediate treatment may be applied before dyeing the wool part. In both dyeing methods, after dyeing, an after-treatment is applied to remove any disperse dye attached to the wool, if the dye used for wool can withstand it.

Polyamide-cellulose blends

Since PA fibres have an affinity for almost all dyes used for cellulose, different possibilities are available for dyeing this blend:

- direct and disperse dyes at pH 8,
- acid or 1:2 metal-complex dyes at pH 5-8 range,
- vat dyes (exhaust and pad-steam process are used),
- reactive dyes.

Application conditions are those typical of each class of dye.

Polyamide-wool blends

Blends with polyamide/ wool ratios varying from 20:80 to 60:40 are used. This blend is particularly important in the carpet sector. Both fibres have affinity for acid and 1:2 metal-complex dyes. However, since PA is more accessible to the dye than wool, it is dyed more deeply, particularly in the case of light colours. To counteract this effect, special levelling agents (also called PA reserving/ blocking agents) are used. These auxiliaries have a relatively high affinity for the PA fibre and retard the absorption of the colourant on this part of the blend.Dyeing is performed in the presence of acetic acid and sodium sulphate.

Acrylic-cellulose blends

PAC-cellulose blends are used for household textiles and imitation fur. The percentage of PAC in the mixtures varies between 30 and 80 %.

PAC can be dyed with cationic or disperse dyes, while direct, vat or reactive dyes can be used for the cellulose component.

The following methods are the most commonly used for dyeing this blend:

continuous dyeing with cationic and direct dyes according to the pad-steam process,

batch dyeing (usually according to the one-bath, two-steps method) with cationic and vat dyes or with cationic and reactive dyes.

Acrylic-wool blends

Among synthetic fibres, PAC fibres are the most suitable for obtaining blends with wool that keep a wool-like character. The blending ratio of PAC to wool varies from 20:80 to 80:20.

Metal-complex, acid and reactive dyes are the dyestuffs typically used for the wool part, while PAC is dyed with cationic dyes.

PAC-wool blends can be dyed using the following exhaustion methods:

- ***one-bath one-step*** - allows shorter dyeing times and lower consumption of water,
- ***one-bath two-step*** - use of reserve agents is not necessary,
- ***two-bath***.

2.3.2.5 Environmental aspects

Potential sources and types of emissions associated with dyeing processes are summarised in the following table.

Operations	Emission sources	Type of emission
Colour kitchen operations	Dye preparation	Discontinuous, low-concentration water emission at the end of each batch (cleaning step)
	Auxiliaries preparation	Discontinuous, low-concentration water emission at the end of each batch (cleaning step)
	Dispensing of dyes and auxiliaries (manual)	Indirect pollution from inaccurate dosing and handling of chemicals (spillage, poor shade repeats, etc.)
	Dispensing of dyes and auxiliaries (automatic)	No emission, provided that the system is regularly calibrated and verified for accuracy
Batch dyeing	Dyeing	Discontinuous, low-concentration water emission at the end of each
	Washing and rinsing operations after dyeing	Discontinuous, low-concentration water emission at the end of each
	Cleaning of equipment	Discontinuous, low concentration water emission
Semi-continuous and continuous dyeing	Application of the colourant	No emission from the process unless dye bath is drained
	Fixation by steam or dry-heat	Continuous emission to air (generally not significant, except for specific situations such as, for example, the thermosol process, drying of carrier-dyed fabrics, etc.)
	Washing and rinsing operations after dyeing	Continuous, low concentration water emission
	Discharging of leftovers in the chassis and feed storage	Discontinuous, concentrated water emission at the end of each lot
	Cleaning of equipment	Discontinuous, low concentration water emission (it can contain hazardous substances when reductive agents and hypochlorite are applied)

Table 2.8. Potential sources and types of emissions associated with dyeing processes.

Due to the low vapour pressure of the substances in the dye bath, emissions to air are generally not significant, and that is why most of the emissions are emissions to water. A few exceptions are the thermosol process, pigment dyeing and those dyeing processes where carriers are employed. In pigment dyeing the substrate is not washed after pigment application and therefore the pollutants are quantitatively released to air during drying. Emissions from carriers are to air and water.

Environmental issues related to the substances employed

Water-polluting substances in the above-mentioned emissions may originate from:

- ***Dyes*** – unfixed are present in spent dye baths (discontinuous dyeing), residual dye liquors and water from washing operations. Rates of fixation depends on: dye, type of fibre and process type and its parameters. Dyestuffs are not or poorly biodegradable in oxiditve conditions so to remove them differents actions are to be taken. Less water-soluble dyes molecules can be removed by mean of coagulation/precipitation or absoption/adsorption on activated sludge. Colour of the dye is also important from environmental impact point of view. For reactive dyestuffs lower amount of dye is needed to get a given shade comparing to other types of dye so less amount of dyestuff need to be removed from the wastewater. Dyestuff that will pass through wastewater treatment plant cause change of water colour and, this way, can interrupt photosynthesis. Beside organic content of the dye can cause aquatic toxicity and give rise of the different pollutants emissions.
    - *AOX emissions* – halogens are more likely present in vat, disperse and reactive dyes. For vat the content can be up to 12% on weight but can be removed with high efficiency through absorption. Some reactive dyes with low fixation are difficult to remove from the waste water because of the low biodegradability. Halogen is also found in discharges of dye-concentrate (pad, kitchen) and non-exhausted dye baths that may still contain unreacted dyestuff. For other classes of dye halogen content is usually below 0,1% so the AOX issue is not releavant. Dyestuffs containing organically bound halogens (except fluorine) are measured as AOX. The only way to limit AOX from dyeing is by dye selection, by more efficient use of dyes or by treating the resulting effluent by decolouration using destructive techniques, such as the free radical oxidation or non-destructive techniques (e.g. coagulation, adsorption). AOX from dyes do not have the same effect as the AOX derived from chlorine reactions (haloform reaction, in particular) arising from textile processes such as bleaching, wool shrink-resist treatments, etc.
    - *Heavy metals emissions* - metals are used as catalysts during the manufacture of some dyes and can be present as impurities, but also in some dyes the metal is chelated with the dye molecule, forming an integral structural element. Dye manufacturers are now putting more effort into reducing the amount of metals present as impurities. This can be done by selection of starting products, removal of heavy metal and substitution of the solvent where the reaction takes place. Most common metals present in dyes are: copper, nickel and chromium. The total amount of metallised dye used is decreasing, but there are still domains where such dyes cannot be easily substituted. The presence of the metal in these metallised dyes can be regarded as a less relevant problem compared to the presence of free metal impurities. Since the metal is an integral part of the dye molecule, which is itself non-biodegradable, there is very little potential for it to become bio-available. Treatment methods such as filtration

and adsorption on activated sludge, which remove the dye from the waste water, also reduce nearly proportionally the amount of bound metal in the final effluent. Conversely, other methods such as advanced oxidation, may free the metal.

- *Toxicity* - there is still a lot of dyestuffs showing aquatic toxicity and/or allergenic effects. About 60 % to 70 % of the dyes used nowadays are azo dyes which, under reductive conditions, may produce amines and some of them are carcinogenic.

- ***Auxiliaries contained in the dye formulation*** - different additives, depending on the dye class and the application method employed, are present in the dye formulations. Since these substances are not absorbed/ fixed by the fibres, they are completely discharged in the waste water.These additives are not toxic to aquatic life, they are in general poorly biodegradable and not readily bioeliminable. This applies in particular to the dispersants present in the formulations of vat, disperse and sulphur dyes. These dyes are water-insoluble and need these special auxiliaries in order to be applied to the textile in the form of aqueous dispersions. The difference between liquid and powder formulations should also be mentioned. Dyes supplied in liquid form contain only one third of the amount of dispersing agent normally contained in powder dyes. The reason for this difference stems from the manufacturing process of powder dyes: the very small particles generated during grinding must be protected during the subsequent drying process and this is possible only by adding high proportions of dispersing agents.Typical additives are listed in the table at the end of this subchapter.
- ***Basic chemicals (e.g. alkali, salts, reducing and oxidising agents) and auxiliaries used in dyeing processes*** – among many different chemicals and auxiliaries the following should be mentioned, in particular:
  - Sulphur-containing reducing agents - present in the waste water from sulphur dyeing in form of sulphides used in the process as reducing agents. In some cases the sulphide is already contained in the dye formulation and in some other cases it is added to the dye bath before dyeing. Sulphides are toxic to aquatic organisms and contribute to increasing COD load. In addition, sulphide anions are converted into hydrogen sulphide under acidic conditions, thereby giving rise to problems of odour and corrosivity. Sodium hydrosulphite (also called sodium dithionite) is another sulphur-containing reducing agent, which is commonly used not only in sulphur and vat dyeing processes, but also as reductive after-cleaning agent in PES dyeing. During the dyeing process sodium dithionite is converted into sulphite (toxic to fish and bacteria) and in some cases this is further oxidised into sulphate. In the waste water treatment plant sulphite is normally oxidised into sulphate, but this can still cause problems. Sulphate, in fact, may cause corrosion of concrete pipes or may be reduced under anaerobic conditions into hydrogen sulphide. Consumption of the reducing agent by the oxygen present in the machine (partially-flooded dyeing machines) needs also to be taken into account. Instead of applying only the amount of reducing agent required for the reduction of the dyestuff, a significant extra amount of reducing agent often needs to be added to

compensate for the amount consumed by the oxygen contained in the machine. This obviously increases oxygen demand of the effluent.

- *Oxidising agents*- dichromate should no longer be used in Europe as an oxidising agent when dyeing with vat and sulphur dyes, but it is still widely used for the fixation of chrome dyes in wool dyeing. Chromium III exhibits low toxicity, while chromium VI is acutely toxic and has been shown to be carcinogenic towards animals. During the dyeing processes with chrome dyes, Cr VI is reduced to Cr III if the process is under control but emissions of Cr VI may still occur due to inappropriate handling of dichromate during dye preparation (care must be taken as dichromate is carcinogenic and may cause health problems for workers handling it). The use of bromate, iodate and chlorite as oxidising agents in vat and sulphur dyeing processes and the use of hypochlorite as stripping agent for decolouring faulty goods or for cleaning dyeing machines may produce AOX emissions. However, only hypochlorite and elemental-chlorine-containing compounds are likely to give rise to hazardous AOX. Salts of various types are used in dyeing processes for different purposes. In particular, large amounts of salt are used in cotton batch dyeing processes with reactive dyes. In addition to the use of salt as a raw material, neutralisation of commonly employed acids and alkalis produces salts as a by-products. Salts are not removed in conventional waste water treatment systems and they are therefore ultimately discharged in the receiving water. Although the mammalian and aquatic toxicity of the commonly employed salts are very low, in arid or semi-arid regions their large-scale use can produce concentrations above the toxic limit and increase the salinity of the groundwater.
- *Carriers* - are still an issue in dyeing of polyester in blend with wool. Carriers may already be added to the dyes by manufacturers. In this case textile finishers will have little knowledge of the loads discharged . They include a wide group of organic compounds, many of them steam volatile, poorly biodegradable and toxic to humans and aquatic life. However, as the active substances usually have high affinity for the fibre (hydrophobic types), 75 - 90 % are absorbed by the textile and only the emulsifiers and the hydrophilic-type carriers such as phenols and benzoates derivatives are found in the waste water. The carriers that remain on the fibre after dyeing and washing, are partially volatilised during drying and fixing operations and can give rise to air emissions. Traces can still be found on the finished product, thus representing a potential problem for the consumer.
- *Other auxiliaries of environmental interest* - other substances that may be encountered in the dyeing auxiliaries and that may give rise to water pollution are: levelling agents, retarders for cationic dyes, auxiliaries for fastness improvement, dispersing agents, complexing agents etc. These are water-soluble hard-to-biodegrade compounds which can pass untransformed or only partially degraded, through waste water treatment systems. In addition, some of them are toxic or can give rise to metabolites which may affect reproduction in the aquatic environment.

- ***Contaminants present on the fibre when it enters the process sequence*** (residues of pesticides on wool are encountered in loose fibre and yarn dyeing and the same occurs with spin finishes present on synthetic fibres).

Additive	Chemical composition	COD mg 0$_2$/kg	BOD$_5$ mg0$_2$/kg	TOC elimination (i)
Dispersants	Lignin sulphonates. Naphthalene sulphonates condensation products with formaldehyde. Ethylene oxide/ propylene oxide copolymers.	1200 650	50 50	15% 15%
Salts	Sodium sulphate, sodium chloride			
Powder binding agents	Mineral- or paraffin oils (+ additives)			
Anti-foaming agents	Acetyl glycols			
Anti-freeze agents	Glycerine Glycols	1200 1600	780 10	90% 95%
Thickening agents	Carboxymethyl cellulose Polyacrylates	1000	0	30%
Buffer systems	Phosphate Acetate			

Table 2.9. Auxiliaries contained in dye formulation

Environmental issues related to the process

Both water and energy consumption in dyeing processes are a function of the dyeing technique, operating practices and the machinery employed.

- **Batch dyeing processes -** generally require higher water and energy consumption levels than continuous processes. This is due to a number of different factors. The higher *liquor ratios* involved in batch dyeing mean not only higher water and energy uses, but also a higher consumption of those chemicals and auxiliaries that are dosed based on the volume of the bath. Consistently with the quality of the different types of substrates, all equipment manufacturers now can offer machines with reduced liquor ratios. Terms like *"low liquor ratio"* and *"ultra-low liquor ratio"* are now commonly used to define the performance/ features of modern machines. Use of low liquor ratio machinery, or selection of the most adequate machine for the size of the lot to be processed, is fundamental to the resultant environmental performance of the process. Another factor to take into consideration is the *discontinuous nature of the batch dyeing operating mode,* especially with regard to operations such as *cooling, heating, washing and rinsing. Shade matching* can be responsible for higher water and energy consumption, especially when dyeing is carried out without the benefit of laboratory instruments. Increased energy and water consumption may also be caused by inappropriate *handling techniques* and/or poorly performing *process control systems.*

- **Continuous and semi-continuous dyeing processes -** consume less water, but this also means a higher dyestuff concentration in the dye liquor. In discontinuous dyeing the dye concentration varies from 0.1 to 1 g/1, while in continuous processes this value is in the range of 10 to 100 g/1. The residual padding liquor in the pads, pumps and pipes must be discarded when a new colour is started. The discharge of this concentrated effluent can result in a higher pollution load compared with discontinuous dyeing, especially when small lots of material are processed. The use of small pipes and pumps and small pad-bath troughs help to reduce the amount of concentrated liquor to be discharged. In addition, it is possible to minimise the discard of leftovers, by using automated dosing systems, which meter the dye solution ingredients and deliver the exact amount needed.

In both continuous and batch dyeing processes, final washing and rinsing operations are waterintensive steps that need to be taken into consideration. Washing and rinsing operations actually consume greater quantities of water than dyeing itself.

2.3.3 Printing

2.3.3.1 Printing processes

Printing, like dyeing, is a process for applying colour to a substrate. However, instead of colouring the whole substrate (cloth, carpet or yarn) as in dyeing, print colour is applied only to defined areas to obtain the desired pattern. This involves different techniques and different machinery with respect to dyeing, but the physical and chemical processes that take place between the dye and the fibre are analogous to dyeing.

A typical printing process involves the following steps:

- colour paste preparation,
- printing,
- fixation,
- after-treatment.

When describing the different printing techniques, a distinction should be made between printing with pigments, which have no affinity for the fibre, and printing with dyes (reactive, vat, disperse, etc.).

Printing with pigments

Pigment printing has gained much importance today and for some fibres (e.g. cellulose fibres) is by far the most commonly applied technique. Pigments can be used on almost all types of textile substrates and, thanks to increased performance of modem auxiliaries, it is now possible to obtain high-quality printing using this technique.

Pigment printing pastes contain a thickening agent, a binder and, if necessary, other auxiliaries such as fixing agents, plasticizers, defoamers, etc.

After applying the printing paste, the fabric is dried and then the pigment is normally fixed with hot air (depending on the type of binder in the formulation, fixation can also be achieved by storage at 20 °C for a few days). The advantage of pigment printing is that the process can be done without subsequent washing comparing with other printing techniques.

Printing with dyes

Printing with dyes is much more complicated process. Following operations are taken:

- ***Printing paste preparation*** - the composition of the pastes is more complex and variable, being determined not by the dye used, but by the printing technique, the substrate, the application and the fixation methods applied. Apart from the dye, printing pastes contain a thickening agent and various other auxiliaries, which can be classified according to their function as follows:
    - oxidising agents,
    - reducing agents,
    - discharging agents for discharge printing,
    - substances with a hydrotropic effect, like urea,
    - dye solubilisers, which are polar organic solvents,
    - resists for reactive resist printing,
    - defoamers.

  All the necessary ingredients are metered (dosed) and mixed together in a mixing station. Since between 5 and 10 different printing pastes are usually necessary to print a single pattern (in some cases up to 20 different pastes are applied), in order to reduce losses, due to incorrect measurement, the preparation of the pastes is done in automatic stations. In modern plants, with the help of special devices, the exact amount of printing paste required is determined and prepared in continuous mode for each printing position, thus reducing leftovers at the end of the run.It is common practice in many printing houses to filter the printing pastes before application, using for example a filter cloth. This operation is especially important for thickeners to prevent free particles from blocking the openings of the screens.

- ***Printing (paste application)*** - is applied to specific areas of the textile using one of the following techniques:
    - *direct printing (which also includes digital and transfer printing)* - the dye is applied to specific areas of a pretreated textile substrate, which can be white or pre-dyed (in light colours).
    - *discharge printing* - in the fixation process that follows the application of the printing paste there is local destruction of a dye applied previously. If the etched (discharge), previously dyed area becomes white, then the process is called *white discharge.* If, on the contrary, a coloured pattern has to be obtained in the etched area after the destruction of the previously applied dye, then the process is called *coloured discharge.* In this case the printing paste must contain a reduction-resistant dye along with the chemicals needed to destroy the previous one. As a

result the pre-dyed background is destroyed according to a pattern and the dye, which is resistant to reduction, takes its place.

- *resist printing* - a special printing paste (called “resist”) is printed onto certain areas of the fabric to prevent dye fixation. In the case of *physical resist* the material is printed with a difficult-to-wet resin that inhibits the penetration of a dye applied in a second stage. With a *chemical resist*, dye fixation is prevented by a chemical reaction. Depending on the way the process is carried out, one can speak of pre-printing, intermediate or over-printing resists. One common procedure is the wet-on-wet process in which the resist paste is initially printed, then the material is overprinted with full cover screen and finally fixed and washed. Over-printing resists can be applied only if the dye, already present in the previously dyed and dried fabric, is still in its unfixed form, as in the case of developing dyes.

The difference between *transfer printing* and the techniques described earlier is that with this technique the surface of the fabric is not directly printed. The pattern is first created on an intermediate carrier using selected disperse dyes and then it is transferred from there to the fabric. The dye is usually fixed by placing the printed paper in contact with the fabric into a thermal pressure system. There is no need for further treatment such as steaming, washing, etc. This technique is applied for polyester, polyamide and some acrylic fibres, using selected disperse dyestuffs according to the specific type of fibre.After printing, the fabric is dried. Water evaporation leads to an increase in dye concentration and at the same time prevents the colours from smearing when the fabric is transported over the guide rollers.

- ***Fixation*** –in this step the aim is to transport as much as possible of the dye, which is retained by the thickener, into the fibres. Fixation is usually carried out with steam. Water vapour condenses on the printed material, swells up the thickener, heats the print and provides the necessary transport medium for the diffusion of the dye. The distribution of the dye between fibre and thickener is an important factor in determining the fixation degree of the dye, which is called the "retaining power" of the thickener.
- ***After-treatment*** – is the last step of the printing process which consists in washing and drying the fabric. When printing with insoluble dyes such as vat dyes this operation also serves as a means to re-convert the dye to the original oxidised state. In this case, after an initial rinsing with cold water, the printed material is treated with hydrogen peroxide. The process is completed with a soap treatment with sodium carbonate at the boiling point. Washing is not necessary with pigment printing and transfer printing.
- Ancillary operations - at the end of each batch and at each colour change various cleaning operations are carried out:
    - the rubber belt, to which the fabric is glued during printing, is cleaned in continuous mode with water to remove excess adhesive and printing paste;

- the printing gears (all systems responsible for feeding and applying the paste to the substrate) are cleaned by first removing as much as possible of the paste residues and then rinsing with water;
- the remaining paste in the containers, in which the paste is prepared (paste vats), are in general previously cleaned up by means of sucking systems before being washed out with water.

2.3.3.2 Printing technology

A variety of different machines can be used for printing fabrics. The most commonly used are described below.

Flat-screen printing

Flat-screen and rotary-screen printing are both characterised by the fact that the printing paste is transferred to the fabric through openings in specially designed screens. The openings on each screen correspond to a pattern and when the printing paste is forced through by means of a squeegee, the desired pattern is reproduced on the fabric. A separate screen is made for each colour in the pattern. Flat-screen printing machines can be manual, semi-automatic or completely automatic.

After printing, the screens and the application system are washed out. It is common practice to squeeze the colour from the screens back into the printing paste mixing containers before washing them.

Rotary-screen printing

Rotary-screen printing machines use the same principle described earlier, but instead of flat screens, the colour is transferred to the fabric through lightweight metal foil screens, which are made in the form of cylinder rollers. The fabric moves along in continuous mode under a set of cylinder screens while at each position the print paste is automatically fed to the inside of the screen from a tank and is then pressed through onto the fabric. A separate cylinder roller is required for each colour in the design.

Rotary-screen printing machines are equipped with both gluing and washing devices analogous to those described earlier for flat-screen printing. The belt is washed in order to remove the residues of paste and adhesive. Not only the belt, but also the screens and the paste input systems (hoses, pipes, pumps, squeegees, etc.) have to be cleaned up at each colour change.

Roller printing

In roller printing, the print paste is supplied from reservoirs to rotating copper rollers, which are engraved with the desired design. These rollers contact a main cylinder roller that transports the fabric. By contacting the rollers and the fabric the design is transferred to the fabric. As many as 16 rollers can be available per print machine, each roller imprints one repeat of the design. As the roller spins, a doctor blade in continuous mode scrapes the excess of paste back to the colour trough. At the end of each batch the paste reservoirs are manually emptied into appropriate printing paste batch containers and squeezed out. The belt and the printing gear (roller brushes or doctor blades, squeegees and ladles) are cleaned up with water.

Jet printing

Jet printing is a non-contact application system originally developed for printing carpets, but now increasingly used in the textile sector.In jet printing, injection of dye into the substrate is made through a jet by means of a controlled air flow. This dye is drained into the balance tank, filtered and recirculated. The dye is supplied continuously to the main storage tank to compensate the amount of dye used.

2.3.3.3 Environmental aspects

Emission sources typical of printing processes are:

- ***printing paste residues*** - are produced for different reasons during the printing process and the amount can be particularly relevant. Two main causes are incorrect measurements and the common practice of preparing excess paste to prevent a shortfall. Moreover, at each colour change, printing equipment and containers have to be cleaned up. Common practice is to use dry capture systems to remove residues before rinsing with water. In this way they can at least be disposed of in segregated form, thus minimising water contamination. Another significant, but often forgotten source of printing paste residues is the preparation of sample patterns. Sometimes they are produced on series production machines, which means high specific amounts of residues produced. There are techniques available that can help to reduce paste residues and techniques for recovery/re-use of the surplus paste. Their success is, however, limited due to a number of inherent technological deficiencies of analogue printing technology.
- ***waste water from wash-off and cleaning operations*** - is generated primarily from final washing of the fabric after fixation, cleaning of application systems in the printing machines, cleaning of colour kitchen equipment and cleaning of belts. Waste water from cleaning-up operations accounts for a large share of the total pollution load, even more than water from wash-off operations. Emission loads to water are mainly attributable to dyestuff printing processes because in the case of pigment printing they are completely fixed on the fibre without need for washing-off. Pollutants that are likely to be encountered in waste water are listed in the table at the end of this chapter.
- ***volatile organic compounds from drying and fixing*** - cause the emission to the air. The following pollutants may be encountered in the exhaust air:
    - aliphatic hydrocarbons (Cio-C_2o) from binders,
    - monomers such as acrylates, vinylacetates, styrene, acrylonitrile, acrylamide, butadiene,
    - methanol from fixation agents,
    - other alcohols, esters, polyglycols from emulsifiers,
    - formaldehyde from fixation agents,

- ammonia (from urea decomposition and from ammonia present, for example, in pigment printing pastes),
- N-methylpyrrolidone from emulsifiers,
- phosphoric acid esters,
- phenylcyclohexene from thickeners and binders.

Pollutants that are likely to be encountered in waste water are listed in the table below.

Pollutant	Source	Remarks
Organic dyestuff	Unfixed dye	The related environmental problems depend on the type of dyestuff concerned
Urea	Hydrotropic agent	High levels of nitrogen contribute to eutrophication
Ammonia	In pigment printing pastes	High levels of nitrogen contribute to eutrophication
Sulphates and sulphites	Reducing agents by-products	Sulphites are toxic to aquatic life and sulphates may cause corrosion problems when concentration is >500 mg/1
Polysaccharides	Thickeners	High COD, but easily biodegradable
CMC derivatives	Thickeners	Hardly biodegradable and hardly bioeliminable
Polyacrylates	Thickeners Binder in pigment printing	Hardly biodegradable, but >70 % bioeliminable (OECD 302B test method)
Glycerin and polyols	Anti-freeze additives in dye formulation Solubilising agents in printing pastes	
m-nitrobenzene sulphonate and its corresponding amino derivative	In discharge printing of vat dyes as oxidising agent In direct printing with reactive dyes inhibits chemical reduction of the dyes	Hardly biodegradable and water-soluble
Polyvinyl alcohol	Blanket adhesive	Hardly biodegradable, but >90 % bioeliminable (OECD 302B test method)
Multiple- substituted aromatic amines	Reductive cleavage of azo dyestuff in discharge printing	Hardly biodegradable and hardly bioeliminable
Mineral oils / aliphatic hydrocarbons	Printing paste thickeners (half-emulsion pigment printing pastes are still occasionally used)	Aliphatic alcohols and hydrocarbons are readily biodegradable Aromatic hydrocarbons are hardly biodegradable and hardly bioeliminable

Table 2.10. Pollutants in waste water

2.3.4 Washing

2.3.4.1 Washing with water

Important factors in washing are:

- water characteristics,
- choice of soaps and detergents,
- hydromechanical action,
- temperature and pH,
- rinsing stage.

Washing is normally carried out in hot water (40 - 100 °C) in the presence of wetting agent and detergent. The detergent emulsifies the mineral oils and disperses the undissolved pigments.

The choice of the surfactants may vary depending on the type of fibre. Mixtures of anionic and non-ionic surfactants are commonly used. An important factor in the selection of a surfactant is its effectiveness in strong alkaline conditions.

Washing always involves a final rinsing step to remove the emulsified impurities.

Fabric washing can be carried out in **rope form** or **open-width**, and both in **discontinuous** or in **continuous** mode. The most commonly used technique is continuous mode in open-width.

2.3.4.2 Dry cleaning

Industrial solvent washing is sometimes necessary especially for delicate fabrics. In this case the impurities are carried away by the solvent, which is usually perchloroethylene. In the same step, softening treatments may also be carried out. In this case, water and surfactant-based chemicals are added to the solvent.

Solvent washing may be carried out continuously in full width (for woven or knitted fabric) or discontinuously with yarn or fabrics in rope form (generally for knitted fabric).

Solvent washing instalations have a built-in solvent treatment and recovery system in which the solvent is purified by distillation and re-used for the next washing process. Residual sludge from distillation must be disposed of as hazardous waste in case of high concentration of solvent.

After distillation, the solvent must be cooled before re-use and thus high amounts of cooling water are required. This water is never contaminated by solvent and can therefore be re-used. In mills having both solvent and water washing facilities, warm water from the cooling plant maybe used for water washing treatments, allowing water and energy savings. In many cases, however, this water is not re-used and it is discharged together with the other effluents.

Both **closed** and **open airflow circuits** can be used for the removal of solvent from fabric:

- ***open circuit machines*** **-** when the washing cycle is over, large amounts of air are taken from the external environment, warmed up with a steam heat exchanger and introduced into the machine, thus obtaining the evaporation of the organic solvent. This process goes on until the solvent is almost completely eliminated from clean fabrics. Solvent-rich-air is then sent to a centralised activated charcoal filtering system. Filters require regular regeneration to ensure optimal cleaning performance. Most modem filters allow discharge into the atmosphere below 3-4 mg/m^3.
- ***closed circuit machines***- the volume of air used to carry out the drying process, instead of being filtered and released into the atmosphere, is internally treated. Such treatment consists in recovering the solvent by condensation using a chiller. When the solvent has been removed from air and recovered, solvent-poor-air is heated by a heat exchanger and then sent again inside the machine. Recovered solvent is sent to a centralised plant, where it is distilled and purified. Closed circuit machines do not require an active carbon filter.

Apart from the above-mentioned air emissions in open-circuit machines, possible emissions during washing operations may result from machine losses (which can be eliminated or reduced by hermetic sealing of the machinery) and from solvent attached to the dried fabric and ultimately released in the atmosphere. Most modem machines have a built-in control system which makes it impossible to open the machine hatch if the solvent concentration in the machine is greater than values established by national regulations.

Other potential sources of emissions are represented by the solvent contained in the residual sludges and active carbon filters.

2.3.5 Drying

Drying is necessary to eliminate or reduce the water content of the fibres, yarns and fabrics following wet processes. Drying, in particular by water evaporation, is a high-energy-consuming step (although overall consumption may be reduced if re-use/ recycling options are adopted).

Drying techniques may be classified as **mechanical** or **thermal**:

- ***mechanical processes***- are used in general to remove the water which is mechanically bound to the fibre. This is aimed at improving the efficiency of the following step.
- ***Thermal processes***- consist in heating the water and converting it into steam. Heat can be transferred by means of:
  - convection,
  - infrared radiation,
  - direct contact,
  - radio-frequency.

In general, drying is never carried out in a single machine, normally drying involves at least two different techniques.

2.3.5.1 Loose fibre drying

The water content of the fibre is initially reduced by either centrifugal extraction or by mangling before evaporative drying.

Centrifugal extraction

Textile centrifugal extractors (hydroextractors) are essentially a more robust version of the familiar domestic spin dryer, and normally operate on a batch principal, although machines capable of continuous operation may be used in very large installations.

When using conventional batch hydroextractors, fibre is unloaded from the dyeing machine into specially designed fabric bags which allow direct crane loading of the centrifuge.

Mangling

Pneumatically loaded mangles may be used to reduce the water content of dyed loose fibre. Such equipment is often associated with a fibre opening hopper, which is designed to break up the dyepack and present the fibre to a continuous dryer as an even mat. Mangling is invariably less efficient than centrifugal extraction.

Evaporative drying

All hot air evaporative dryers are of essentially similar design consisting of a number of chambers through which hot air is fan circulated. Consecutive chambers operate at different temperatures, fibre passing from the hottest into progressively cooler chambers. Fibre may be transported on a brattice or conveyer belt, or may be carried through the machine on the surface of a series of “suction drums”. High efficiency dryers with perforated steel conveyer belts have been developed, which even out the air pressure drop across the fibre matt. This design results in more even drying and lower thermal energy requirements.

While the majority of dryers are steam heated, a number of manufactures supply **radio frequency dryers**. Fibre is conveyed on a perforated polypropylene belt through the radio frequency field and air flow is fan assisted. With these machines the fibre is not subjected to such high temperatures and the moisture content of the dried material can be controlled within fine limits.

Radio frequency dryers are reported to be significantly more energy efficient than steam heated chamber dryers. However, the higher efficiency is not always gained if a more global analysis is made, comparing the primary energy needed for production of electric power with methane gas consumed for thermal energy production. Radio frequency dryers are mainly used where the cost of electricity is low.

2.3.5.2 Hanks drying

Centrifugal extraction

Drained hanks from the dyeing machine can contain (in the case of wool) up to 0.75 kg water per kg of dry fibre (or higher depending on the hydrophilicity of the fibre). Moisture content is normally reduced by centrifugal extraction, prior to evaporative drying, using equipment identical to that described above for loose fibre. Yarn is normally unloaded from the dyeing machine into fabric bags held in round carts to facilitate direct crane loading of the centrifuge. Hydroextraction reduces the moisture content to approximately 0.4 litres/kg dry weight.

Evaporative drying

Evaporative dryers consist of a number of heated chambers with fan assisted air circulation, through which the hanks pass suspended on hangers or poles, or supported on a conveyer.

The hank sizes employed in carpet yarn processing require a slow passage through the dryer to ensure an even final moisture content, and a residence time of up to 4 hours is not uncommon. Air temperature is maintained below 120 °C to prevent yellowing (wool yellows above the boiling temperature).

All designs are capable of **continuous operation**. Thermal input is normally provided by a steam heated exchanger and many designs incorporate air-to-air heat exchangers on the dryer exhaust to recover heat.

Less commonly, hanks may be dried by employing a dehumidifying chamber. Moisture is recovered by condensation, using conventional dehumidification equipment. In comparison to evaporative dryers, yarn residence time tends to be longer, but energy consumption is lower.

2.3.5.3 Yarn packages drying

The moisture content of dyed packages is initially reduced by centrifugal extraction. Specially designed centrifuges, compatible with the design of the dyeing vessel and yarn carriers are employed.

Traditionally packages were oven dried, very long residence times being required to ensure adequate drying of the yam on the inside of the package. Two methods are currently used:

- ***rapid (forced) air drying***- generally operate by circulating hot air from the inside of the package to the outside at a temperature of 100 °C, followed by conditioning, in which remaining residual moisture is redistributed in a stream of air passing from the outside to the inside of the package. Rapid air drying is sometimes being combined with initial vacuum extraction
- ***radio frequency drying***- operate on the conveyer principle and are perhaps more flexible than the types mentioned above. Lower temperatures can be used and energy efficiency is said to be high.

2.3.5.4 Fabric drying

The drying process for fabric usually involves two steps:

- the first one is aimed at removing water which is mechanically bound to fibres,
- the second one is necessary to dry completely the fabric.

Hydro-extraction by squeezing

The fabric is squeezed by means of a padding machine through two or three rollers covered with mbber. This process cannot be applied to delicate fabric.

Hydro-extraction by suction

The fabric is transported flat over a "suction drum" which is linked to a pump. The external air is sucked through the fabric and thereby removes the excess water. The resulting residual humidity is still about 90 %.

Centrifugal hydro-extractor

The design of this machine is similar to the one described earlier for loose fibre and yarn hydroextraction. With heavy fabric, an horizontal axis machine may be used.

This is the most efficient method for mechanical water removal, but it cannot be applied to delicate fabrics prone to form permanent creases.

Stenter

This machine is used for full drying of the fabric. The fabric is conveyed through the machine in open width. A hot current of air is blown across the fabric thereby producing evaporation of the water.The fabric is sustained and moved by two parallels endless chains. The fabric is hooked undulating and not taut to allow its shrinking during drying.

Most common stenter designs are:

- ***horizontal***– the fabric enters wet from one side and exits dried from the other. It moves horizontally without direction changes. Horizontal stenter frames occupy more space and are less efficient (in terms of energy consumption) than multi-layer ones.
- ***multi-layer*** – the fabric enters and exists from the same side. It is deviated many times, which makes this equipment unsuitable for delicate fabrics.

Hot-flue dryer

This machine is composed of a large metallic box in which many rolls deviate the fabric (in full width) so that it runs a long distance (about 250 m) inside the machine. The internal air is heated by means of heat exchangers and ventilated.

Contact dryer (heated cylinder)

In this type of machinery the fabric is dried by direct contact with a hot surface. The fabric is longitudinally stretched on the surface of a set of metallic cylinders. The cylinders are heated internally by means of steam or direct flame.

Conveyor fabric dryer

The fabric is transported within two blankets through a set of drying modules. Inside each module the fabric is dried by means of a hot air flow.

This equipment is normally used for combined finishing operations on knitted and woven fabrics when, along with drying, a shrinking effect is also required in order to give the fabric a soft hand and good dimensional stability.

Aero dryer

This machine can be used for washing, softening and drying operations on woven and knitted fabrics in rope form.

During the drying phase the fabric in rope form is re-circulated in the machine by means of a highly turbulent air flow. Water is thus partly mechanically extracted and partly evaporated.

Thanks to the particular design of this machine it is possible to carry out in the same machine wet treatments such as washing. In this case the bottom of the machine is filled up with water and the required chemicals and the fabric is continuously soaked and squeezed.The capacity of this machine is determined by the number of channels (from 2 to 4).

2.3.6 Finishing (functional finishing)

The term "finishing" covers all those treatments that serve to impart to the textile the desired end-use properties. These can include properties relating to visual effect, handle and special characteristics such as waterproofing and non-flammability.

Finishing may involve **mechanical/physical** and **chemical treatments**. Moreover, among chemical treatments one can further distinguish between treatments that involve a chemical reaction of the finishing agent with the fibre and chemical treatments, where this is not necessary (e.g. softening treatments).

Some finishing treatments are more typical for certain types of fibre (for example, easy-care finishes for cotton, antistatic treatment for synthetic fibres and mothproofing and anti-felt treatments for wool). Other finishes have more general application (e.g. softening).

In the case of fabric (including carpets in piece form), the finishing treatment often takes place as a separate operation after dyeing. However, this is not a rule: in carpets, for example, mothproofing can be carried out during dyeing and, in pigment dyeing, resin finishing and pigment dyeing are combined in the same step by applying the pigment and the film-forming polymer in the dyeing liquor.

In more than 80 % of cases, the finishing liquor, in the form of an aqueous solution/dispersion, is applied by means of padding techniques. The dry fabric is passed through the finishing bath containing all the required ingredients, and is then passed between rollers to squeeze out as much as possible of the treating solution before being dried and finally cured. Washing as final step, tends to be avoided unless absolutely necessary.

In order to reduce the pick-up, other so-called minimum application techniques are gaining importance. These are topical application methods like:

- ***kiss-roll (or slop-padding)*** application, where the textile is wetted by means of a roller, which is immersed in a trough and which applies a controlled amount of liquor on only one side of the textile,
- ***spray application***,
- ***foam application***.

Apart from particular cases where there are problems of incompatibility between the different auxiliaries, both with padding and long liquor application techniques (batch processes), all the finishing agents necessary to give the textile material the desired properties are applied in a single bath rather than in different steps.

2.3.6.1 Chemical finishing treatments

Easy-care treatments

Easy-care finishings are applied to cellulose-containing fibres, to impart characteristics such as easy-to-wash, creasing resistance during wash and wear, no ironing or minimum ironing. These properties are now required for cellulose fibres to allow them to compete with synthetic fibres such as polyamide and polyester.

Easy-care recipes consist of various ingredients:

- cross-linking agent,
- catalyst,
- additives (softeners, hand builder most commonly, but also water-repellents, hydrophilizing agents, etc.),
- surfactants as wetting agent.

Water-repellent treatments (hydrophobic treatments)

Water-repellent treatments are applied to fabrics, for which waterproofing properties are required but which also need air and water-vapour permeability.

Softening treatments

Softeners are used not only in finishing processes, but also in batch dyeing processes, where they are applied in the dyeing baths or in the subsequent washing baths.

The application of softening agents does not involve curing processes. In continuous or semi-continuous processes the impregnated fabric is dried in the stenter frame.

Flame-retardant treatments

Flame-retardant finishing has become more and more important and is compulsory for some articles. Flame-retardant treatments should protect the fibre from burning, without modifying the handle, the colour or the look of the fabric.

They are generally applied to cotton and synthetic fibres. In some specific cases, in particular in the carpet sector, they can also be required for wool, even though this fibre is already inherently flame resistant.

Flame-retardant properties are achieved by the application of a wide range of chemicals, which either react with the textile or are used as additives.

There are other approaches available to produce textile products with flame-retardant properties including:

- the addition of specific chemicals in the spinning solution during fibre manufacturing,
- the development of modified fibres with inherent flame-retardant properties,
- back-coating of finished textile-covered articles (e.g furniture, matresses), whereby a fire- resistant layer is attached to one side of the finished textile.

Antistatic treatments

The process consists in treating the fabric with hygroscopic substances (antistatic agents) which increase the electrical conductivity of the fibre, thus avoiding the accumulation of electrostatic charge.

These finishing treatments are very common for synthetic fibres, but they are also applied to wool in the carpet sector for floorcoverings that have to be used in static-sensitive environments.

Mothproofing treatments

The mothproofing of wool and wool-blends is mainly restricted to the production of textile floorcoverings, but some high-risk apparel is also treated (for example military uniforms). For apparel application, mothproofing is usually carried out in dyeing. Floorcoverings may be mothproofed at different stages of the production processes, such as during raw wool scouring, spinning, yam scouring, dyeing, finishing or later in the backing line.

Bactericidal and fungicidal treatments

These finishes may be applied to chemicals (to preserve auxiliaries and dye formulations) and to apparel, for example in odour suppressant for socks and for the treatment of floorcoverings for the healthcare sector and to provide anti dust-mite finishes. Close analysis shows that more and more textile products (clothing and underwear) are being treated with anti-microbial agents.

Anti-felt treatments

Anti-felt finishing is applied in order to provide anti-felt properties to the good. This will prevent shrinking of the finished product when it is repetitively washed in a laundry machine.

Two treatments, which are also complementary, are applied:

- ***oxidising treatment (subtractive treatment)*** - the specific chemicals used attack the scales of the cuticles and chemically change the external structure of the fibre. This treatment has traditionally been carried out using one of the following chlorine-releasing agents:
    - sodium hypochlorite – the oldest process, difficult to control, can change wool characteristic;
    - sodium salt dichloroisocyanurate – has the ability to release chlorine gradually, thereby reducing the risk of fibre damage;
    - active chlorine (no longer used).

  All these chlorine-based agents have recently encountered restrictions because they react with components and impurities (soluble or converted into soluble substances) in the wool, to form absorbable organic chlorine compounds (AOX).Alternative oxidising treatments have therefore been developed. In particular, peroxysulphate, permanganate, enzymes and corona discharge come into consideration. However, the only alternative to chlorine-based agents readily available today is peroxysulphate.Both with chlorine-based agents and peroxysulphate, sodium sulphite is then added as an antioxidant to the same liquor at slightly alkaline pH. This is a reductive aftertreatment to avoid damage and yellowing of the wool fibre at alkaline pH.The goods are subsequently rinsed. If necessary, they are treated with a polymer (resin).

- ***treatment with resins (additive treatment)*** - in additive processes, polymers are applied to the surface of the fibre with the aim of covering the scales with a "film". The polymer must have a high substantivity for wool. Cationic polymers are the most suitable for this treatment because, after the previous oxidative and reductive pretreatment, the wool surface becomes anionic. The polymer may be, in some case, sufficiently effective on its own to make pretreatment unnecessary. However, the combination of subtractive and additive processes has the greatest technical effect.
- ***combined treatments (Hercosett processes)*** - the oldest combination process is the so called Hercosett process (by C.S.I.R.O), which consists in chlorine pretreatment followed by application of a polyamide-epichloridrine resin.The Hercosett process has been widely used for years as anti-felt finishing of wool in different states (loose fibre, combed top, yam, knitted and woven fabric) due to its low cost and high quality effects. However, the effluent shows high concentrations of COD and AOX. Alternative resins have been developed, based on polyethers, cationic aminopolysiloxanes, synergic mixtures of polyurethanes and polydimethylsiloxanes, but they all have some limitations concerning their applicability. New processes have also been developed, but so far the results achieved with the Hercosett process cannot be fully matched by any alternative, which is why it is still the preferred process particularly for treatments such as the anti-felt finishing of combed tops.

2.3.6.2 Environmental aspects

Among textile finishing processes, the chemical ones are those that are more significant from the point of view of the emissions generated. Emissions are quite different between continuous and discontinuous processes. The environmental aspects related to this processes are discussed below together with the description of the process itself.

Environmental issues associated with continuous finishing processes

With some exceptions (e.g. application of phosphor-organic flame-retardant), continuous finishing processes do not require washing operations after curing. This means that the possible emissions of water pollution relevance are restricted to the system losses and to the water used to clean all the equipment. In a conventional foulard, potential system losses at the end of each batch are:

- the residual liquor in the chassis,
- the residual liquor in the pipes,
- the leftovers in the batch storage container from which the finishing formulation is fed to the chassis.

Normally these losses are in the range of 1 - 5 %, based on the total amount of liquor consumed; it is also in the finisher's interest not to pour away expensive auxiliaries. However, in some cases, within small commission finishers, losses up to 35 or even 50 % may be observed. This depends on the application system and the size of the lots to be finished. In this respect, with application techniques such as spraying, foam and slop-padding (to a lower extent due to high residues in the system) system-losses are much lower in terms of volume (although more concentrated in terms of active substance).

Residues of concentrated liquors are re-used, if the finishing auxiliaries applied show sufficient stability, or otherwise disposed of separately as waste destined to incineration. However, too often these liquors are drained and mixed with other effluents.

Although the volumes involved are quite small when compared with the overall waste water volume produced by a textile mill, the concentration levels are very high, with active substances contents in the range of 5 -25 % and COD of 10 to 200 g/litre. In the case of commission finishing mills working mainly on short batches, the system losses can make up a considerable amount of the overall organic load. In addition, many substances are difficult to biodegrade or are not biodegradable at all and sometimes they are also toxic.

The range of pollutants that can be found in the waste water varies widely depending on the type of finish applied.

In the drying and curing operation air emissions are produced due to the volatility of the active substances themselves as well as that of their constituents. Furthermore air emissions (sometimes accompanied by odours) are associated with the residues of preparations and fabric carry-over from upstream processes.The emission loads depend on the drying or curing temperature, the quantity of volatile substances in the finishing liquor, the substrate and the potential reagents in the formulation. The range of pollutants is very wide and depends on the active substances present in the formulation and again on the curing and drying parameters.

Another important factor to consider regarding air emissions is that the directly heated (methane, propane, butane) stenters themselves may produce relevant emissions.

Environmental issues associated with discontinuous processes

The application of functional finishes in long liquor by means of batch processes is used mainly in yarn finishing and in the wool carpet yarn industry in particular. Since the functional finishes are generally applied either in the dye baths or in the rinsing baths after dyeing, this operation does not entail additional water consumption with respect to dyeing. For the resulting water emissions, as with batch dyeing, the efficiency of the transfer of the active substance from the liquor to the fibre is the key factor which influences the emission loads. The efficiency depends on the liquor ratio and on many other parameters such as pH, temperature and the type of emulsion (micro- or macro-emulsion). Maximising the efficiency is particularly important when biocides are applied in mothproofing finishing. The main issues worth mentioning are the application of mothproofing agents (emissions of biocides) and the low level of exhaustion of softeners (emissions of poorly biodegradable substances).

2.3.7 Coating and laminating

Usually, coated and laminated textiles consist of a textile substrate - typically a woven, knitted, or non-woven textile fabric - combined with a thin, flexible film of natural or synthetic polymeric substances.

A coated fabric usually consists of a textile substrate on which the polymer is applied directly as a viscous liquid. The thickness of the film is controlled by applying it via a blade or similar aperture.

A laminated fabric usually consists of one or more textile substrates, which are combined with a pre-prepared polymer film or membrane by adhesives or heat and pressure.

The basic techniques for coating/laminating fabrics require the following conditions:

- the fabric to be coated/laminated is supplied full width on a roll,
- the fabric is fed under careful tension control to a coating or laminating heat zone,
- after application of the coating auxiliaries, the fabric is passed through an oven to cure the composite and remove volatile solvents before cooling and rolling up.

In the textile industry the flame lamination of foams is a widely used technique: a pre-prepared thin, thermoplastic foam sheet is exposed to a wide slot flame burner located before the laminating rolls. No drying or curing oven is required in this process. Air emissions produced during this treatment are highly irritant and may trigger allergic reaction in susceptible persons.

2.3.7.1 Carpet back-coating

The backing process is an important production step which is applied to improve the stability of textile floor-coverings. Moreover, backing may have a positive influence on properties such as sound-proofing, stepping elasticity and heat insulation.

One can distinguish the following types of coatings:

- ***Pre-coating*** - common feature of tufted carpets is that they are pre-coated after tufting to permanently anchor the needled pile loops in the carrier layer. The pre-coating material used consists of:
    - x-SBR latex, which is a dispersion containing a copolymer produced from styrene, butadiene and carbonic acid,
    - fillers,
    - water,
    - additives (e.g. thickeners, anti-foam, foam-stabilisers, etc.).

  The pre-coating can be applied:

    - unfoamed, by means of slop-paddin,
    - foamed, by means of the doctor-blade technique.

  During the subsequent drying stage, thanks to the formation of hydrogen bonds, the polymer chains are netted into a three-dimensional web and an elastic plastic layer is produced.

Foam coating–used methods consist in the application of a foam layer onto a pre-coated carpet.The foam finish is carried out in two steps: foam application and foam solidification through drying. The lattice is foamed with air and then applied by means of a doctor-blade onto the precoated carpet.

Most commonly used foam coating methods are:

- SBR foam coating
- The SBR foam must be stabilised until it is solidified in the vulcanisation oven. For this stabilisation, two methods are used:
  - the non-gel process, which uses surfactants as foam stabilisers
  - the gel process, which uses ammonium acetate (AA gel system) or silicium fluoride (SF gel system) as gelling agents.

  The foam is composed of:the SBR colloidal dispersion; a paste, which contains a number of active additives; inactive fillers (mainly chalk, which is added to the ready-compounded paste); water; thickeners (e.g. polyvinyl alcohol, methyl cellulose, polyacrylates); colourants and pigments; anti-oxidants and ozone stabilisers.

- PU foam coating

  The ICI polyurethane coating process is the most commonly applied. The carpet is prepared by steaming and then reaches the spray chamber where the components of the polyurethane (diisocyanate and an alcohol) are sprayed. The C02 produced during the chemical reaction is embedded into the foam. The coating is reinforced in an infrared heating field and in a subsequent reaction field.

- ***Textile back-coating***- consists in the application of a textile fabric onto the pre-coated carpet. The connection between the carpet and the textile fabric is obtained through the application of a layer of:
  - Laminating glue

    In this process an x-SBR latex is applied to the carpet by slop-padding. After the application of the textile fabric, the final reinforcement of the latex is carried out by means of heat treatment. The latex composition is similar to that used for pre-coating, with a higher share of polymer dispersion in order to allow a higher adhesive power.

  - Melting glue

    This system uses thermoplastic polymers (mainly polyethylene), which are meltable by means of heat. In powder lamination (and in particular in powder scattering lamination) polyethylene powder is evenly sprinkled onto the back of the carpet. Subsequently the polymer is melted in an infrared field. In the next stage the fabric is pressed into the melting glue. Through subsequent cooling, the melting glue becomes permanently connected between the textile fabric and the bottom side of the carpet.

Another textile backing process by means of melting glue is the so-called AdBac process. In this case the carpet is constructed using a primary cloth (carrier layer) with low melting point additives, hi the next stage the secondary cloth (also with a low melting point) is brought into contact with the back of the carpet before this enters the heating zone. The higher temperature melts the cloths, which are then forced together by nip rolls at the exit of the heating zone. The carpet is then cooled.

- ***Heavy coating*** - is mainly used for the coating of self-lying (SL) tiles. The coating process consists in the application of the coating material by means of slop-padding or doctor blade and subsequent reinforcement. In most cases the coating material is applied into layers (two-coat technique). After the first layer, which may also serve as a pre-coating layer, a glass-fibre web may be added. The second coating application follows. The following coating materials are used:
    - APO (abbreviation for “atactical polyolefm”);
    - bitumen (enriched with inorganic and organic additives)
    - PVC (polyvinylchloride)
    - EVA (ethylen vinyl acetate).
        - Reinforcement,
        - Back finish.

2.3.7.2 Environmental aspects

The main environmental concerns in coating/laminating operations relate to air emissions arising from solvents, additives and by-products contained in the formulations of the coating compounds. A distinction must therefore be made between the various products available.

Coating powders

The emission potential of coating powders is in most cases negligible with the exception of polyamide 6 and its copolymers. In some cases softeners (often phthalates) can be found in the emissions.

Coating pastes

The emissions from the coating pastes result mainly from the additives (except in the case of PA 6 which is mentioned above). These are mainly:

- fatty alcohols, fatty acids, fatty amines from surfactants,
- glycols from emulsifiers,
- alkylphenoles from dispersants,
- glycol, aliphatic hydrocarbons, N-methylpyrrolidone from hydrotropic agents,
- aliphatic hydrocarbons, fatty acids/salts, ammonia from foaming agents,
- phthalates, sulphonamides/esters ex softeners/plasticisers,
- acrylic acid, acrylates, ammonia, aliphatic hydrocarbons from thickeners.

Polymer dispersions (aqueous formulations)

The emission potential of polymer dispersions is quite low compared to coating pastes. Components, that are responsible for air emissions, are the dispersing agents, residual compounds from the polymerisation and monomers arising from incomplete reaction during polymerisation. The latter are particularly relevant to the workplace atmosphere and odour nuisances.

Melamine resins

Melamine resins are widely applied. Melamine resins are produced by the reaction of melamine and formaldehyde and subsequent etherification mostly with methanol in aqueous medium. The products can contain considerable amounts of free formaldehyde and methanol. During their application the cross-linking reaction of the resin with itself or with the fabric (e.g. cotton) is initiated by an acid catalyst and/or temperature, releasing stoichiometric amounts of methanol and formaldehyde.

Polymer dispersions (organic solvent-based formulations)

Solvent coating is not very common in the textile finishing industry. When this technique is applied, exhaust air cleaning equipment based on thermal incineration or adsorption on active carbon is normally installed.

2.4 Manufacture of end products

So far the fundamental unit processes in the textiles industry that are within the scope of this Guide havebeen described. The information given has been structured by fibre type, which has made it possible to explain those issues that are determined by the physico-chemical behaviour of the fibre. From a practical point of view, however, a subdivision of the textile industry activities into sub-sectors based on the type of the fibre offers little practical aid.

In practice, there are established patterns of activity, with finishing mills tending to concentrate on particular kinds of make-up or end-product (e.g. yarn, woven fabric, carpet, etc.), because this is defined by the specialist machinery used. This degree of specialisation does not apply to the same extent to the fibre. Although in the past the predominance of natural fibres made possible the identification of separate sectors based on the fibre (mainly cotton and wool), nowadays the proliferation of man-made fibres means that finishers almost always process a wide variety of fibres, even if one type is dominant within a particular mill (e.g. wool, cotton, etc.).

As an aid to the application of this guide, therefore, the rest of this chapter gives practical information on the main categories of mills that are actually found in this sector (integrated mills should be seen as a combination of these main categories).

Typical mills categories are listed below.

Wool scouring mills	
Mills finishing yarn and/or floe	- mainly CV, PES, PAC and/or CO floe material; - mainly WO floc/tops/yarn;

	- mainly CO yarn; - mainly PES yarn; - mainly WO, PAC and/or CV yarn
Mills finishing knitted fabric	- mainly CO; - mainly CO with a significant proportion of printing; - mainly synthetic fibres; - mainly WO
Mills finishing woven fabric	- mainly CO and/or CV; - mainly CO and/or CV with a significant proportion of printing; - mainly WO; - mainly PA.
Carpet industry	- wool and wool-blend carpet yarn/ loose fibre; - dyehouses; - piece carpet dyeing and printing mills; - integrated carpet manufacturing companies.

Table 2.11. Typical mills categories

2.4.1 Wool Scouring Mills

Wool processed in Europe is mostly imported. Most of the wool produced in Europe is in fact coarse wool which is suitable for the manufacturing of carpets, but not for use in apparel. Merino wool (fine wool) is therefore imported mainly from Australia, New Zealand, South Africa, Argentina, Uruguay and Brazil.

The organisation of the scouring sector reflects the two main systems used to process wool: the **woollen** and the **worsted system**. Scourers tend to specialise in one or the other.

Woollen system scourers normally only scour the wool (sometimes they may blend it before dispatching it to the customer).

Worsted system scourers usually scour, card and comb the wool thus producing a sliver of parallel fibres which is called top. Because of this difference, worsted system scourers are usually referred to as combers.

Within Europe, significant quantities of wool are also obtained from skins of slaughtered animals by a process called fellmongering in which the skins are treated chemically or biochemically to loosen the wool roots so that the wool can readily be separated from skins.

Most of the scourers have an on-site waste water treatment plant to treat their effluent. The majority discharge the treated effluent to sewer, but there are several scourers who discharge directly to surface waters. Those in the latter category have to treat their effluent to higher standards. Of the scourers who discharge to sewer, some treat only the heavily contaminated effluent from the scouring section and discharge the rinse water flowdown without treatment; others mix the two effluent streams before treatment.

Broadly speaking, there are five main types of effluent treatment process used by scourers:

- coagulation/flocculation;

- evaporation (sometimes combined with incineration with full closure of the water cycle);
- membrane filtration;
- anaerobic/aerobic biological treatment;
- spreading to land or lagooning (after grease separation, in extensive wool producing areas).

Some scourers use combinations of the above processes. All of the effluent treatment processes employed by scourers produce a sludge or a concentrate which has to be disposed of safely. Sludge disposal routes used include landfill, composting, incineration, pyrolysis/gasification and brick manufacture.

2.4.2 Mills finishing yarn and/or floe

A common feature of floe and yarn finishing is that all process steps are normally carried out in the same equipment. The basic process sequence is:

- pretreatment (scouring/bleaching);
- dyeing;
- finishing (mainly softening by addition of softening agents in the last rinsing bath, but also flame retardant or mothproofing treatments for carpet wool fibre).

Pretreatment can be carried out as a separate step, especially in the case of natural fibres, or together with dyeing by adding additional specific auxiliaries in the dye bath. The second option is common when the amount of impurities on the fibre is not significant and they are easy to remove, or when auxiliaries (e.g. preparation agents, spinning lubricants) are specially chosen not to interfere with the dyeing process.

Bleaching is normally not applied for synthetic fibres. With natural fibres, bleaching is commonly omitted for dark shades, whereas for light shades it is often combined with scouring. After washing, the material is dyed in the same machine and then submitted to final washing and rinsing.

For dyeing, it is common practice, in the case of floe and tops material, to achieve the desired final shade by thorough mixing of individual dyeings. With yarn, on the other hand, the required shade has to be achieved with only one dyeing since, unlike floe and tops, the shade cannot be corrected by compensation. For this reason, a higher standard of accuracy is required in the development of the dye recipe in the laboratory.

The dyes and auxiliaries applied vary with the fibres processed.

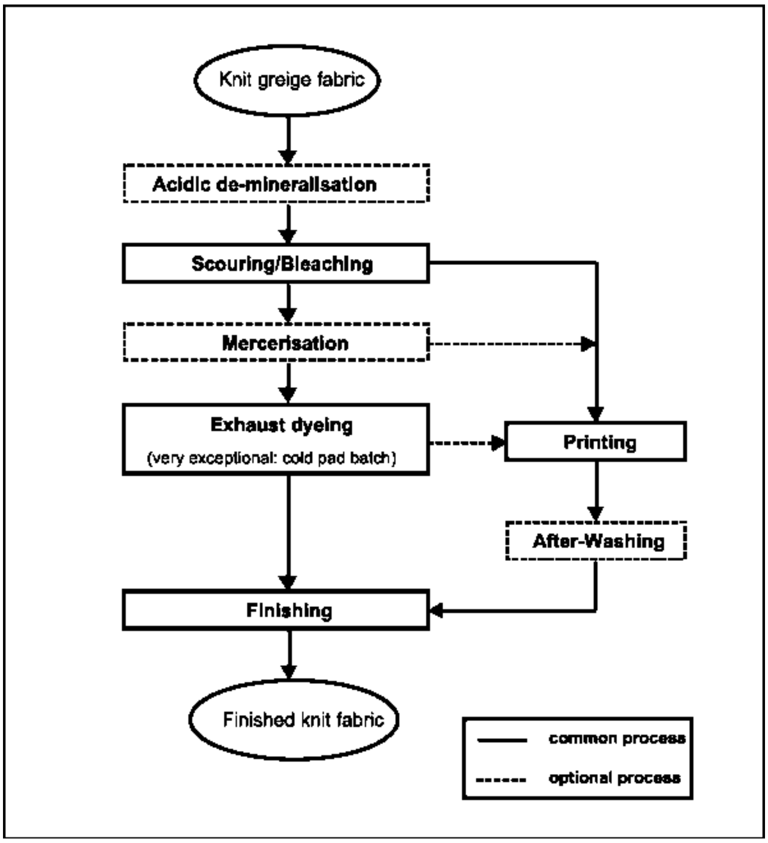
Mercerising treatment may be desired for cotton. If so, the material is processed in hank form. Mercerisation is carried out in a separate machine and is normally the first treatment applied.

Anti-felt treatment is another optional operation; it is applied only on wool and mainly on tops.

2.4.3 Mills finishing knitted fabric

Mills finishing knitted fabric consisting mainly of CO

The typical process sequence for finishing knitted fabric consisting mainly of cotton is shown on the scheme below. The dotted lines indicate processes that are not obligatory or are not common practice. Mercerisation is also indicated with a dotted line because this additional treatment is only required for certain articles.



Scouring is generally a batch operation, but large installations often do it in continuous mode. Hydrogen peroxide is the most commonly applied bleaching agent in cotton mills today.

Cotton knitted fabric can be dyed with different classes of dyestuffs such as reactive, direct, sulphur and vat dyestuffs. Reactive dyestuffs are the most commonly used. Direct dyestuffs may be used for lighter shades and sulphur dyestuffs for dark shades. Vat dyestuffs may be used for very high light fastness requirements.

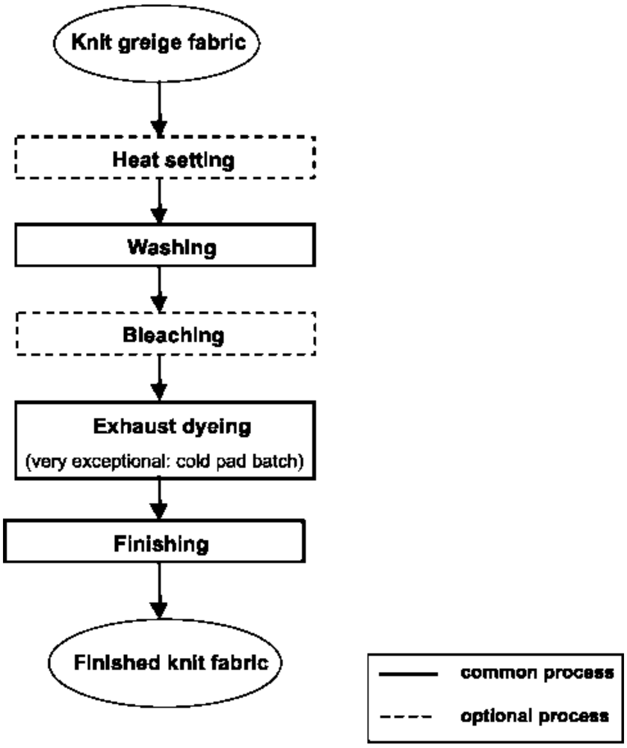
In printing, two further subclasses can be identified:

- mills finishing cotton knitted fabric without a printing section;
- mills finishing cotton knitted fabric with a printing section.

Pigment printing is widely applied for knitted fabric and does not need the after-washing step required when printing with reactive, disperse and vat dyes (also quite common techniques in this sector).

Mills finishing knitted fabric consisting mainly of synthetic fibres

The typical process sequence for finishing knitted fabric mainly consisting of man-made fibres is shown below. Optional operations are indicated with dotted lines.



Before dyeing, the fabric is normally washed out in order to remove preparation agents and impurities. Heat-setting is not always needed, but when carried out this operation can take place either before washing (on the raw fabric) or after the washing step.

Depending on the required degree of white, bleaching may be needed.

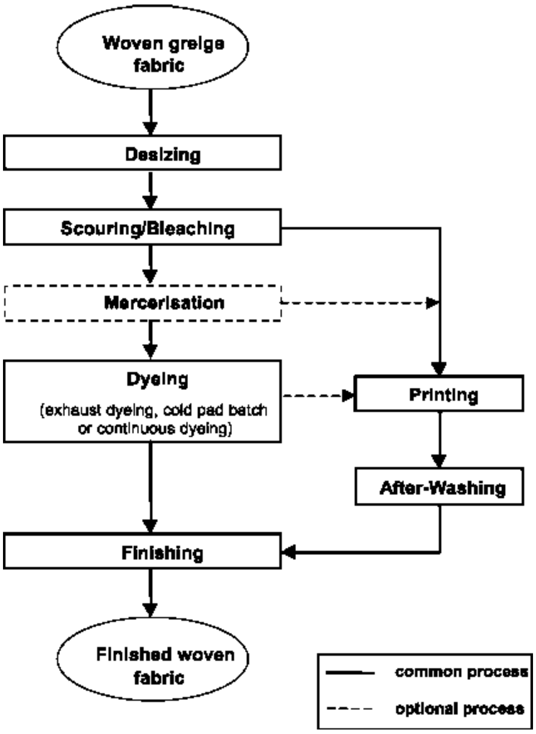
Mills finishing knitted fabric consisting mainly of WO

The process sequence that is reported in the next chapter is also applicable to this category of finishing mills (see the below scheme).

2.4.4 Mills finishing woven fabric

Mills finishing woven fabric consisting mainly of CO and/or CV

The typical process sequence for the finishing of woven fabric consisting mainly of cotton is shown below. Optional operations are indicated with dotted lines.



Woven fabric consisting mainly of cotton and cotton blends is finished on semi-continuous/ continuous lines or in discontinuous mode mainly depending on the size of the lot.

Pretreatment operations such as desizing, scouring and bleaching are very often combined in one single step in continuous lines. Pretreatment of viscose usually requires alkali treatment and washing only, provided that the sizing agents are water-soluble, which is normally the case.

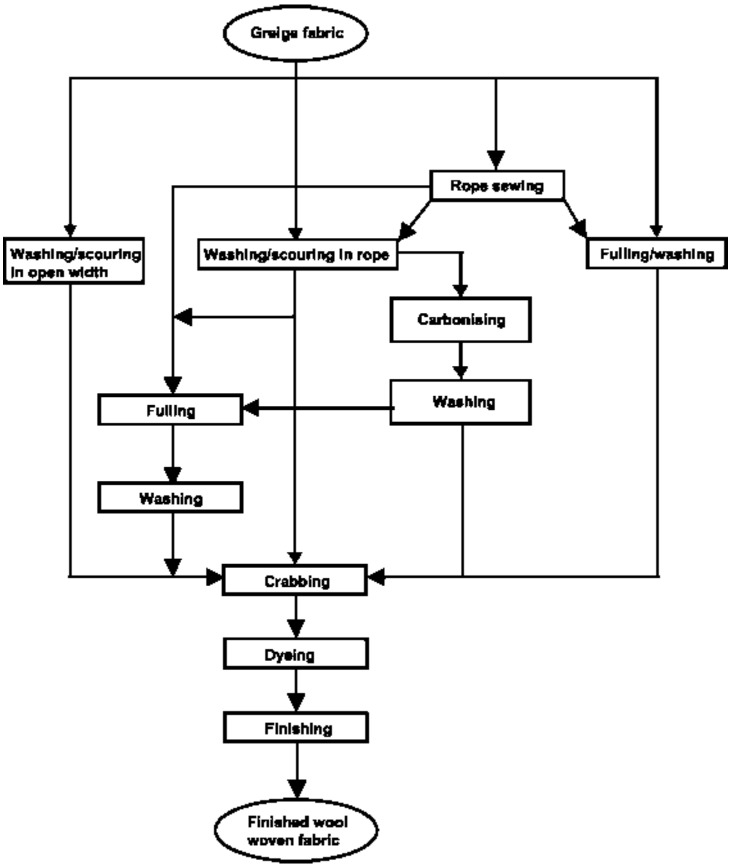
Further treatments may be exceptionally applied, such as pretreatment with liquid ammonia (carried out at a very few sites in Europe only).

For printing, two further subclasses can be identified:

- mills finishing cotton woven fabric without a printing section;
- mills finishing cotton woven fabric with a printing section.

Mills finishing woven fabric consisting mainly of WO

The typical process sequence for the finishing of woven fabric consisting mainly of wool (woollen and worsted wool) is shown below.



Both water washing and solvent washing (dry cleaning) are common in the wool sector. Washing in an aqueous medium is carried out either in rope (in batch) or in open-width (mostly in continuous, but also in batch). Heavy fabrics (woollen wool) are preferably treated in rope form, whereas washing in open width is preferred for fine worsted fabric.

Carbonising and fulling are optional treatments in the basic process sequence. Carbonising is applied only on woollen wool fabric, which is also the most common application of fiilling treatments.

Crabbing can be carried out before or after dyeing, depending on the desired effect. Crabbing on raw fabric is done in order to set the dimensions of the fabric, so that they will not change during use or during the subsequent processes.

Mills finishing woven fabric mainly consisting of synthetic fibres

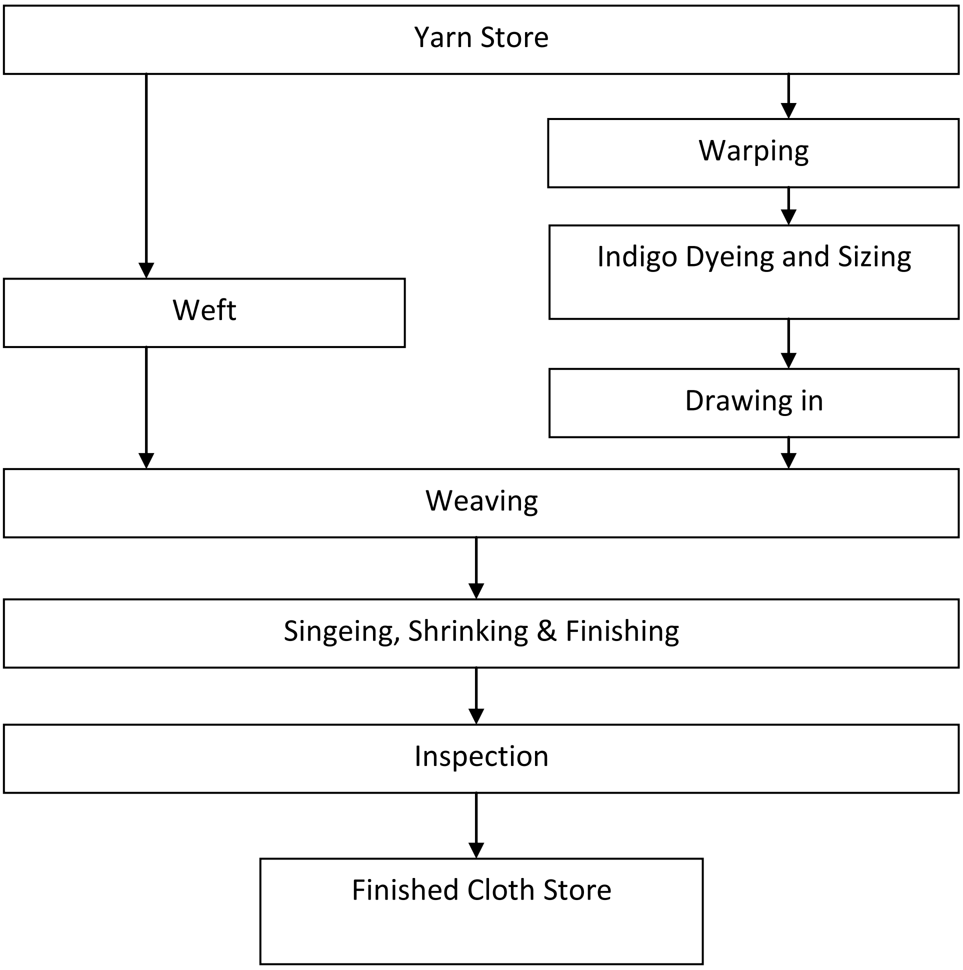
The process sequence for the finishing of woven fabric consisting mainly of man-made fibres is similar to the one for synthetic fibres knitted fabric. However, here the washing/desizing step is more important because all sizing agents need to be removed. Synthetic sizing agents are normally used, which are easily removed with water, often in continuous washing machines.

In fabric with a certain percentage of elastane, silicones are also present. The complete removal of these substances can be very difficult. Dyeing is carried out in continuous or in batch dyeing machines. The use of disperse dyes is dominant.

2.4.5 JEANS PRODUCTION PROCESS

Due to the great importance of jeans production in Turkey, a brief explanation is provided in the following about the process to produce this kind of product.

Jeans are made from denim. Denim is a cotton twill fabric of white frame which is dyed in colour blue indigo. To make denim the process is as follows:after spinning machines convert the cotton into yarn, some of the yarn is dyed with a blue color and then glued to enhance its strength.A bale warper is used, and afterwards this blue yarn is crossed with white yarn to make the weft, by using air jet or shuttle.The weft can be blended with elastomeric fibers(2%) to form stretchy fabrics. Afterwards different treatments are applied until the denim is obtained, lasting the process overall 20 days.

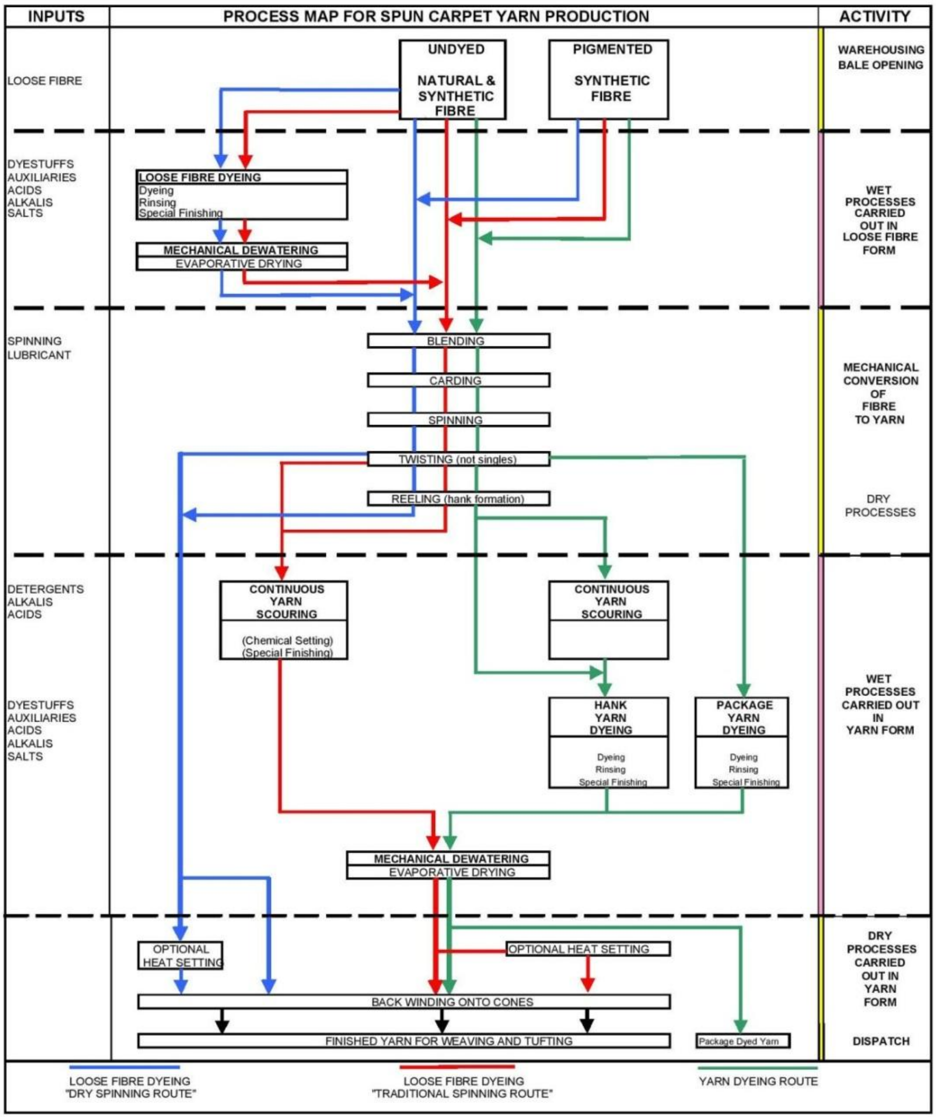


2.4.6 The Carpet industry

Wool and wool-blend carpet yarn dye-house

The production of spun dyed yarn can be regarded as a specific sector within the carpet manufacturing industry. Mills can be identified as dyehouses processing mainly wool and wool-blend fibres. Different treatments are carried out in order to convert white loose fibre into dyed carpet yarn. Wet processes essentially consist of dyeing and other ancillary operations carried out either in loose fibre or yarn form. Dry processes consist, in turn, in blending, carding, spinning, etc. These processes have already been described in previous sections. Depending on when colouration takes place raw fibre flows through some or all of these processes.

General process flow diagram for wool and wool-blend carpet yarn production is shown below.



As can be seen on the above diagrame, three basic process (red, blue and green arrows) sequences are possible:

- **Dry spinning route** - so called because there is no wet processing after yarn formation, begins with colouration at the loose fibre stage. This is followed by yarn formation and finally twist setting. This process sequence is of relatively recent origin and requires the consistent use of wool with a low lanolin content and specialised spinning lubricants, which can be left on the yarn without causing subsequent soiling of the carpet. The process is particularly useful in the production of yarn for large volume plain shade carpets and for effect yarns, obtained by blending together fibre dyed to different shades. While this production sequence is the most economical in terms of resource consumption, the selection of clean raw materials and the ongoing maintenance of the mill in a clean condition are essential.
- **Traditional loose stock dyeing route** - was originally used to produce large batches of yarn to the same shade for plain carpets. Loose fibre is first dyed and then converted to yarn using what is still sometimes referred to as the “oil spinning” process; this terminology arose from the practice of using spinning lubricants based on emulsions of mineral oil. Even small traces of residual mineral oil would lead to a marked propensity for the carpet to soil in service, and so yarns prepared by this route were thoroughly cleaned by scouring (washing) in hank form. While the use of mineral oil-based lubricants has been largely replaced with water-soluble synthetic products, the practice of scouring the yarn is still judged to be essential by many processors in order to avoid potential claims arising from soiling. Unlike the dry spinning process, this route allows greater flexibility in the purchase of raw materials, so that wool with a higher lanolin content can be used.
- **Yarn Dyeing Route** - clean fibre is first converted into yarn before dyeing. This process is particularly suitable for the production of the small coloured lots required for patterned carpet weaving or the bespoke trade, where white yarn can be held in stock and dyed as required to fill orders. The process is, however, by no means restricted to small batches, and dyeing machines with capacities of up to 4 tonnes are used to produce plain shades for both tufting and weaving.

In the case of integrated yarn manufacturers, it is common to find two or more of these process streams operating side by side and sharing common wet processing equipment. Since the dyeing and finishing techniques used apply equally to all three sequences, they are discussed in the following sections without further considering the different routes mentioned. Variants are described where they occur, and the relevance of any dry process segments is discussed where they have a significant impact on environmental performance or emissions.

2.4.6.1 Carpet loose fibre dye-house

Fibre is conventionally dyed in loose form (loose stock) when a large quantity of yarn is required to be of precisely the same shade, for example in a large solid shade (plain coloured) carpet where subtle variations in colour would be visible in service. Single colour batches may be made up of a number of individual dyeings, the dyer adjusting the dye addition to each dyeing in order to achieve the desired final shade of the yarn. Thorough mixing of the individual dyeings in a batch is achieved in a specific mechanical blending operation and during carding. Loose fibre dyeing, therefore, need not be as level as, for example, yarn dyeing, where there is no possibility of levelling the colour by further mechanical processing.

Dyed loose fibre is also used to achieve multicoloured effects in some yarns. In this process fibre dyed to different shades is blended together to produce a large range of designs, such as the “heather” styles in fashion at the present time. Such blends may contain dyed and undyed natural fibre and undyed and pigmented synthetic fibre.

Where the final yarn will contain a blend of wool and synthetic fibres (typically 80 % wool and 20 % polyamide) the required weights of the two components are normally dyed separately to optimise application conditions and dyestuff selection for each fibre type.

- Loose-fibre dyeing processes

  Scoured wool and new synthetic fibre are presented to the dye-house in a “clean” state and usually require no further treatment to remove contaminants before dyeing. If purchased from outside sources, fibrous raw materials normally arrive on site in the press-packed bales used universally by the textile industry to transport raw fibre.

  Various types of machines are used for dyeing wool and synthetic fibres in loose form. These include conical pan, pear shaped and radial flow machines. Loose fibre is typically packed into these machines manually.

  Dyestuffs are dissolved in hot water before being added to the circulating bath. Typical dyestuffs and chemicals for wool and wool-blends are employed.

  In the majority of cases all chemical and dyestuff additions are made manually to the open dyeing machine. Less frequently, or if “pressure” dyeing machinery is being utilised (for synthetic fibres, because wool is normally dyed at atmospheric pressure), pre-dissolved chemicals and dye are introduced to the circulating dye bath from special addition tanks.

  The dye bath is typically run for 10-15 minutes to ensure even penetration of the liquor through the fibre pack before commencing the heating cycle, raising the temperature of the dye liquor to 98 °C at a rate of 1 - 2 °C per minute. On reaching top temperature, dyeing may continue for up to 60 minutes, during which time the dye bath pH may be checked and adjusted by adding further acid to achieve maximum dye uptake. Progress of the dyeing is normally judged by eye and fibre samples are then removed for comparison with a standard.

  A dyeing which is judged to be on shade will be terminated and the machine drained. A dyeing which is not of the required colour may have further additions of one or more dyestuffs, the dye bath being returned to the boil after each addition. Because of the blending operation which follows loose fibre dyeing, it is uncommon for there to be more than one shade addition unless the machine load is the only fibre in a batch.

Dyeing is followed by rinsing with cold water, to remove any surface-bound dyestuff and to cool the dyepack before manual unloading. The machine may be filled with cold water and then run for 10-15 minutes before draining. The use of “flood rinsing” in which the dye bath is allowed to refill and then run continuously to drain during the rinsing operation is now much less common due to increases in water charges and effluent disposal costs.

Liquor from both the dyeing and rinsing process may be recycled for further use. In this case the machine must be fitted with an external holding tank. The dye bath may be recycled if a number of dyeings of the same shade are being performed to make up a bigger dye lot. In this case the dye bath is pumped to the reserve tank and dropped back to the dyeing vessel when required for the next dyeing. The selection of dyestuffs and dyeing conditions which promote maximum uptake of dye are required for the successful operation of this process.

In such circumstances it is more usual to recycle the rinse liquor, as the temperature of this liquor is lower and more compatible with dyeing start temperatures. Depending on the design of the machine a reserve tank may not be required for the operation of this process, as the fibre carrier can often be removed with the dyeing vessel full. Both these alternatives conserve water, and to a lesser degree, thermal energy.

- Application of functional finishes

A number of functional finishes may be applied to the loose fibre, either during the dyeing process itself or by application from an additional bath following dyeing/rinsing. This is particularly relevant in the “dry spinning” route where there will be no further wet processing after yarn formation. Finishes applied at the loose fibre stage include insect-resist treatments, antistatic treatments, anti-soiling treatments and treatments to counteract yarn/carpet colour change due to light exposure in service.

For expediency these finishes are combined with dyeing whenever possible, aftertreatments only being used when the chemistry of the two finishes is incompatible or if they require widely differing conditions of temperature and pH. Co-application with the dyes is simply accomplished by adding the product to the dye bath, usually with the dyeing auxiliaries.

Aftertreatments may require a fresh bath of clean water, or alternatively the rinse bath may be clean enough for re-use.

Specific techniques have been devised to minimise the concentration of mothproofing agents present in the spent liquors from loose fibre dyeing. The formulated commercial product is added at the beginning of the dyeing cycle and dyeing carried out as normal. At the end of the dyeing cycle the pH of the dye bath is lowered with the addition of formic acid and boiling is continued for a further 20 - 30 minutes. These strongly acidic conditions promote uptake of any active ingredient not adsorbed by the wool fibre under normal dyeing conditions and residual concentration can be reduced by up to 98 %.

Rinsing the fibre at moderate temperatures is known to cause desorption of mothproofer bound on or close to the surface of the wool fibre. Active ingredient concentrations in the spent rinse bath may consequently be significantly higher than those present in the dye bath. Techniques to minimise the impact of rinse desorption have been developed, in which the rinse bath is recycled, forming the next dye bath, thus eliminating all residues from the rinse liquor and reducing overall water consumption by 50 %.

Fibre in a drained carrier will contain up to 2 litres/kg of residual water (dry fibre weight). This is initially reduced by either centrifugal extraction or by mangling before evaporative drying in a hot air dryer.

2.4.6.2 Carpet yarn dye-house

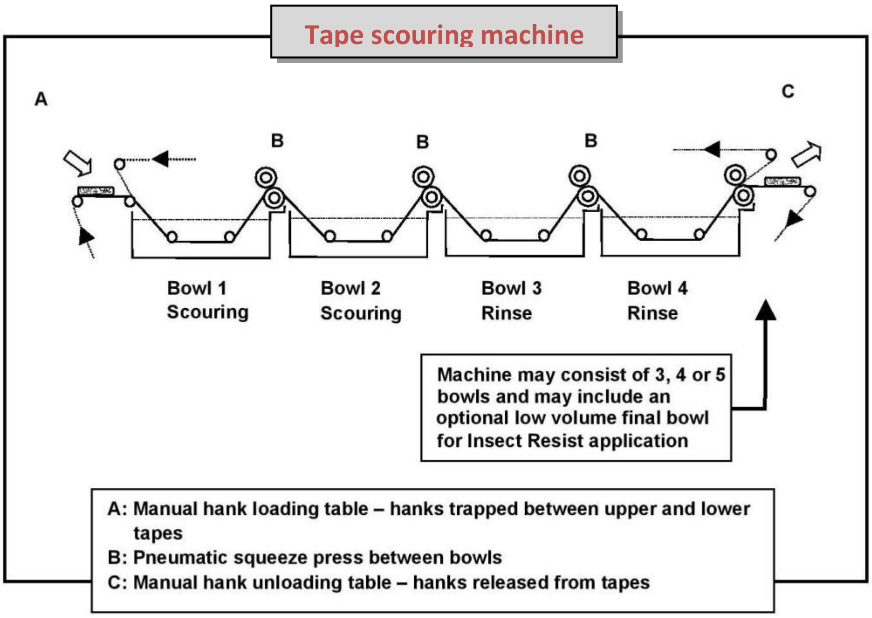
On integrated sites the spun undyed yarn may be held in a bulk store as either hanks, wound onto cones or wound onto the special centres compatible with package dyeing equipment. Batches of suitable size are drawn from this material to fill individual orders. Commission yarn processors generally receive hanks baled in conventional wool bales.

In hank-based processes the bales are normally brought into the dyehouse and opened at the side of the scouring or dyeing machine ready for manual loading

- Yarn scouring

Scouring is generally carried out as a semi-continuous process in which batches of yam are transported through a series of aqueous baths containing detergent and alkali or rinse water. Scouring can be carried out both on dyed and undyed yarn. To prevent cross contamination with dyestuffs, integrated yarn manufacturers may operate two scouring machines, one being reserved for scouring white yarn prior to dyeing and the second for the scouring of coloured yam.

Yarn may be scoured using either hank scouring or package to package (sometimes referred to as single end) processing machinery.

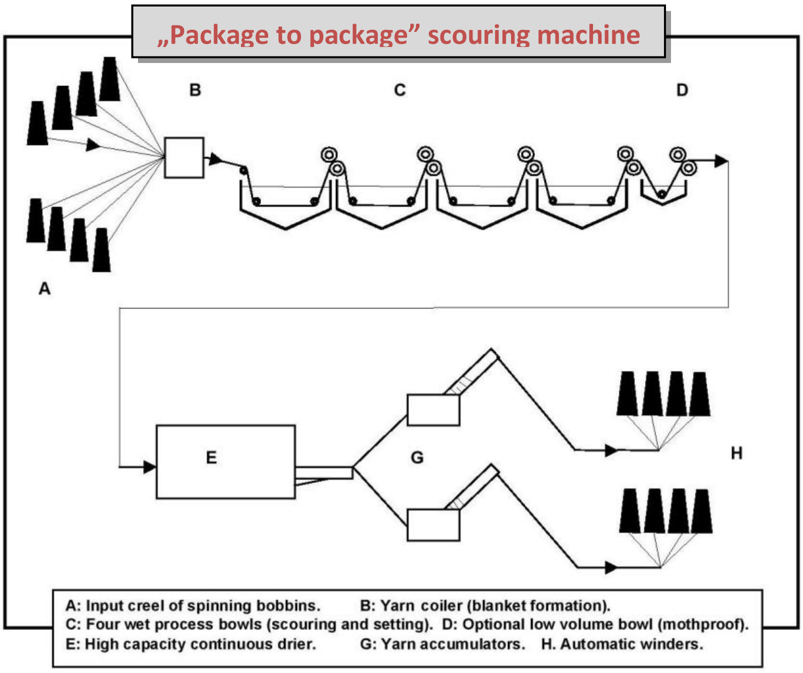


Machine may consist of 3, 4 or 5 bowls and may include an optional low volume final bowl for Insect Resist application

A: Manual hank loading table – hanks trapped between upper and lower tapes
B: Pneumatic squeeze press between bowls
C: Manual hank unloading table – hanks released from tapes

In *tape scouring machines* hanks are transported through the machine trapped between an upper and lower set of nylon tapes which run in an endless belt through each bowl and mangle set, guided by intermediate rollers in the bottom of each bowl. Bowl working volume is typically between 1200 and 1800 litres. Throughput capacity typically ranges from 500 to 1500 kg/hour. Residence time in each bowl varies between 20 and 45 seconds. Heating is provided by either closed coils in the base of the machine or live steam injection.

Each bowl is initially charged with the required chemicals and further additions are made during processing, either manually or with a metering device. In machines used only for scouring, the process liquor may flow from last bowl towards first bowl, thus providing a simple countercurrent extraction system. Specific water consumption varies widely, depending on the quantity of yarn processed through the machine before dropping the liquor for cleaning and the extent of any flowdown to drain from the scouring bowls. Values between 2 and 7 litres of water per kg yarn are common.



„Package to package" scouring machine

A: Input creel of spinning bobbins. B: Yarn coiler (blanket formation).
C: Four wet process bowls (scouring and setting). D: Optional low volume bowl (mothproof).
E: High capacity continuous drier. G: Yarn accumulators. H. Automatic winders.

"Package to package" scouring machines are less common and are of more recent design. With this machinery the whole process may be automated, including drying. Coiling devices take yarn from a number of individual cones and form this into an endless blanket of overlaid coils, laid down automatically onto a moving conveyer belt. The conveyer passes through each of the scouring and rinse bowls. The yarn is transferred to a second conveyer, which then passes through the dryer. The yarn blanket is then uncoiled and the yarn finally rewound onto cones.

The scouring bowls are of larger volume (3500 litres) than tape scour machines and heating may be by direct gas firing. Most machines are equipped with dual yarn coilers, giving an overall capacity of up to 500 kg/hour.

Both hank and single end machines may be utilised only for scouring or the process may be modified to include simultaneous chemical setting of yarn twist and the application of insect-resist (IR) agents.

- Scouring to remove lubricant

  When the machines are operated only *to remove lubricant,* the first two bowls are charged with detergent and alkali and operate at 50 - 60 °C, while the remaining bowls serve to rinse the yarn with clean water at 20 - 30 °C. Chemical additions are made initially to set the bath concentration at a predetermined level, which is then maintained by further additions during processing.

- Scouring and insect-resist treatment

  Four-bowl machines are normally used if the scouring process is to incorporate a simultaneous insect-resist (IR) treatment. Bowls 1 & 2 are charged as above for scouring, bowl 3 contains clean water for rinsing, and bowl 4 is adapted for insect-resist application. Bowl 4 may be of the low volume type (100 - 200 litres), designed specifically for the treatment of yarn with insect- resist agent in order to minimise the volume of the process liquor and the resulting emissions.

In these installations, insect-resist agent is applied by a process of “continuous exhaustion” rather than physical impregnation and the active substance is stripped from the bath by the yarn, equilibrium bath concentration being maintained by continuous chemical metering at a rate proportional to yarn throughput.

Application is carried out at 50 - 60 °C under acidic conditions (approximately pH 4.5 by either formic or acetic acid) to promote rapid uptake of the active substance in the short yarn residence times available.

The insecticide content of the bowl is such that it cannot be discharged to drain and therefore storage tanks are used to retain the liquor between treatment cycles. Heavy contamination of the liquor with dyestuff removed from the yarn would lead to a change of shade in subsequent yarn lots and so a simple adsorptive filter system may be used to remove dyestuff before storage. This consists of a quantity of wool fibre packed into a filter housing and through which the liquor can be circulated. The liquor is preheated to a minimum of 70 °C to assist effective dyestuff removal. Operating with this liquor renovation system permits re-use of the liquor without the need to discharge to drain.

In the absence of these abatement systems the spent treatment liquor can be pumped from the scouring machine and added to a dark shade dyeing, where uptake at the high dyeing temperatures minimises emissions of active substance. Both loose fibre and yarn dyeing can be done in this way.

A third abatement option uses chemical hydrolysis of the active ingredient to destroy residual insecticide. Spent liquor is pumped from the machine and treated in a separate tank at 98 °C with sodium hydroxide (4g/l) for 60 minutes. The ester and cyano-ester linkages in permethrin and cyfluthrin undergo rapid hydrolysis under these conditions and more than 98 % abatement is achieved. The primary degradation products are at least one order of magnitude less toxic to aquatic invertebrates when compared to the parent molecule. Liquors treated in this way are normally discharged to drain, where the high alkali-content is neutralised by acids from dyeing processes.

- Chemical twist setting

Five-bowl machines are normally employed if chemical twist setting is to be carried out at the same time as scouring. In this mode Bowls 1 and 2 contain sodium metabisulphite (10 to 20 g/1) in addition to detergent and alkali and Bowl 4 may be charged with hydrogen peroxide (5 to 10g/l) to neutralise any residual bisulphite. In all other respects the process is similar to that described above.

Hanks leave the final mangle of the scouring line with a moisture content of approximately8 litres per kg (dry weight). If the material is to receive no further wet processing, this residual moisture is further reduced by centrifugal extraction before evaporative drying in a hot air dryer.

Scouring in hank form may also be carried out using batch *solvent processing equipment,* although this practice is now less common. Perchloroethylene is the solvent of choice, and these machines operate on the totally enclosed principle, washing, rinsing and drying being accomplished sequentially within a horizontal drum. All machines are fitted with solvent recovery systems to distil used solvent and recover solvent vapour during drying.

- Hank and package dyeing processes

Traditionally, carpet yarn dyeing is carried out in hank form, where liquor circulation in the dyeing machine produces a yarn with a characteristic physical property, often described as loft or fullness. Hank dyeing machines are mostly of the Hussong type.

In other sectors of the textile industry it is common to dye yam in package form - wound onto a perforated centre, through which dye liquor can be circulated under pressure. This process has considerable cost advantage over hank dyeing in that it requires no reeling operation to form the hank and consequently no winding of the hank back onto cones in preparation for weaving or tufting. With wool and wool-blend yarns the extension applied during package winding results in the yarn being set in a “lean” condition and the resultant yarn does not have the required physical characteristics for carpet manufacture. There are, however, a number of ways of overcoming these objections and package dyeing is slowly gaining credence in the carpet yarn dyeing industry. Three basic types of machines may be used for package dyeing wool yarns: horizontal or vertical spindle machines or tube type machines.

Although the machinery employed in hank and package-dyeing processes is different, the dyeing procedures and techniques are essentially the same and are described together.

Considerable care is required to obtain a level (even) dyeing on yarn as there are no opportunities to even up the colour by mechanical blending, as is the case with loose fibre dyeing. Faulty dyeings must be corrected by manipulation in the dye bath, by either removing or adding colour to achieve the final shade. This process can add significantly to the resources consumed in yarn dyeing.

In comparison to synthetic fibres, the rate of dyeing and the extent of dye uptake is less predictable when dyeing wool, as natural variations in the physical and chemical composition of the fibre have a marked effect on these important parameters.

The dyeing of carpet yarns predominantly composed of a blend of wool and polyamide fibre further compromises the dyer because the two fibres have markedly different dyeing properties and special dyeing auxiliaries must be used to achieve a commercially acceptable product. Problems associated with level dyeing are further compounded by the fact that very few shades can be achieved with one single dyestuff; most shades require the simultaneous application of a number of colours in various proportions and which may have different rates of uptake.

The usual approach is to carry out trial laboratory dyeing on a sample of the particular fibre blend and then to apply 5 - 10 % less dye in the full scale dyeing, the final shade being achieved by adding additional dye in small portions to achieve the final shade. Depending on the dyestuffs, it may be necessary to cool the dye bath for each of these additions in order to promote even migration of the added dye.

Dyeings which are “overshade” can be corrected by stripping dyestuff from the fibre using an excess of levelling agent or reducing conditions, and then adding further colour to achieve the correct shade. This is a practice of last resort in most dyehouses.

This shade matching procedure is an essential part of the dyeing processes as most dyeing is carried out to an agreed standard, either for internal use in the case of an integrated site or by agreement with the customer. Shade matching is predominantly carried out by eye, the dyer comparing the dyed material with a reference pattern under standard illumination.

In other sectors of the textile industry it is common to use colour matching spectrophotometers to determine the reflectance spectra of the dyed material for comparison with a numerical standard. In some instances these measurements may also be used to generate the dyeing recipe from the standard. These techniques are less successful with carpet yarn because a sample of yarn prepared to represent the cut pile of a carpet, viewed end on, must be used for the result to be meaningful. Despite these difficulties a number of manufacturers do use this technology, claiming significant improvements in batch-to-batch matching and subsequent reductions in material wastage.

Hank dyeing machines may be loaded with either dry or wet yarn. In the latter case the yarn may be carrying moisture from the scouring operation or may have been deliberately wetted out to facilitate even packing. This technique is often applied when loading large hanks of yarn with a high twist factor. Package dyeing machines are loaded dry.

Dyestuffs and chemicals typical of wool and polyamide fibres are employed. Preparation for dyeing normally consists of filling the machine with water at 15 - 30 °C and adding acids, salts and dyeing auxiliaries as required by the recipe. With hank dyeing machines it is conventional to raise the lid and yarn from the dye bath before adding predissolved dyestuffs. In closed package dyeing machines dyestuffs are added from linked transfer tanks.

The dye liquor is circulated for 10 -15 minutes at 15 - 30 °C before commencing the heating programme, raising the temperature of the dye bath, according to the dyeing programme in order to maximise exhaustion.

At this stage the dyer will obtain a sample of the dyed yarn for comparison with a standard, in the case of hank dyeing by raising the load from the dye bath, or with package dyeing equipment, through a sampling port in the machine case. A dyeing which is judged to be on shade at this stage is terminated and the dye bath drained. If further additions of dyestuff are required the dye bath may be cooled, in the case of hank dyeing machines by partial draining and refilling with cold water or in package dyeing machines by circulating cooling water through an internal heat exchange core.

Following addition of dyestuff, the dye bath will be returned to the boil and boiled for 30-60 minutes before a further yarn sample is taken for shade matching. This operation may be repeated several times before the dyer is satisfied that the bulk material matches the standard. The spent dye bath is then drained and the yarn rinsed in clean water at 15-30°C for 10-20 minutes before finally being allowed to drain, ready for unloading.

In some instances the spent rinse bath may contain little or no residual colour. As the temperature of this liquor is compatible with dyeing start temperatures, it may be retained in the dyeing machine and used for a subsequent dyeing. This practice reduces water usage by up to 50 %.

- Application of functional finishes

  A number of functional finishes may be applied, either with the dyestuffs or from additional baths of clean water following dyeing. These include insect-resist treatments, flame-retardant treatments and antistatic treatments.

  - Insect-Resist treatments

    Traditionally formulated insecticides, based on synthetic pyrethroids or Sulcofuron, were added to the dyeing with the dyestuffs. To minimise residues and control fugitive emissions this basic procedure has been modified. The formulated product is now added to the dyeing at a later stage; to avoid the spillages that occur during yarn lowering and dyeing, auxiliaries,which do not interfere with exhaustion,are selected. Emissions from dyeings carried out under acidic conditions are normally within permitted limits, but experience has shown that these standards cannot be met when dyeing under more neutral conditions. In this case, the insect-resist agent is applied from a blank aftertreatment bath in the presence of formic acid at a temperature of 70-80°C.

  - Antistatic treatments

    Antistatic finish applied to the pile yarn is mainly based on a cationic surfactant system, which is readily applied to the fibre under mildly alkali conditions. Cationic compounds are not compatible with anionic dyestuffs and these materials cannot, therefore, be incorporated in the dye bath, but must instead be applied as aftertreatments. The process consists of preparing a fresh bath of clean water, adjusting the pH and adding the required quantity of the proprietary product. The liquor is raised to 60 °C and run at this temperature for 20 - 30 minutes, followed by rinsing in clean water.

- Flame-retardant treatments

  Potassium salts of fluoro complexes of zirconium (potassium hexafuorozirconate) are typically used for wool and wool-blend fibres. Typical application conditions for carpet wool yarn are as follows:

  - rinsing is required to remove interfering sulphate and phosphate ions, if present;
  - bath set up at 20-30°C, pH 3 with hydrochloric acid (10% o.w.f.) or formic acid (15 % o.w.f.) and citric acid (4 % o.w.f.);
  - addition of potassium hexafluorozirconate (3 to 8 % o.w.f. depending on the final specification to be achieved and the substrate) dissolved in 10 times its weight of hot water;
  - temperature raised at 1 - 2 °C per minute to 60 °C and held at this temperature for 30 minutes;
  - rinsing in cold water for 10 - 20 minutes.

- Other treatments

  In addition to application of the above functional finishes, which are all invariably carried out in conjunction with colouration, yarn dyeing equipment may be used for other specific yarn preparation or treatment procedures, principally bleaching and twist setting.

- Bleaching

  The industry favours the neutral white colour obtained by an oxidation bleach, followed by a reductive bleach. Typical processing conditions would be:

  - at 40 °C, run yarn in liquor containing 3 % o.w.f. proprietary stabiliser, 1.5 % o.w.f. sodium tri-polyphosphate, 20 % o.w.f. hydrogen peroxide (35 %). Raise liquor to 70 °C, circulate 40 minutes. Drain.
  - run in a fresh bath containing 0.2 % o.w.f. formic acid (85 %) and 0.75 % o.w.f. sodium hydrosulphite. Raise to 50 °C, circulate 20 minutes, drain and rinse in cold water.

- Yarn (dye bath) twist setting

  This process is not always carried out as a separate treatment. In fact, during the hank dyeing of wool yarns the twist inserted during spinning is stabilised by chemical changes within the fibre at the temperatures reached by the boiling dye bath.

  Yarn may, however, be twist set in hank form using conventional hank dyeing equipment. Typical processing conditions would be:

  - raise dye bath to 80 °C, add 5 % on the weight of yarn sodium metabisulphite, immerse yarn, circulate liquor for 15 minutes, drain machine;

- rinse cold with liquor containing 0.8 % o.w.f. hydrogen peroxide (35 %) for 15 minutes.

2.4.6.3 Integrated Carpet Manufacturing Mills

Fully integrated carpet manufacturers carry out all the mechanical processes, wet processes (pretreatment, dyeing, printing and finishing operations) required to convert natural and synthetic fibres into finished carpet. Such companies may also produce their own synthetic fibres from raw polymer feedstock. Regarding the natural fibres processed they can in some cases select and purchase natural fibres and operate the whole chain of processes from wool scouring to dyeing, yarn spinning and carpet weaving/tufting. However, usually not all of these operations are carried out at the same site.

The conversion of the fibre into finished carpet can follow different routes depending on the style of the carpet to be produced.

- Tufted carpet

  Yarn can be manufactured from:

  - staple fibres, from both synthetic (PA, PP, PES, PAC) and natural (wool and cotton) fibres;
  - continuous filaments, exclusively from synthetic fibres (mainly PA, PP and PES).
  - The *carrier materials* (primary backing) usually consist of:
  - PP woven fabrics or webs;
  - PES woven fabrics or webs;
  - jute fabrics.
  - *Finishing* of tufted carpets involves:
  - dyeing and/or printing;
  - coating;
  - mechanical finishing;
  - chemical finishing.

Dyeing and chemical finishing can be applied on loose fibre, yarn or piece, while the other operations are carried out on the final carpet.

- Needle felt carpet

  Almost all fibres may be used for the production of needle felts (PP, PA, PES, PAC, wool, cotton jute/ sisal, coconut fibre and viscose). However, mostly man-made fibres are used.Needle felts finishing involves:

  - dyeing (rarely done),
  - coating,
  - mechanical finishing (rare),
  - chemical finishing.
- Woven carpet

  Both natural and synthetic fibres are used in woven carpet production.

Carpets are woven using dyed yarns (so piece dyeing is not applied in woven carpet production). The final carpet is then submitted to mechanical and chemical finishing treatments.

3 CURRENT EMISSION LEVELS AND CONSUMPTION OF ENERGY AND RAW MATERIALS.

This chapter provides information on current levels of emissions to air and water, together with chemicals usage, waste generation and energy consumption from Turkish and Spanish textile installations, and when available from textile installations at EU level (data coming from Chapter 3 of the BREF for the textile industry).The aim is to reflect the current environmental performance of the sector and main emissions, as compared to the performance that can be achieved using the Best Available Techniques described in the next chapter of this guide and in Chapter 4 of the BREF for the textile sector.

In addition, as a complementary reference of the current situation, the currently applicable environmental legislation relevant for the textile sector in Turkey is listed in Annex.

3.1 Water consumption & emissions to water.

The main environmental problem facing the textile industry lies in the wastewater it generates and the chemicalsload contained init. In the textile industries water consumption is one of the most important factors to take into account, as it is high and necessary for the production process.

The parameters analyzed in waste water of textile industries are, apart from thoselisted in applicable legislation, the parameters specified in the BREF for the textile sector.

The table below shows emission data for the most relevant parameters for the textile industryincluded in the European Pollutants Release and Transfer Register (E–PRTR) for the textile sector, which are quantified in tons/year emitted into the wastewater. Data are shown of several Turkish and Spanish companies. In additiontypical average ranges of textile companies within the EU arestated in the BREF for the textile sector are shown in the last column.

	SPANISH COMPANIES				**TURKISH COMPANIES**	**EU typical ranges (info from BREF)**
EMISSIONS TO WATER mg/l (PARAMETER)	**Company 1 Textile finishing**	**Company 2 Textile finishing**	**Company 3 Dyeing bobbins and beams**	**Company 4 Textile finishing**	**Company 1 Textile finishing**	**mg/l**
N	50	16,4	9,1	19,4	146,4	15-18
P	4,2	3,7	0	2,7	2,4	1.9-2.3
As	0	0	0	0		---
Cd	<0,01	0	0	0	0,38	---
Cr	0,1	0	0	0	0,34	0.03-0.15
Cu	0,018	0,1	0	0	1,98	0.03-0.1
Hg	<0,0004	0,0001	0	0		
Ni	<0,02	<0,01	0	0		< 0.02
Pb	<0,01	<0,01	0	0		
Zn	0,0079	<0,01	0	0	0,08	0.03-0.08
Total organic carbon (TOC) in C total or DOC/3	0	0	125	0		
Cl	0	156,9	112,5	0		
CN	0	0	0	0	0,12	
F	0	0	0	0	0,6	

Table 3.1. Emissions to water from several companies of Spain and Turkey, and typical range of emissions at EU level.

Nitrogen and phosphorus are included in the list because theyare contained in dyes and chemicals used in the textile finishing process. Metals are also listed due to their toxicity in the aquatic environment and their high content in acid dyes containing metals. Regarding organic and organochlorine compounds used in dyeing operations (azoic dyes) and whitening, they are difficult to remove from the wastewater, significantly increasing the cost of the treatment of the discharges produced.

Regarding the parameter “colour”, it can constitute a relevant issue for some installations in Turkey, and measures must be taken to respect national applicable legislation. At EU level there are no common standards for this parameter.

To reduce the colouring of the waste waters from textile industry, the US Environmental Protection Agency recommends biological processes as the first treatment stage, which can be completed with a chemical coagulation or an absorption process to eliminate to a high extent the colouring of the water.

3.2 Air emissions

The textile industry produces emissions into the atmosphere due to the exhaust gases emitted by the machinery of the production process, and for the correct compliance with the legislation they must be channelled if they emit any of the pollutants listed in the following table:

	SPANISH COMPANIES				**TURKISH COMPANIES**
ATMOSPHERIC EMISSIONS BOILER (PARAMETER)	**Company 1 Textile finishing**	**Company 2 Textile finishing**	**Company 3 Dyeing bobbins and beams**	**Company 4 Textile finishing**	**Company 1 Textile finishing**
SO_x(mg/Nm^3)	0	2	5	0	
NO_x (ppm)	18	12	6	40	3,1
Non-methane volatile organic compounds	0	0	0	0	
CO(ppm)	0	11	5	12	0
Dust					0,02
SO_2(mg/Nm^3)					0,61

Table 3.2. Emisssion of exhaust gases.

Specific emissions can be generated both in certain phases of the production process (primarily drying processes, as shown in the table below) as in auxiliary phases (combustion installations).

	SPANISH COMPANIES			
ATMOSPHERIC EMISSIONS DRYING PROCESS (PARAMETER)	**Company 1 Textile finishing**	**Company 2 Textile finishing**	**Company 3 Dyeing bobbins and beams**	**Company 4 Textile finishing**
SO_x(mg/Nm^3)	0	2	--	0
NO_x (ppm)	0	2	--	2
Non-methane volatile organic compounds	0	0	--	0
CO (ppm)	15	7	--	8
Dust				
SO_2(mg/Nm^3)				

Table 3.3. Atmospheric emissions in the drying process for several Spanish and Turkish installations.

3.3 Odour emissions

Another problem to be taken into account is odour emissions, which can be very annoying in particular treatments.

One of the measures for the reduction of bad smells in the process is the substitution of mineral oils by other agents with greater biodegradability and at the same time, less volatile.

3.4 Noise emission

The main focus of noise emission in the textile process is the machinery used in the stages of spinning and weaving. In the (internal) working areas dedicated to spinning sound levels can reach from 70 to 100 dB(A) and in the case of weaving they can vary between 85 and 108 dB(A). Depending on the machinery used, noise levels will be higher or lower.

3.5 Solid & liquid waste in the textile sector

3.5.1 Waste typical for the sector

The most common waste in the textile sector are, as in any industrial sector, classified into 2 categories, hazardous and non-hazardous. In the following table the places where the different kinds of waste are generated are shown:

Waste	Place	E.W.C.
Contaminated textiles	All processes	15.02.02
Contaminated packaging	All processes	15.01.10
Fluorescent tubes	All processes	20.01.21
Oils	All processes	13.02.06
Oil filters	Machine	16.01.07

Table 3.4. Typical waste and places where it is generated.

Other kinds of waste specific to the textile industry are the following ones:

Waste	E.W.C
Waste not in need of control:	
Waste yam	04 02 21/22
Waste fabric (spoilt works, trials, selvedge cuttings)	04 02 22
Wastes from shearing and raising	04 02 21/22
Textile dust	04 02 99
Waste in need of control	
Dyes and pigments	04 02 16*/17
Residual padding dyeing liquors	04 02 99
Residual printing pastes	08 03 99
Residual padding finishing liquors	04 02 99
Oil-containing condensates from off-gas treatment (stenters)	19 01 06*
Sludge from process waste water treatment	04 02 19*/20

Table 3.5. Specific waste in the textile sector.

3.5.2 General waste: packaging, waste oils, waste solvents etc.

Classified wastes generally are containers of paper, plastic and cardboard, metal packaging, electrical equipment and machinery oils, all of them containing dangerous substances.

Waste	E.W.C
Waste not in need of control:	
Waste packaging glass, other glass from demolition and construction	15 01 07, 17 02 02
Paper board	15 01 01
Wood packaging, other wood	15 01 03, 17 02 01
Iron scrap (pipes, old machines)	17 04 05
Electric cables	17 04 11
Metal drums (clean)	15 01 04
Plastic drums (clean)	15 01 02
Non-contaminated plastic wrap	15 01 02
Waste in need of control:	
Waste oil	13*
Oil-contaminated cloths	15 02 02*
Non-halogenated organic solvents	14 06 03*
Dyestuffs and pigments containing dangerous substances	04 02 16
Contaminated packaging material	15 01 10*
Electronic scrap	16 02*
Waste in need of high control due to their high risk to health and environment:	
Waste from oil/water separators	13 02*
Halogenated organic solvents PCB-containing condensers	16 02 09*

Table 3.6. General waste (not specific to the textile sector).

In the following tables amounts (expressed in tonnes/year) generated by several Turkish and Spanish textile companies are shown (first table: hazardous, second table: non-hazardous):

	SPANISH COMPANIES				**TURKISH COMPANIES**	
WASTE (E.W.C.) Hazardous	**Company 1 Textile finishing**	**Company 2 Textile finishing**	**Company 3 Dyeing bobbins and beams**	**Company 4 Textile finishing**	**Company 1 Textile finishing**	**Company 3 Textile finishing**
13.01.10 / 13.02.05 / 13.02.06 / 13.03.07	0,12		0,1	20 Litres/year		
15.01.11				0,33		
08.01.11				0,2		
15.02.02	0,003	0,225	0,021	0,2	0,04	8
15.01.10	2,8	1,69	3,5		48	22
20.01.21	0,62		0,005			0,159
16.01.07	0,004					0,019
13.01.13					7	

Table 3.7. Hazardouswaste generated in several Spanish, and Turkish companies.

	SPANISH COMPANIES				**TURKISH COMPANIES**	
WASTE (E.W.C.) Non-Hazardous	**Company 1 Textile finishing**	**Company 2 Textile finishing**	**Company 3 Dyeing bobbins and beams**	**Company 4 Textile finishing**	**Company 1 Textile finishing**	**Company 3 Textile finishing**
15.01.01		33,22	2,85	3,83		140
19.09.06			0,005			
15.01.04			1,3			
15.01.02			1,6			20
04.02.22			19			5
04.02.99	73					
04.02.21				3		

Table 3.8. Non-hazardous waste generated in several Spanish and Turkish companies.

3.6 Chemical usage

Chemicals used depend on the type of textile process developed: dyeing, finishing, whitening… based on each of the stages more products are consumed or on the contrary, as it is the case of spinning, aren't needed. Data from Spanish and Turkish companies are shown below (the first table for raw materials, the second one for auxiliary materials):

	SPANISH COMPANIES			**TURKISH COMPANIES**			
RAW MATERIALS (ton/year)	**Company 1 Textile finishing**	**Company 2 Textile finishing**	**Company 3 Dyeing bobbins and beams**	**Company 4 Textile finishing**	**Company 1 Textile finishing**	**Company 2 Textile finishing**	**Company 3 Textile finishing**
Sulfuric acid	90				0		0,1
Sodium hydroxide	170			50	298		
Hydrogen peroxide	48			67	37,5	49	197
Acetic acid	3			9	5,4	138	78
Detergents [1]and washing preparations	54				191,6	42	116
Sodium chloride				90	44,1		8651
Synthetic organic coloring matter and color lakes and preparations				14	200	108	
Formic acid				27	0		1
Substance Synthetic organic and inorganic dye, dyeing preparations				7			237
Others (please specify)							

Table 3.9. Consumption of raw materials for several Spanish and Turkish companies.

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[1] For a precise and detailed definition of detergent and methods to measure the content of detergents in waste watersplease see Annex V.

	SPANISH COMPANIES				**TURKISH COMPANIES**		
Auxiliary materials (kg/year)	**Company 1 Textile finishing**	**Company 2 Textile finishing**	**Company 3 Dyeing bobbins and beams**	**Company 4 Textile finishing**	**Company 1 Textile finishing**	**Company 2 Textile finishing**	**Company 3 Textile finishing**
Binders	1045		1045		54		
Dispersants	2410		2410	8210			
Fixer	98200	73041	98200	1350			
Salts	52100 (sodium hydrosulfite)	155700	52100 (sodium hydrosulfite)	162000	1125	8841	
Acid	55000	36474	55000	40500	90		
Sequestrant	8700	1939	8700	4050			
Surfactants		8167		16650	191,6		
Antifoaming		1044		1710	4		
Levelling agents		41625		2475			
Retardants				10800	2,1		
Sodyum Karbonat / Sodyum Bikarbonat					136		
Apretanlar					45		
Others (please specify)							

Table 3.10. Consumption of auxiliary materialsfor severalSpanish and Turkish companies.

3.7 Energy consumption

The energy consumption in the textile sector is variable depending on the degree of optimization of the process. There are systems that make possible the reduction of energy consumption, as for example, heat exchangers, cooling systems, steam condensers or cogeneration systems. Data from Spanish and Turkish companies are shown below:

	SPANISH COMPANIES				**TURKISH COMPANIES**		
ENERGY	**Company 1 Textile finishing**	**Company 2 Textile finishing**	**Company 3 Dyeing bobbins and beams**	**Company 4 Textile finishing**	**Company 1 Textile finishing**	**Company 2 Textile finishing**	**Company 3 Textile finishing**
Natural Gas (MWh)	28700	26912	9209	13252	66807	16102	27172
Diesel (m^3)		11			0		20
Electric power (MWh_e)	2875	4139	1652	1506	11750	4829	11660

Table 3.11. Consumption of energy in several Spanish and Turkish companies.

3.8 Typical emissions from the carpet subsector

In the tables of this section are shown the range of values corresponding to 4 companies of the carpetsector in Spain with production > 10 T/year, and typical average ranges of carpet production companies within the EU stated in the BREF for the textile sector.

3.8.1 Raw Materials.

In the carpets production sector the chemicals which are mainly consumed are shown below:

Raw Materials T/year	SPANISH COMPANIES	EU typical ranges (info from BREF)
Dyes	3000 - 5000**T/year**	3 – 7 kg/tn textile
H_2SO_4	30 - 50**T/year**	36 – 140 kg/tn textile
H_2O_2	40 -60**T/year**	
CH_3-COOH	3 - 5**T/year**	
Detergents[2]	8 - 11 **T/year**	1 – 5 kg/ tn textile
Water	50000 - 65000 m^3/year	35 – 54 m^3 / tn textile

Table 3.12. Table for interval of consumption of raw materials in carpet production companies in Spainand in the EU.

3.8.2 Energy consumption.

The average values of energy consumption for carpet productioninstallations (with a production of 10 T/day) are as follows:

	SPANISH COMPANIES	EU typical ranges (info from BREF)
Energy electrical	900 - 1200 **Mw/h**	11 – 15 GJ / tn textile
Energy Gasoil T/year	0,5 - 1	
Energy Fuel-oil T/year	400 - 600	

Table 3.13. Interval of consumption of energy in carpet production companies in Spain and in the EU.

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[2] For a precise and detailed definition of detergent and methods to measure the content of detergents in waste waters please see Annex V.

3.8.3 Atmospheric Emissions (Boiler).

Air emissions can come from the boilers used frequently in carpet production companies. Some figures for some companies are shown below:

ATMOSPHERIC EMISSIONS BOILER	SPANISH COMPANIES	EU typical ranges (info from BREF)
SO_2(mg/Nm^3)	600 - 800	not quantified
NO_x (ppm)	700 - 900	
CO (ppm)	6 - 9	
CO_2 (%)	8 – 10%	

Table 3.14. Interval of atmospheric emission boiler in carpet production companies in Spain and in the EU.

3.8.4 Wastewater emissions.

In the table below are shown typical values of waste water parameters for carpet production companies, together with some reference values mentioned in the BREF reference document for the textile sector:

WASTEWATER	SPANISH COMPANIES	EU typical ranges (info from BREF)
pH	6 - 8	6 - 9
COD (mg O_2/l)	400 - 800	1500 - 1700
BOD_5 (mg O_2/l)	300 - 500	80 - 750
TKN (mg/l)	17 - 50	not quantified
SS (mg/l)	20 - 40	50 - 150
Conductivity (µS/cm)	3000 - 7000	1000 - 8000
Cl^- (mg/l)	500 - 2000	not quantified
Detergents[3] (mg/l)	0,5 - 3	not quantified

Table 3.15. Interval of result of analysis in wastewater in carpet production companies in Spain and in the EU.

3.8.5 Hazardous and non-Hazardous Waste.

In this subsector, the most representative waste generated are as follows:

	SPANISH COMPANIES	EU typical ranges (info from BREF)
WASTE (E.W.C.) Hazardous	T/year	
15.01.10	5 -10	not quantified
WASTE (E.W.C.) Non-Hazardous	T/year	
15.01.06	2- 3	not quantified

Table 3.16. Interval of production of waste hazardous and nonhazardous in carpet production companies in Spain and in the EU.

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[3] For a precise and detailed definition of detergent and methods to measure the content of detergents in waste waters please see Annex V.

4 BEST AVAILABLE TECHNIQUES IN THE TEXTILE SECTOR

4.1 Generic BAT for the whole sector.

Introduction

In any sector, an integrated environmental permitmust contain reference to the use of the best available techniques (BATs) or other good environmental practices that offer similar environmental results concerning the activity as a whole.

The BATs which are mentioned and described in this Chapter come from the BREF for the textiles industry, published in 2002. In addition, some best environmental practices and several explanations have been included, part of which come from the mentioned BREF, and part coming from more updated implementation experience in Spain and Poland. In any case clear distinction is made between BATs and other techniques or practices which are not considered as BATs in BREFs.

It must be noted that the Ministry of Environment and Urbanisation published in december 2011 the “Communication 28142 on integrated pollution prevention and control in the textile sector”, where also many BATs of the BREF for the textiles industry are mentioned. In this Chapter reference is made to that Communication, and differences with it are emphasized.

Each company will have to identify within its application for the integrated environmental permit the techniques that are used in it which are considered as BATs in any of the existing BREFs (naturally in the case of textile installations the most relevant BREF is the BREF for the textiles industry). In the cases whereduring the assessment of the permit application the Competent Authority will request to achieve a certain emission level for a certain pollutant, the operator will have to justify how he or she will achieve that goal. Some BATs have associated emission levels stated in the corresponding BREF, so if the operator uses them it will be understood that those associated emission levels will be achieved.

If the operator chooses to use techniques other than BATs to achieve the emission level required by the Competent Authority, he or she will have to justifyhowsuch techniques will achieve that goal.

The BATs are particularly effective techniques from the environmental point of view due to its lower resource consumption and/or environmental impact, and which are viable from the technical and financial perspectives for the industries falling under the scope of the Industrial Emissions Directive, and particularly in the case of the textile sector for those who have a production capacity exceeding 10 T/day in operations of dyeing, bleaching or mercerization.

Compared to other available techniques used to perform a particular operation or practice in an industrial facility, a BAT implies a significant environmental benefit in terms of saving of resources and/or reduction of the environmental impact produced.

Apart from this first requirement, aBAT must be available in the market and also compatible with the production of articles of quality, with no harmful substances and whose manufacture does not involve a major occupational or industrial hazard (low productivity, complexity, etc.). It must be borne in mind that in the case of the textile industry, safety in the use of substances is priority criterion above the protection of the environment.

And finally, a technique cannot be BAT if it is economically unviable for an industry. The adoption of BATs by an installation should not imply a cost involving a risk to the continuity of the activity.

It is worth recalling that some BATs that may be technically and economically viable for new facilities, may not be in the case of existing installations.

4.1.1 Management.

Technology by itself is not sufficient; it needs to go together with environmental management and good housekeeping. Management of an installation that uses potentially polluting processes requires the implementation of many of the elements of an Environmental Management System(EMS).

A series of good environmental practices applicable to the textile sector, which can be considered general principles on the prevention of pollution in the sector are briefly described below. The following are BATs (corresponds to sections A.1 and A.2 of the “Communication 28142 on integrated pollution prevention and control in the textile sector”):

- **Education and environmental training to employees**, promoting their active participation in environmental management.
- **Equipment maintenance**: emission controls, maintenance of filters and systems of effluent treatment, calibration of equipment, proofing thermal isolation of high temperature machines, etc.
- **Handling of chemical substances**: the staff responsible for the handling of chemicals must be provided the training needed for the performance of the activity. Also, storage areas must be located in spaces equipped with systems of containment of spills.
- **Automation of the cuisine of colors and the different dosing equipment**. Automation of systems for the dosing of reagents involves a significant decrease in the margin of error in the measures, avoiding subsequent adjustments of color or other treatments and consequent consumption of resources (in the Communication 28142 dyes are not included).
- **Provision of information concerning the items and matters raw material in general**. This information must be provided by the supplier.

The following best environmental practices are not considered best available techniques, although they are good for reducing the environmental impact:

- **Management of the baths**: just-in-time automated preparation of the bath, search for the best bath relations, optimisation of the use of water, etc.
- **Optimization in the use of resources** minimization in consumption of water, energy, and raw materials..

- **Reduction of packaging, use of recyclable containers and textile waste recycling**.
- **Evaluation of input and output flows**: flow diagrams and mass balances are considered useful tools for the identification of the potential for optimization of the sector.
- **Creation of a preventive maintenance program to ensure the proper functioning of wastewater treatment plants**(in the Communication 28142 this is not mentioned).

Good practices, which will help us improve the performance of the staff of the company must be applied to prevent and avoid a high degree of contamination or a dangerous situations for the environment, and enhance the performance of all the teams in the process.

To get a proper management of the textile chain since the beginning of the process it is very important to apply the following tool:

Development of technological improvement plans based on the optimization of the management of Stocks.

Stock management is one of the fundamental activities within the supply chain management because the level of stocks can sometimes become the highest investment by the company, covering even more than 50% of the total costs in the distribution sector.

The need for inventories has been fostered by the difficulty of coordinating and managing the real-time needs and requirements of the clients with the production system, and the production needs with the ability of providers to supply the materials within the agreed deadline.

The textile sector has a rate of possession close to 25% of the inventory, and a volume of inventory exceeding 30% of turnover. These numbers generate a high financial leverage, generating some very important cost of warehousing and obsolescence. The obsolescence in the textile sector is the highest in the market, reaching a 23% of the annual average inventory.

There are studies of enterprises at the level of the Region of Valencia, where the main objective is the design, development and subsequent implementation of a management tool for technical sheets for the area of design, which this developed using free or open source software.

It has been observed that, on occasions, the poor definition of the specifications of the product is the cause of some problems, such as: the product does not have the expected quality, the garment does not conform to the original design, preparation time and cost is greater than is really necessary, the consumption of raw materials and chemical products is high and unnecessary, etc. Therefore a need arises to analyse the process of elaboration of the specifications and define a way of improving it.

The need is detected in companies within the textile-clothing sector, to have a management tool of the technical specifications for the definition of all the characteristics of the products, from the grouping of materials to be used, the sizes manufactured, colours available, etc. For this reason, it is advisable to develop, customize, validate and implement a software tool for the making and management of advanced technical data sheets in companies of the textile sector, to achieve greater specialization and better organization of the companies.

4.1.2 Use of chemicals.

The main measures to take in the use of chemical products are as follows:

BAT is to:

1. Replacement or disposal of chemicals used throughout the textile chain, other environmentally sustainable(corresponds to sections A.2.2.3 – A.2.2.5 of the “Communication 28142 on integrated pollution prevention and control in the textile sector”).

   Surfactants are used for many different purposes in the textile industry (e.g. detergents, lubricants, etc.). Some surfactants are considered problematic because of their por biodegradability and toxicity to aquatic species. Concerns currently focus on APEO and in particular NPE. The main alternatives for APEO are fatty alcohol ethoxylates, but also for other surfactants substitutes are often available that arereadily biodegradable or bioeliminable in thewaste water treatment plant and that do not form toxic metabolites.BAT is to substitute alkylphenol ethoxylates and other hazardous surfactantswith susbtitutes that are readily biodegradable or bioeliminable in the waste water treatmentplant and do not form toxic metabolites

   Complexing agents can often be avoided. Nevertheless, when they need to be used, compounds are available as an alternative to conventional sequestering agents that are readily biodegradableor at least bioeliminable and that do not contain N or P in their molecule (e.g. polycarbonates,polyacrylates, gluconates, citrates and some sugar-acrylic acid copolymers). Costs are comparable, although higher quantities may be necessary in some cases.Avoid or reduce the use of complexing agent in pretreatment and dyeing processes and select biodegradable or bioeliminable complexing agents.

   Antifoaming agents are often based on mineral oils. Typical active ingredients in mineral oilfree products are silicones, phosphoric esters, high molecular alcohols, fluorine derivatives andmixtures of these components. Silicones are eliminated only by abiotic processes in waste water and above certain concentrations they hinder the transfer/diffusion of oxygen into the activatedsludge. Tributylphosphates are odour intensive and strongly irritant and high molecular-weight alcohols are odour intensive and cannot be used in hot liquors.Minimise or avoid their use by:

   - Using bath-less air-jets, where the liquor is not agitated by fabric rotation.
   - Re-using treated bath for cooling and heating purposes.
   - Select anti-foaming agents that are free from mineral oils and that are characterised by high bioelimination rates.

2. Through the use of independent equipments for dyeing and application of softeners, as well as through the use of cationic softeners, it is possible to reuse rinse baths, increase the concentration of active substances and, consequently, reduce considerably product losses. For example: Padding machines (**foulards**) are used to apply dyestuffs or other chemicals onto the fabric in open-width form. The fabric passes through the pad trough where it picks up the liquor. After leaving the pad trough, the fabric is squeezed between rubber rolls. The amount of liquor picked up depends mainly on the pressure produced by the two rolls, the speed at which the fabric is transported and the type of substrate. The level in the trough is automatically maintained to compensate for liquor picked up by the fabric. The liquor is kept in circulation to avoid differences in temperature and/or concentration(it is related to the technique explained in section B.2.19 of the "Communication 28142 on integrated pollution prevention and control in the textile sector").

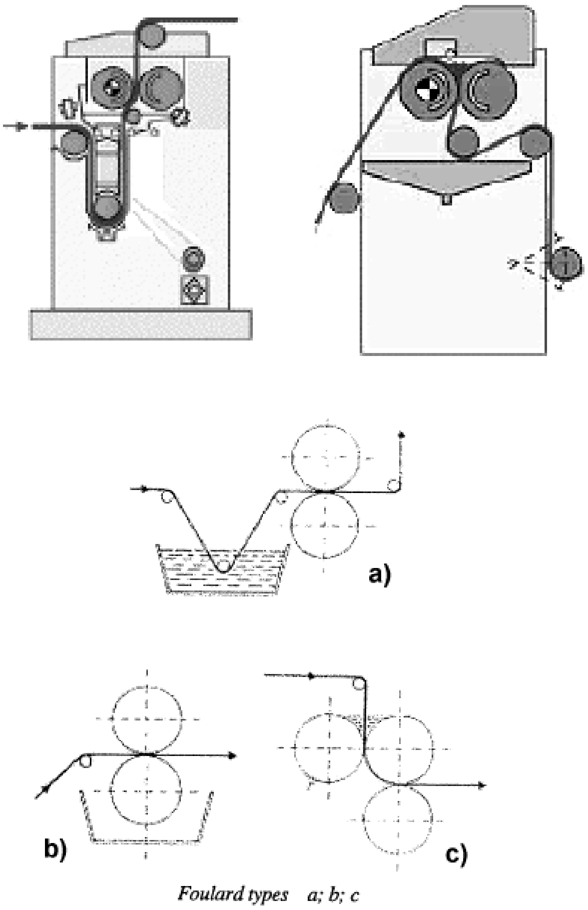

Figure 10.11 (textile BREF): Foulard types

3. Optimize the process conditions to promote appropriate chemical reactions and thus achieve higher performance of the products used(corresponds to section B.2.8 of the "Communication 28142 on integrated pollution prevention and control in the textile sector").

In the dyeing stage it is of great importance to have the volume control in the vats of the baths. To do this a proper design of the padder is needed. A padder is a machine that has the function of impregnating textile material with any fluid, in this case the bath of dye, but usually during this process every time a change of colour is required it is necessary to empty the container with the associated loss of bath. There is an alternative, which is a padder where the volume of the bath of the container can be decreased to achieve the reduction of losses of bath.

Well-known PES dyeing carriers can be avoided (except for PES/WO and elastane/WO blends) by dyeing under high-temperature conditions. Another attractive option is the use of non-carrier dyeable PES fibres, such as polytrimethylene terephthalate (PTT) polyester fibres. However, due to differences in physical and mechanical properties, these fibres do not cover exactly the same product market and cannot be regarded as “substitutes” for PET-based polyester fibres. When carriers cannot be avoided, conventional active substances - based on chlorinated aromatic compounds, o-phenylphenol, biphenyl and other aromatic hydrocarbons - can be replaced with less harmful compounds such as, benzylbenzoate and N-alkylphthalimide.

In order to avoid the use of sodium hydrosulphite in PES after-treatment, two different approaches are proposed: the use of reducing agents based on a special short-chain sulphinic acid derivatives or the use of disperse dyes that can be cleared in alkaline medium by hydrolytic solubilisation instead of reduction. Short-chain sulphinic acid derivatives are biodegradable, non-corrosive, have very low toxicity and, unlike hydrogen hydrosulphite, they can be applied in acidic conditions without the need for repeated bath changes and shifts in pH (water and energy savings). With alkali-clearable dyes the use of hydrosulphite or other reducing agents can be avoided altogether.

Dispersing agents typically present in disperse, vat and sulphur dye formulations have been improved by:

1. their partial substitution with optimised products based on fatty acid esters, or
2. the use of mixtures of modified aromatic sulphonic acids. The first option is only applicable for liquid formulations of disperse dyes (the dyestuff pallette is currently limited). These dispersing agents are bioeliminable and their amount in the formulation can be significantly reduced compared to conventional formulations. The dispersing agents indicated in the second option show a higher degree of bioelimination compared to the conventional condensation products of naphthalene sulphonic acid with formaldehyde. They can be used both for disperse and vat dyes (solid and liquid formulations).

Pre-reduced sulphur dyestuffs (liquid formulations with sulphide content <1 %) or non-prereduced sulphide-free dyestuffs are available in various different forms (water-soluble in the oxidised, powder, liquid form, or in stable suspension). All these dyestuffs can be reduced without any sodium sulphide, using glucose alone (only in one case) or in combination with dithionite, hydroxyacetone or formamidine sulphinic acid. Stabilised non-pre-reduced sulphidefree dyestuffs are reported to be more expensive than the other types of sulphur dyes.

Poor dye fixation has been a long-standing problem with reactive dyeing in particular in batch dyeing of cellulose fibres, where a significant amount of salt is normally added to improve dye exhaustion. With the use of sophisticated molecular engineering techniques it has been possible to design bifunctional and low-salt reactive dyes that can attain >95 % fixation rate even for cellulosic fibres, with considerably higher performance (reproducibility and level dyeing) than traditional reactive dyes. Hot rinsing avoids the use of detergents and complexing agents in the rinsing and neutralisation steps after dyeing. Substituting cold rinsing with hot rinsing leads to higher energy consumption, unless thermal energy from the rinsing effluent is recovered.

4. Printing (corresponds to section B.2.13.1 of the “Communication 28142 on integrated pollution prevention and control in the textile sector”).

   Minimising the volume of the printing paste supply system (i.e. diameters of pipes and squeegees) has major effects in reducing printing paste losses in rotary-screen printing. A further reduction can be achieved by improving paste recovery from the supply system itself. A recent technique consists in inserting a ball in the squeegee, before filling the system. At the end of a print run, the ball is pressed back, thus pumping the printing paste in the supply system back into the drum for re-use. Today, computer-assisted systems offer more opportunities for recovery printing pastes. Printing paste recovery and reuse systems are applied in textile finishing mills (for flat fabrics), but not for carpets. The main reason is that guar-gum (the most common thickener used for carpets) has a limited shelf-life (biodegradable compound) and therefore it cannot be stored for a long time before re-use.

   An alternative to analogue printing is the use of digital techniques, which are gaining importance in the textile and in the carpet sector. In digital printing the selected dyes are dosed on-demand, based on computed requirements. This avoids printing paste residues at the end of each run.

5. Finishing (corresponds to section B.2.16.2 of the “Communication 28142 on integrated pollution prevention and control in the textile sector”).

   In order to reduce pick-up, so-called minimum application techniques (e.g. kiss-roll, spray and foaming application systems) are gaining importance as substitutes for padding systems. In addition, various techniques are available for reducing energy consumption in stenter frames (e.g. mechanical dewatering equipment to reduce water content of the incoming fabric, optimising control of exhaust airflow through the oven, installation of heat recovery systems).

4.1.3 Selection of raw materials.

The table below lists the BAT identified for a some raw materials for preventing at source the environmental impact arising from pollutants present on the fibre before it enters the finishing process.

Raw material	BAT
Man-made fibres	Select material treated with low-emission and biodegradable / bioeliminable preparation agents
Cotton	1. Select material sized with low add-on techniques (pre-wetting of the warp yarn) and high-efficiency bioeliminable sizing agents 2. Use the available information to avoid processing fibre material contaminated with the most hazardous chemicals such as PCP 3. use organically grown cotton when market conditions allow
Wool	4. Use the available information to avoid processing fibre material contaminated with the most hazardous chemicals such as OC pesticides residues 5. Minimise at source any legally used sheep ectoparasiticides by encouraging the development of low pesticide residue wool by continuing dialogue with competent bodies responsible for wool production and marketing in all producing countries 6. Select wool yarn spun with biodegradable spinning agents instead of formulations based on mineral oils and/or containing APEO.

Table 4.1. BAT identified for a some raw materials for preventing at source the environmental impact

In the textile industry a large number of dyes, pigments and auxiliary products is applied. Basically they can be classified into:

- Dyes and pigments,
- Basic reactants including all inorganic chemicals and organic pollutants reducing or oxidizing as well as aliphatic organic acids,
- Auxiliary products containing mainly organic compounds, with the exception of those that are considered in the previous section. They are also known as specialties and its exact composition is unknown.

4.1.4 Water and energy management.

The stage which produces highest water consumption is dyeing. One of the measures proposed in the dyeing stage is the replacement of the conventional washing by enzymatic treatment, whereby the hydrolyzed dye will be extracted from the fabric and the dye bath, reducing water and energy consumption.

Another point to take into account to optimize the consumption of water in textile processes is to start by controlling the levels of consumption. Based on this control the consumption of water can be reduced through several complementary actions, as improving work practices, reducing the proportion of liquor used in the discontinuous process, improving the efficiency of the washing, combining processes (for example, scouring and unlashing) and reusing or recycling the water. These measures can significantly reduce consumption of water and also the energy used for heating process baths. There are other specific techniques (e.g. valves, tanks and machines, the separation of hot and cold water flows and the recovery of heat from the hot flow) to optimize energy consumption.

BAT is to:

Monitor water & energy consumption in the various processes, as mentioned earlier(corresponds to section B.2.20.2 of MoEU'sCommunication 28142).

Install flow control devices and automatic stop valves on continuous machinery(corresponds to section A.4.2 of MoEU's Communication 28142).

Install automatic controllers for control of fill volume and liquor temperature in batch Machines(corresponds to section A.4.3 of MoEU's Communication 28142).

Establish well-documented production procedures in order to avoid wastage of resources from inappropriate work practices(corresponds to section A.4.4 of MoEU's Communication 28142).

Optimise scheduling in production and adjust processes in pretreatment to quality requirements in downstream processes.

Investigate the possibility of combining different treatments in one single step(corresponds to section B.2.2.3 of MoEU's Communication 28142).

Install low- and ultra-low liquor ratio machinery in batch processes.

Introduce low add-on application techniques in continuous processes.

Improve washing efficiency in both batch and continuous processing(corresponds to section B.2.20 of MoEU's Communication 28142).

Re-use cooling water as process water (also allowing heat recovery)(corresponds to sections A.4.10 and C.4.8 of MoEU's Communication 28142).

Investigate possibilities for water re-use and recycling by systematic characterisation of quality and volume of the various process streams in order to identify processes for which the substances contained in the various waste streams are still valuable and/or do not interfere with the quality of the product. For recycling purposes in batch processes it is convenient to install machinery with built-in features that facilitate recovery and re-use of waste streams(corresponds to section A.4.11 of MoEU's Communication 28142).

Fit hoods and covers ensuring full closure of machinery that could give rise to vapour losses.

Insulate pipes, valves, tanks, machines to minimise heat losses(corresponds to section A.4.12 of MoEU's Communication 28142).

Optimise boiler houses by applying re-use of condensed water, preheating of air supply, heat recovery from combustion gases.

Segregate hot and cold waste water streams prior to heat recovery and recover heat from the hot stream.

Install heat recovery systems for off-gases(corresponds to section A.4.15 of MoEU's Communication 28142).

Install frequency-controlled electric motors(corresponds to section A.4.16 of MoEU's Communication 28142).

4.1.5 Waste management

Certain specific process residues, as residual printing pastes and residual padding liquors, are very aggressive and, insofar as possible, must be kept separate from wastewater flows.

These residues should be removed properly: thermal oxidation can be a technique appropriate due to its high calorific value.

Regarding pesticide residues present in the raw wool fibre, several organizations have information showing the content of pesticides in greasy and scoured wool. Manufacturers can use this information to minimise at source any legally used pesticides such as OP and SP ectoparasiticides, and to avoid processing wool contaminated with the most hazardous chemicals, such as OC pesticides,unless an analytical certificate is provided. In the absence of such information, sample testing should be carried out to determine the content of pesticides, but this option increases the costs of the manufacturer. Cooperation programmes between sectorial associations and the main producer countries have led to a progressive reduction of the average content in waste of OP and SP in wool, as well as to the development of systems of certification of low waste content.

The waste management policy must be to prevent the generation of waste, and promote policies of prevention, minimization, optimization, recovery and treatment; at all stages of the production cycle. Control of waste generated at the enterprise is essential, to reduce from the origin waste production.As an example, the volumes of the containers in which the raw materials are receivedshould be quantified, to ask the supplier if it is possible to receive raw with larger containers; another measure is to facilitate recycling.

4.2 BATs for specific operations.

4.2.1 Pretreatment.

Removing knitting lubricants from fabric(corresponds to section B.2.1 of MoEU's Communication 28142)

- Select knitted fabric that has been processed using water-soluble and biodegradable lubricants instead of the conventional mineral oil-based lubricants:
- Mineral oils substitution in knitted fabric manufacturing.
- Carry out the thermofixation step before washing and treat the air emissions generated from the stenter frame by dry electrofiltration systems that allow energy recovery and separate collection of the oil. This will reduce the contamination of the effluent:
- Air emission abatement techniques.
- Remove the non-water soluble oils using organic solvent washing.

- Cleaning and washing with solvent (Wash bowls, Dirt separation, Solvent evaporation system, Vapour recovery unit, Solvent destruction, Air emissions, Auxiliary water, Energy consumption).

Desizing (corresponds to section B.2.2 of MoEU's Communication 28142)

- Select raw material processed with low add-on techniques:
- Selection of sizing agents with improved environmental performance.
- Minimising sizing agent add-on by pre-wetting the warp yarns.
- Adopt the oxidative route when it is not possible to control the source of the raw material:
- Application of the oxidative route for efficient, universal size removal.
- Combine desizing/scouring and bleaching in one single step:
- One-step desizing, scouring and bleaching of cotton fabric.
- Recover and re-use the sizing agents by ultrafiltration:
- Recovery of sizing agents by ultrafiltration.

Bleaching (corresponds to section B.2.3 of MoEU's Communication 28142)

- Use hydrogen peroxide bleaching as preferred bleaching agent combined with techniques for minimising the use of hydrogen peroxide stabilisers or using biodegradable/bioeliminable complexing agents:
- Substitution for sodium hypochlorite and chlorine-containing compounds in bleaching operations.
- Selection of biodegradable/bioeliminable complexing agents in pretreatment and dyeing processes.
- Use sodium chlorite for flax and bast fibres that cannot be bleached with hydrogen peroxide alone. A two-step hydrogen peroxide-chlorine dioxide bleaching is the preferred option. It must be ensured that elemental chlorine-free chlorine dioxide is used. Chlorine-free chlorine dioxide is produced using hydrogen peroxide as the reducing agent of sodium chlorate:
- Substitution for sodium hypochlorite and chlorine-containing compounds in bleaching operations.
- Effluent from hypochlorite bleaching is kept separate from the other streams and mixed effluents in order to reduce formation of hazardous AOX.

<u>Mercerising</u>(corresponds to section B.2.4 of MoEU's Communication 28142)

- Recover and re-use alkali from mercerising rinsing water:
- Recovery of alkali from mercerized.
- Or re-use the alkali-containing effluent in other preparation treatments.

4.2.2 Dyeing(corresponds to section B.2.5 of MoEU's Communication 28142).

Dosage and dispensing of dye formulations

- reduce the number of dyes (one way to reduce the number of dyes is by using trichromatic systems)

- Use automated systems for dosage and dispensing of dyes, only considering manual operation for dyes that are used infrequently
- In long continuous lines where the dead volume of the distribution line is comparable with the volume in the padder, give preference to decentralised automated stations that do not premix the different chemicals with the dyes before the process and that are fully automatically cleaned.

General BAT for batch dyeing processes(corresponds to section B.2.6 of MoEU's Communication 28142)

- Use machinery fitted with: automatic controllers of fill volume, temperature and other dyeing cycle parameters, indirect heating & cooling systems, hoods and doors to minimize vapour losses.
- Choose the machinery that is most fitted to the size of the lot to be processed to allow its operation in the range of nominal liquor ratios for which it is designed. Modern machines can be operated at approximately constant liquor ratio whilst being loaded at a level as low as 60 % of their nominal capacity (or even 30 % of their nominal capacity with yarn dyeing machines).
- Select new machinery (low- or ultra-low liquor ratio, in-process separation of the bath from the substrate, internal separation of process liquor from the washing liquor, mechanical liquor extraction to reduce carry-over and improve washing efficiency, reduced duration of the cycle linked to automation of the processes).
- Substitute overflow-flood rinsing method in favour of drain and fill or other methods (smart rinsing for fabric).
- Re-use rinse water for the next dyeing or reconstitution and re-use the dye bath when technical considerations allow.

BAT for continuous dyeing processes(corresponds to section B.2.7 of MoEU's Communication 28142)

BAT is to reduce losses of concentrated liquor by:

- Using low add-on liquor application systems and minimising volume capacity of the dip trough when using pad dyeing techniques.
- Adopting dispensing systems where the chemicals are dispensed on-line as separate streams, being mixed only immediately before being fed to the applicator.
- Using one of the following systems for dosing the padding liquor, based on measurement of the pick up.
- Increase washing efficiency according to the principles of counter-current washing and reduction of carry-over.

PES & PES blends dyeing with disperse dyes (corresponds to section B.2.8 of MoEU's Communication 28142)

- Avoid the use of hazardous carriers by using non-carrier dyeable polyester fibres, dyeing in HT conditions without use of carriers, substituting conventional dye carriers with compounds based on benzylbenzoate and Nalkylphthalimide.

- Substitute sodium dithionite in PES aftertreatment.
- Use optimised dye formulations that contain dispersing agents with high degree of bioeliminability.

Dyeing with sulphur dyes(corresponds to section B.2.9 of MoEU's Communication 28142)

- Dyeing with sulphur dyes.
    - Replace conventional powder and liquid sulphur dyes with stabilised non-pre-reduced sulphide-free dyestuffs or with pre-reduced liquid dye formulations with a sulphide content of less than 1 %
    - Replace sodium sulphide with sulphur-free reducing agents or sodium dithionite, in that order of preference
    - Adopt measures to ensure that only the strict amount of reducing agent needed to reduce the dyestuff is consumed (e.g. by using nitrogen to remove oxygen from the liquor and from the air in the machine)
    - Use hydrogen peroxide as preferred oxidant.

Batch dyeing with reactive dyes(corresponds to section B.2.10 of MoEU's Communication 28142)

- Use high-fixation, low-salt reactive dyes.
- Omitting the use of detergents in afterwashing of cotton dyed with reactive dyes.

Pad-batch dyeing with reactive dyes(corresponds to section B.2.11 of MoEU's Communication 28142)

- Alternative process for continuous (and semicontinuous) dyeing of cellulosic fabric with reactive dyes. This process includes an impregnation step on a padding machine. After being squeezed, the fabric is wound onto a roll and stored at room temperature. The roll is kept in slow rotation until the desired chemical processes (e.g. fixation of the dyestuffs, etc.) are complete. At the end the fabric is washed in an open-width washing machine. This process is commonly used for pretreatment (e.g. desizing) and dyeing (mainly with direct and reactive dyes). It is characterised by low water and energy consumption (about 50 – 80 % less than conventional systems) and good repeatability.

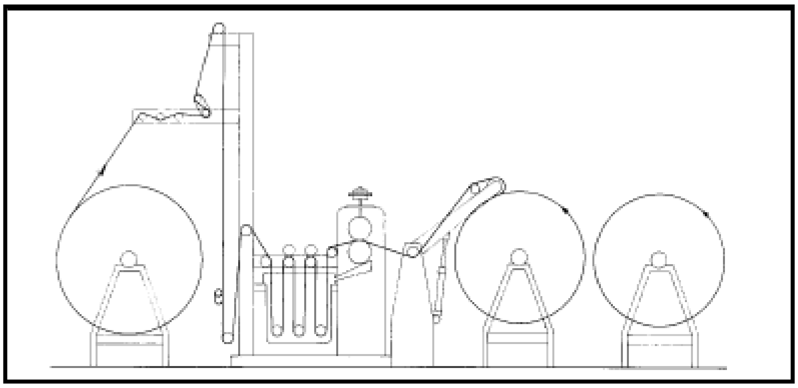

Figure 10.13 (Bref Textil): Schematic layout of a pad-batch plant

Wool dyeing(corresponds to section B.2.12 of MoEU’s Communication 28142)

- Low-chrome and ultra-low-chrome afterchroming methods for wool.
- Emission reduction in dyeing wool with metal-complex dyestuffs.
- pH-controlled dyeing techniques.

4.2.3 Printing.

Process in general(corresponds to section B.2.13 of MoEU’s Communication 28142)

- Reduce printing paste losses in rotary screen printing by:
- Volume minimisation of printing paste supply systems in rotary screen printing machines.
- Recovery of printing paste from supply system in rotary screen printing machines.
- Recycling of residual printing pastes.
- Reduction of water consumption in cleaning operations.
- Ink-jet digital printing for flat fabric.
- Digital jet printing of carpet and bulky fabric.

Reactive printing(corresponds to section B.2.14 of MoEU’s Communication 28142)

- Urea substitution and/or reduction in reactive printing.
- Reactive two-step printing.

Pigment printing(corresponds to section B.2.15 of MoEU’s Communication 28142)

- Pigment printing pastes with optimised environmental performance.

4.2.4 Finishing (corresponds to section B.2.16 of MoEU's Communication 28142).

Process in general

- Minimise residual liquor, energy consumption.
- Use low air emission optimised recipes (Emission factor concept (emissions to air)).

Easy-care treatment(corresponds to section B.2.17 of MoEU's Communication 28142)

- Formaldehyde-free or formaldehyde-poor easy-care finishing agents.

  Easy-care finishings are applied to cellulose-containing fibres to impart characteristics such as easy-to-wash, creasing resistance during wash and wear, no ironing or minimum ironing. These properties are now required for cellulose fibres to allow them to compete with synthetic fibres such as polyamide and polyester.

  Easy-care recipes consist of various ingredients:

  - cross-linking agent
  - catalyst
  - additives (softeners, but also water-repellents, hydrophilizing agents, etc.)
  - surfactants as wetting agent.

  Easy-care finishing is mainly carried out on cellulosic fibres and their blends in order to increase the crease recovery and/or dimensional stability of the fabrics.

  Easy-care finishing agents are mainly compounds synthesised from urea, melamine, cyclic ureaderivatives and formaldehyde. Cross-linking agents (reactive groups) are composed of free or etherificated N-methylol groups.

  A problem that may arise is that formaldehyde-based cross-linking agents may release free formaldehyde. Formaldehyde isthought to be carcinogenic and is a threat to the workforce (formaldehyde can also bereleased,for example, during cutting operations). The presence of free formaldehyde or partlyhydrolysable formaldehyde on the finished fabric also represents a potential risk for the finalconsumer. The European Eco-label scheme sets a threshold of 30 ppm for products that comeinto direct contact with the skin.

  Low-formaldehyde or even formaldehyde-free products are an alternative.

The following table shows different cross-linking agents, indicating their potential to release formaldehyde, from a high release potential (first row) to formaldehyde-free (last row). The ones with lowest release potential should be used[4]:

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[4] This should be taken into account for example in jeans production facilities.

Type of cross-linking agent	Formaldehyde release potential
Dimethylol urea	High
Melamine formaldehyde condensation products	High
Dimethyloldihydroxyethylene urea (DMDHEU)	High
Dimethyloldihydroxyethylene urea (DMDHEU) derivatives (most commonly used)	Low
Modified dimethyldihydroxyethylene urea	Formaldehyde-free

Table 4.2. Different cross-linking agents.

In the carpet sector it is always possible to avoid formaldehyde emissions by using formaldehyde-free easy-care finishing agents, whereas in the textile sector the use of formaldehyde-poor agents may be inevitable.

Mothproofing treatments(corresponds to section B.2.18 of MoEU’s Communication 28142)

Process in general

General techniques to minimise the emission of insect resist agent active substance.

- Mothproofing of yarn produced via the dry spinning route
  Specific process modifications to minimise the emission of insect resist agent active substance during yarn production by “dry-spinning route”.
- Mothproofing of loose fibre dyed / yarn scoured production
  Specific process modifications to minimise the emission of insect resist agent active substance during the treatment of stock dyed-yarn scoured production.
- Mothproofing of yarn dyed production
  Specific process modifications to minimise the emission of insect resist agent active substance during the treatment of yarn dyed production.

Softening treatments(corresponds to section B.2.19 of MoEU’s Communication 28142)

- Avoiding batch softening.

  The reason to avoid batch softening is the following: In batch processing softening agents are often applied after the dyeing process directly in the dyeing machine (e.g. jet, overflow) using the exhaustion method.Unfortunately, this limits the choice of softening agents to environmentally harmful cationic agents and gives rise to a 10 – 20 % loss of the whole volume of the warm softening bath.

  - Therefore alternative techniques have been developed: application of softeners by ***pad mangles*** or by ***spraying*** and ***foaming application systems***.

    The advantages of these techniques are that the use of cationic softening agents can be avoidedand any chemical loss can be reduced to a few percent.

    The amount of residual liquors is also reduced compared with the waste water volume produced by a batch process. In this respect, the best performances are achieved with application techniques such as spraying and foaming, which allow minimum system-losses (residual liquor in the chassis, residual liquor in the pipes and leftovers in the batch storage containers).

However, the concentration of active substance is much higher, which makes these liquors not suitable for treatment in a biological system.

Another advantage of applying the softeners in separate equipment after the batch dyeing process is that it is then possible to re-use the dyeing or rinse baths as there is no longer a problem with the presence of residual cationic softeners, which would otherwise limit the adsorption of the dye in the subsequent dyeing process.

In more than 80 % of cases, the finishing liquor, in the form of an aqueous solution/dispersion,is applied by means of padding techniques. The dry fabric is passed through the finishing bathcontaining all the required ingredients, and is then passed between rollers to squeeze out asmuch as possible of the treating solution before being dried and finally cured. Washing as finalstep, tends to be avoided unless absolutely necessary.

Normally these losses are in the range of 1 – 5 %, based on the total amount of liquorconsumed; it is also in the finisher's interest not to pour away expensive auxiliaries. However, in some cases, within small commission finishers, losses up to 35 or even 50 % may be observed.This depends on the application system (e.g. size of foulard chassis) and the size of the lots to be finished. In this respect, with application techniques such as spraying, foam and slop-padding, system-losses are much lower in terms of volume (although more concentrated in terms of active substance).

4.2.5 Washing(corresponds to section B.2.20 of MoEU’s Communication 28142).

- Water & energy conservation in batch washing and rinsing.
- Water & energy conservation in continuous washing and rinsing.
- Use of fully closed-loop installations for fabric washing (scouring) with organic solvent.

4.2.6 Wool scouring.

For effluent treatment in the wool scouring sector (water-based process), it is a BAT to use integrated dirt removal/grease recovery loops combined with evaporation of the effluent and incineration of the sludge (corresponds to section C.4.9 of MoEU's Communication 28142).

The implementation of dirt removal/ grease recovery loops allows water and energy savings (net specific water consumption figures of 2 - 4 l/kg greasy wool have proven to be achievable for coarse and fine wool). Additionally, a valuable by-product is obtained (25 to 30 % of the grease estimated to be present in the wool scoured), along with a significant reduction of the organic load sent to the effluent treatment plant. If the dirt removal/ grease recovery loop is combined with evaporation of the effluent and incineration of the sludge, with full recycling of the water and energy, additional environmental benefits are achieved in terms of water savings and amount of solid waste to be disposed of. Nevertheless, the technology is complex and is reported to involve very high capital costs and high running costs.

Wool scouring with organic solvents avoids the use of water in the actual cleaning process. The only source of water emission is moisture introduced with the wool, steam used in vacuumejectors and moisture recovered from air drawn into the equipment. This water is contaminated with perchloroethylene (PER). To avoid any risk of diffuse emissions, the water stream is treated in two steps, comprising a solvent air stripping unit and a residual solvent destruction unit. Since pesticides partition strongly to the solvent and are removed with the grease, the clean wool is reported to be pesticide free. This has beneficial implications for the downstream processes where the wool is finished. Another positive effect of this technique is the reduced energy consumption, due to the low latent heat of an organic solvent compared to water.

The replacement of perchloroethylene is compulsory, for being classified as a substance of very high concern (SVHC) according to the REACH Regulation, and there are the following alternatives:

Scenario	Substance / Technique	Comments
Dry Cleaning	Hydrocarbons	All hydrocarbon solvents used in dry cleaning consist of aliphatic hydrocarbons. Inherent properties of petroleum-based solvents include high flammability, volatility and odour. Toxicity varies by compound. All of the solvents are volatile organic compounds (VOCs) and flammable. The machines predominately used for petroleum solvents are closed-loop machines equipped with primary control.
	Decamethylcyclopentasiloxane (Trade Name: Green Earth®) CAS: 541-02-6	Decamethylcyclopentasiloxane (D5) or volatile methyl siloxane is an odourless, colourless liquid that has many consumer and industrial applications. D5 solvent is mostly being used in hydrocarbon machines. Although, Green Earth is used in some converted tetrachloroethylene machines, the manufacturer does not recommend this option. In order for tetrachloroethylene machines to be

		converted, the following assemblies must be installed by the manufacturer: filtration system; temperature control sensors; pre-water separator filter; water separator; and electrical control panel. It is not classified as a VOC.
	Propylene glycol ethers (examples are propylene glycol t-butyl ether (CAS: 57018-52-7) and dipropylene glycol tert-butyl ether (CAS: 132739-31-2). These have been used under the trade name Rynex® Cleaning.	It can be used in most hydrocarbon machines without modifications. Converting tetrachloroethylene machines to use Rynex is not recommended by the solvent manufacturer and what is more this is not a cost effective strategy. Some advocates consider that Rynex is the best alternative from a cleaning standpoint as it removes both solvent and water soluble components. Glycol ether is an aggressive cleaner and does not require spotting. However, water separation is difficult and the cycle time is long.
	Traditional / Professional wet cleaning	Wet cleaning uses computer-controlled washers and dryers with detergents that have been specially formulated for the process. The washers used in wet cleaning use a frequency-controlled motor to control the rotation of the wash drum. As a result, a gentle wash action is produced and smoother acceleration and deceleration can be created. The wash program software can determine the appropriate combination of time, water level, water temperature, extraction, and drum rotation when manual operation is not desired. Washers are also designed to mix water with cleaning agents prior to entering the drum. Wet cleaned garments must be carefully dried in preparation for finishing. Wet cleaning generally takes about 45 minutes from wash through drying, not including the finishing time. The dryers used in wet cleaning are based on humidity and are able to end the cycle when the desired humidity level in the garments has been achieved. Wet cleaning systems may also be gentler on buttons and ornamental pieces on clothing.
	Green Jet®	The Green Jet machine cleans and dries garments in a single computer-controlled unit. The machine is designed to receive a full 45 pound load of garments. It then dehydrates the garments to remove humidity and reduce surface tension, which allows mechanical action and pulsating air jets to dislodge and remove non-soluble soil from the garments. This soil is then collected in a lint chamber. Next, a pre-determined amount of water-based cleaning solution is injected through air jet nozzles to re-hydrate the fabric. After about a pint of solution has been injected, heavy felt pads attached to the ribs and the cylinder absorb the soluble soil. After the cleaning process, the unit goes into a conventional dry cycle and then a cool-down cycle.
	Carbon dioxide	Carbon dioxide and detergent are used for cleaning. It is a non-aggressive cleaner with a short cycle time; however,

		the equipment is very expensive. It is mainly favoured in the USA where grants are available to industry agreeing to change to using it. Carbon dioxide (CO_2) cleaning is a process that has been developed for use by commercial and retail dry cleaners. CO_2 is a non-flammable, non-toxic, colourless, tasteless, odourless naturally-occurring gas that, when subjected to pressure, becomes a liquid solvent. The liquid CO_2 cleaning machines have a configuration which is similar to a solvent machine. The system is closed loop and comes equipped with a cleaning chamber, storage unit, filtration, distillation, and lint trap. Washing, vapour recovery, and drying are all performed in the cleaning chamber. Liquid CO_2 and detergent are circulated through the clothes via jets inside the chamber. The jets are placed such that fluid impact upon the clothes results in rotation. Next, the CO_2 is pulled out to prevent the dirt from being re-deposited on the clothing. At the end of the cycle (35-40 minutes), the pressure is released and the CO_2 returns to a gaseous state, with dirt and substances removed from the clothing (the dirt and debris end up in the bottom of the tank). Cooling and drying of the clothes occurs as the liquid CO_2 evaporates.
	n-propyl bromide (n-PB) CAS: 106-94-5 Trade name: DrySolv	This solvent is currently being considered as an alternative substance to tetrachloroethylene in dry cleaning. However, n-PB is classified as a toxic substance. It is reprotoxic (R60, R63), irritant to eyes, respiratory tract and skin (R36/37/38), highly flammable (R11) and harmful (R48/20) such that it can cause serious damage to health by prolonged exposure through inhalation.
	Cold Water Cleaning System	Cold water cleaning systems (washer and dryer) can wash and dry all fabrics including fine fabrics. It is claimed to use 100% water and biodegradable detergents to clean garments. Garments are washed in chilled water which is expected to minimize shrinking and may leave the use of tensioning equipment at the discretion of the dry cleaners.
	Propylene glycol-ether-based solution (Trade Name: ImpressTM Dry Cleaning System)	It is compatible with hydrocarbon machines. As with any hydrocarbon or glycol ether is considered a VOC.
	Mixture of normal-, iso-, and cyclo-paraffins (Trade Name: Hydroclene Fluids)	It is a complex solvent with the ability to dissolve a broad range of strains.

Table 4.3. Alternatives for perchloroethylene.

4.2.7 Use of less hazardous chemicals in pretreatment, dyeing, finishing, printing, washing.

The persistent organic pollutants (POPs), are produced and releasedunintentionally in industrial and combustion processes. Measures to reduce or eliminate releases from unintentional production were subject of article 5 of the Stockholm Convention on POPs. Releases derived from anthropogenic sources should be reduced in accordance with this article. The Convention’s target is the sustained reduction of these substances and their final disposal when feasible.

POPs that are produced and released unintentionally, identified in the Stockholm Convention are:

- Polychlorinated dibenzodioxins and dibenzofurans (PCDDs or simply dioxines, and PCDFs or simply furanes, respectively)
- Hexachlorobenzene (HCB)
- Polychlorinated biphenyls (PCBs)
- Pentachlorobenzene

To avoid finding harmful substances transferred by chemicals used in the processes to textile products, the following techniquecan be used:

Dyeing (using cloranil) and finishing (with alkaline extraction) of textiles and leather

Dioxines (PCDDs) and furanes (PCDFs) contamination has been found both in textiles and leather. The presence of PCDDs and PCDFs in the textiles and leather is due to the use of chlorine chemicals, especially pentachlorophenol and chloronitrophenol, to protect the raw materials (cotton, wool and other fibres, leather), and due to the use of dyes contaminated with dioxins. Smaller amounts of PCDDs and PCDFs can be formed in the finish and during incineration of the sludge generated during the process.

There are alternatives to the listed dye pigments, so they should not be applied.

Some possible alternatives to pentachlorophenol and chloronitrophenol are: Ortho-phenylphenoll, (OPP), **4-chloro-3-methylphenol, (CMK),** 2-N-octyl-4-isothiazolin-3-one (OIT).

Regarding the best available techniques, the primary and most efficient to prevent contamination of textiles and leather with PCDDs/PCDFs, would be not to use biocides and dyes contaminated with dioxins in production chains. Also, if these substances are used, preference should be given to lots that have low concentrations (substances distilled or purified in some other way). Burning textile, upholstery, leather and carpets should be avoided as much as possible, to prevent the formation of PCDDs/PCDFs.

In order to avoid or reduce the formation and emission of PCDDs/PCDFs in the incineration of sludge from wastewater treatment and flotation product, one should apply the best available techniques and best environmental practices described in the “Guidelines on best available techniques and provisional guidance on best environmental practices (PNUMA 2008), section VI.D: Fossil fuel-fired utility and industrial boilers”. However, other environmental friendly techniques should also be considered.

Alternatives:
(2-benzothiazolylthio)methyl thiocyanateTCMTB; Registry number CAS 21564-17-0

Ortho-phenylphenolloPP; Registry number CAS 90-43-7
4-chloro-3-methylphenolCMK; Registry number CAS 59-50-7
2-N-octyl-4-isothiazolin-3-one OIT; Registry number CAS 26530-26-1

4.3 Waste water treatment and sludge disposal.

The following techniques are determined as general BAT for the treatment of waste water from the textile finishing and carpet industry:

- Treatment of textile waste water in activated sludge system with low food-to-microorganisms ratio (F/M) (corresponds to section D.2 of MoEU's Communication 28142).
- Treatment of selected and segregated, non-biodegradable waste water stream by chemical Oxidation (corresponds to section D.5.4 of MoEU's Communication 28142).
- Waste water treatment by flocculation/precipitation and incineration of the resulting sludge (corresponds to section D.7.3 of MoEU's Communication 28142).
- Anaerobic removal of residual dyestuff from padding liquors and printing paste residues (corresponds to section D.3 of MoEU's Communication 28142).

In the textile finishing subsector it is proposed to use advanced oxidation with a “Fenton” type reaction as a viable pre-treatment technique (depending on the type of effluent, the elimination of the Chemical Oxygen Demand (COD) can reach 70% to 85%, and the residual COD, which is largely biodegradable due to the change of the compound is suitable for biological treatment). In any case, it is advisable to maintain more “aggressive” kinds of waste, such as residual printing paste and padding bath liquors, outside the wastewater flow and use other ways of disposal (waste operators authorized for the disposal of such waste).

However, if concentrated water streams containing non-biodegradable compounds cannot be treated separately, additional physical-chemical treatments would be required to achieve equivalent overall performance. The wastewater treatment techniques most used in the Textile Sector are the following ones:

- Tertiary treatments following the biological treatment process, such as adsorption on activated carbon with recycling of the activated carbon to the activated sludge system and destruction of the adsorbed non-biodegradable compounds by incineration or radical treatment of the excess sludge (biomass and spent activated carbon).
- Combined biological physical and chemical treatments with the addition of powdered activated carbon and iron salt to the activated sludge system with reactivation of the excess sludge by “wet oxidation” or “wet peroxidation” (if hydrogen peroxide is used).
- Ozonation of recalcitrant compounds prior to the activated sludge system.
- Ozonation and UV treatment to remove the color and eliminate bacteria from the effluent.

It has been demonstrated that the sludge generated by scouring of wool has excellent technicalproperties when mixed with clay to make bricks. The economic details will primarily depend on the agreement reached between the scouring company and the bricks' manufacturer. According to the information received, this technique would be cheaper than landfilling, composting and incineration.

In addition, the criteria established in the current national applicable legislation on the control of colour-related parameters has to be taken into account.

To help the operators and the Competent Authorities in the assessment of the BATs which could be used to improve the environmental performance, the following table summarizesthe main specific technologies to the sector and the environmental improvement obtained by using them. A higher score means a bigger improvement in the corresponding topic (waste generation, waste water discharges, etc). A score of 5 means there is no positive or negative impact associated. A second table explains afterwards what does each score mean in quantitative terms.

TECHNOLOGY APPLIED	ENVIRONMENTALIMPROVEMENT					
	WASTE	WATER	AIR EMISSIONS	CONSUMPTION energy	CONSUMPTION raw materials	NOISE
SPINNING AND WEAVING						
Replacement of conventional lubricants for machines by water soluble oils	5	7	5	7	5	5
Replacement of mineral oils (who have low biodegradability) in the processes of preparation of synthetic fibre by fatty acid esters	6	7	5	5	5	5
Replacement of mineral oils for the spinning of the wool by products based on glycol	5	7	6	5	5	5
Reducing use of chemical products in the knitting factory	5	7	5	6	7	5
Synthetic paraffin in the formula for Warp	5	7	6	6	6	5
PRETREATMENT						
Recovery of slashing agents	6	8	6	6-7	7	5
Oxidative route for the disposal of slashing agents	5	7	6	6	5	5
Enzymatic Scouring	5	9	7	8	7	5
Unslashing, Scouring and laundering of cotton in a single stage	5	9	7	7	6	5
Demineralization and unslashing of cotton using a Pad-Batch system	5	8	6	6	5	5
Alkali recovery from mercerization	5	8	5	5	6	5
Pretreatment of cotton with cationizing agents	5	7	5	5	6	5
Replacement of compounds with Cl in the bleaching	5	7	6	5	5	5
Minimization of complexing agents in the bleaching	5	7	5	5	5	5
Washing of wool: grease recovery loops	4	8	6	5	5	5
Washing of elastic knit fabrics before the thermofixation	5	8	8	5	5	5
DYEING						
Minimization of the loss of the dye bath in the padding	6	8	5	6	7	5

process						
Optimization of the Jetdye	5	8	7	6	7	5
Optimization of the dye in Jet Overflow	5	7	7	7	6	5
Optimization of the dyeing bath	5	7	6	6	6	5
Econtrol process: Dyeing of cellulosic fabrics with reactive dyes	5	8	6	7	5	5
New reducing baths for dyeing polyester disperseddyes	5	7	5	5	5	5
Subsequent treatment with enzymes in dyeing with reactive dyes	5	6	6	6	6	5
Use of new sulphurous dyes	7	8	7	6	5	5
Selection of new ranges of reactive dyes	5	7	5	7	7	5
Dyeing by exhaustion with reactive dyes on cellulose fibres	5	8	5	5	5	5
Replacement of dyes using chromium and chroming, by reactive dyes	5	8	5	6	5	5
Dyeing of wool with Premetallized dyes	5	8	5	5	6	5
Dyeing of polyester and blends with alternative Carriers or without Carriers	5	8	6	5	5	5
Washing and dyeing knit fabrics of polyester in a single bath	5	9	7	8	5	5
Biodegradable dispersants	5	8	5	5	5	5
New oxidizing system fordyeing with sulphurous dyes	7	8	7	6	5	5
Use of supercritical carbon dioxide	5	7	7	6	6	5
Use of liposomes as auxiliaries in wool dyeing	6	8	6	7	6	5
PRINTING						
Pigment printing pastes with optimised environmental performance	5	9	7	7	7	5
Recycling of residual printing pastes	7	6	5-6	5	8	5
Volume minimisation of printing paste supply systems in rotary screen printing machines	5	9	5	5	7	5
Reactive two-step printing	5	7	5	5	7	5
Urea substitution and/or reduction in reactive printing	5	6	4	6	5	5
Ink-jet digital printing for flat fabric	7	9	7	6	7	7
FINISHING AND SINIZING						
Easy-care finishing exempt of or with low content of formaldehyde	5	9	9	5	5	5
Catalysis by enzymes	5	7	6	6	6	5
Systems for minimum application of finishing	5	7	7	7	5	5
Minimization of the softening agents in Batch processes	5	7	6	6	6	5
Minimization of emissions of products with insecticides	5	7	4	4	5	5
ELIMINATION OR SUBSTITUTION OF CHEMICALS						
Substitution of the complexing agents composed of nitrogen and/or phosphorus	6	8	5	4	4	5
Selection of anti-foaming	5	7	6	5	5	5

agents environmentally friendly						
Replacement of surfactants by biodegradable surfactants	5	7	5	5	5	5
Plasma technology	6	7	6	6	6	5

Table 4.4. Main specific technologies to the sector and the environmental improvement.

Value of 0 - 4: environmental disadvantages
Value of 5: No positive or negative impact
Value of 6-9: environmental improvements

To have a more precise idea of the meaning of the scores shown in the table above, the table below shows the improvement in the environmental performance linked to each score in quantitative terms:

	VALUE ASSOCIATED TO THE IMPACT ON ENVIRONMENTAL PERFORMANCE					
	4	**5**	**6**	**7**	**8**	**9**
WASTE	**no reduction**	**noinfluence in environmental performance**	20 % reduction	30% reduction	40% reduction	> 50% reduction
WATER	**not biodegradable**		reduction 10 - 20%	reduction 30 - 40%	reduction 50 - 60%	reduction > 60%
AIR EMISSIONS	**high pollution**		20 % reduction	30% reduction	40% reduction	> 50% reduction
ENERGY CONSUMPTION	**high consumption**		reduction 10 - 20%	reduction 30 - 40%	reduction 50 - 60%	reduction > 60%
CONSUMPTION OF RAW MATERIALS	**high consumption**		20 % reduction	30% reduction	40% reduction	> 50% reduction
NOISE	**high noise**		reduction 10 - 20 dBA	reduction 30 - 40 dBA	reduction 50 - 60 dBA	reduction > 70 dBA

Table 4.5. the improvement in the environmental performance linked to each score in quantitative terms.

5 MEASUREMENT AND CONTROL OF EMISSIONS

This chapter tries to answer the most difficult task in the whole process of granting an integrated permit: setting certain conditions applicable to an installation. As in the textile area many installations can differ as well as the surrounding environment may also differ, it is impossible to present all circumstances. Therefore the chapter is rather a signpost than a prescription and it must be remembered that common sense + professional knowledge have to be taken into account for each specific case.

5.1 Operating Conditions.

Installations do not always work in normal and ideal conditions. While setting conditions for a permit, this fact must be taken into consideration. Generally speaking the following operating conditions may take place:

- start-up of an installations or a part of it,
- normal working conditions,
- not normal working conditions: they may happen as a result of unexpected circumstances and incidents,
- closure of an installation or a part of it.

Another circumstance is an industrial accident which should be also considered while setting conditions for a permit.[5]

It is clear that for the textile industry in general there is no typical start-up phase similar to, for example, combustion plants where before the proper combustion process is on the line, higher emissions of pollutants take place. In the textile industry it is hard to think of similar situations (though if an installation includes a boiler a start-up may happen), but some other connected installations, such as wastewater treatment plant may need a start-up once they are built and before they reach a normal working conditions. All such circumstances should be described in the permit and specific emission limit values should be given for the start-up phase if it is possible to set them.Regarding the start-up period there is no specific EU regulation for the textile industry, nor there is for the closure of textile installations. This means that national law should be taken into account while dealing with these issues. But a general remark on conditions other than normal isstated in the IEDas well as in the Turkish draft of the By-law on Integrated Environmental Permits: a permit must include considerations about what to do in such cases.

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[5] This is a requirement of the IED – as most textile installations do not fall under the SEVESO Directive (control of major-accident hazards involving dangerous substances), their permits should contain a reference to major accidents – prevention methods as well as activities foreseen once they happen.

Permit prescriptions for not normal working conditions

On the first place, it must be emphasized that in a permit a sentence like “No such conditions are foreseen.” should not be an option, because such conditions almost always occur in practice. If no prescriptions are established, it will lead later to problems. For example, if there isa situation where due to a breakdown of an installation an operator has an excessive amount of waste that stores in a place other than stated in a permit. From a formal point of view he/she may be fined for an infringement of the permit, because situation should not happen as no one described it neither in the application nor in the permit. If this had beenpredicted, it could have been stated in the permit as follows: “A storage place for waste produced during not normal conditions is building X.”

It should be kept in mind that defining prescriptions in a permit for conditions other than normal does not consist just in establishing special emission levels for those situations. In most cases they will be rather descriptive conditions such as the sentence above.

Of course, it is impossible to think of all hypothetical situations that may happen to an installation. A good advice for operators as well as for competent authorities is to think about the consequences of malfunction of the different parts of the installation, such as:

what will happen if the wastewater treatment plant breaks down?,

what will happen if a chemical leakage to the soil appears?, or

what will happen if a wastewater flow meter breaks down?

Example:

In the following lines a few sentences which can be useful to be written in a permit for a textile factory in are presented:

“In case of a start-up, stop or an incident of equipment necessary for a proper wastewater management it is required:

- Control every measuring and technical devices of the wastewater treatment plant for their proper work and once a week check sedimenting tanks and other equipment for wastewater treatment. In case of damage immediately start all activities necessary for removing it.
- In case of damage to a wastewater flow meter, immediately proceed to a repair. In the meantime amount of wastewater should be calculated based on the use of water.
- In case of uncontrolled release of substances in the production area, it is required to prevent their access to the sewage system and inform of the situation a specialist for environmental protection and a technical director.”

Regarding closure prescriptions for an installation, in the case of the textile industry it is not problematic. In general no special conditions such as in other cases , e.g. landfills (where a site remediation, monitoring, proper shaping etc.) must be stated in a permit.

5.2 Surface waters and sewage systems

Two cases may be distinguished: i) wastewater is discharged to an external sewage system or to a wastewater treatment plant not belonging to the installation, ii) wastewater is discharged directly to a surface water body.

In the first case the prescriptions in the permit will be in general more easy to be fulfilled by the operator: emission limit values may be easily achievable and the operator will not have to invest a lot in wastewater treatment. Also possible exceedance of normal pollutant discharge levels in not normal working conditions have in practice small or no negative impact on the environment provided that the wastewater treatment plant where the discharge goes has enough treatment capacity.

In situations where pollutants are discharged directly to surface waters, it is a totally different case – treatment must take place before discharge.

As for groundwater it is legally forbidden in many EU countries to discharge wastewater to it.This is because the wastewater from the textile sector often contains hazardous substances and discharging them to groundwater would be not in line with the Directive 2006/118/WE (the Groundwater Directive).

5.2.1 Selection of parameters and pollutants

- **pollutants to which ELVs must be assigned**

When discussing about pollutants that must be stated in an integrated permit, the following assumptions have to be kept in mind:

a. The wastewater composition depends on the chemicals and materials used in the textile processes as well as on the kind of wastewater treatment – therefore selection of pollutants for a permit is the most difficult issue for a competent authority and requires some expert knowledge,as for example people from the textile association,to discuss with them a specific technology, applied chemicals and based on that define substances that may appear in the wastewater.

b. In the current By-law on wastewater different emission standards of water pollutants are possible depending on the processes used in the textile industry – currently **these is the minimum set of pollutants to which ELVs must be assigned;**

c. The values stated in that By-law are not always emission limit values according to BAT, but this is sometimes not easy to check, because the BREFfor the textiles industry in fact does not provide any emission limit values for wastewater discharges (it provides BATs, but no emission levels associated to them).Thus, if emission levels are in line with the law, it is hard to say that an installation is not in line with BAT in terms of wastewater treatment.

d. **There is not a unique list of pollutants to which ELVs must be assigned**. In the table below a list of the most common pollutants to be found in wastewater from the textile industry is presented but this should not be regarded as a closed list. Always bear in mind that different specific chemicals are used for elaborating different end-products and that this list is open. On the other hand, if in a factory there is no usage of chemicals containing some of the heavy metals listed here, there is no point in stating them in the permit.

e. Definition of emission value levels: they should be calculated based on national law but according to the EU rules they can be stricter if circumstances require it, for example if the environmental status of the natural recipient is bad (it is very polluted or it is a small river which can bear only small pollutant loads). A golden rule is that emissions cannot cause infringements of environmental quality standards.

f. If wastewater is discharged to a public sewage system, there is more flexibility as even high levels of pollutants may be acceptable as input for a wastewater treatment plant. For some wastewater parameters stated in the permit the emission value levels can depend on the capacity of the concrete wastewater treatment plant to which the discharge will go. In such cases the applicant for a permit should provide the competent authority with an agreement between him and the operator of the wastewater treatment plant where the values should be defined.

Parameter in wastewater	Remarks
Colour	All cases
BOD_5	All cases
COD	All cases
Total solids	All cases
pH	All cases
Temperature	All cases
Conductivity	All cases
Total organic carbon (TOC)	All cases
Cl	All cases
Total N and NH_4	All cases
Total P	All cases
Detergents	All cases
SO_4^{2-}/S^{2-}	If dyes containing sulphur are used
As, Cd, Hg, Cr, Cu, Ni, Pb, Zn, Sb	Only if present in the chemicals used in the processes
Hydrocarbons/Mineral oils	Mainly where cotton is used (mineral oils are used in the cotton preparation)
Biocides	Can be required for wool scouring

Table 5.1. Parameter in wastewater

There are no ranges of pollutants' levels in the table as there are no emission limit values set for them for the textile industry in the EU. Bear in mind that ranges in the Chapter 3 of the Textile BREF are only for informative purposes.

- **other pollutants to be reported to European Pollutant Release and Transfer Register (E-PRTR)**

It must be underlined that textile installations that fall under the scope of the applicable legislation on Integrated Environmental Permits fall also under the EU Regulation 166/2006 of 18 January 2006 concerning the establishment of a European Pollutant Release and Transfer Register and amending Council Directives 91/689/EC and 96/61/EC.[6] However an operator of an installation has to report only:

(a) releases to air, water and land of any pollutant specified in Annex II (of the Regulation 166/2006) for which the applicable threshold value specified in Annex II (of the Regulation 166/2006) is exceeded. See Annex IV of this guide for more details;

(b) off-site transfers of hazardous waste exceeding 2 tonnes per year or of non hazardous waste exceeding 2000 tonnes per year, for any operations of recovery or disposal with the exception of the disposal operations of land treatment and deep injection referred to in Article 6 of the Regulation, indicating with "R" or "D" respectively whether the waste is destined for recovery or disposal and, for transboundary movements of hazardous waste, the name and address of the recoverer or the disposer of the waste and the actual recovery or disposal site;

(c) off-site transfers of any pollutant specified in Annex II (of the Regulation) in waste water destined for waste-water treatment for which the threshold value specified in Annex II (of the Regulation), column 1b is exceeded.

For comfort of the users of this guide in Annex III can be found the Annex II of the Regulation 166/2006.

IMPORTANT NOTE

The following rules should be remembered:

a. The fact that in a permit there is no mention to a certain substance does not mean that there is no obligation of reporting it to PRTR, however to avoid confusion it is recommendable to cover all PRTR substances that may be released by an installation at least in the application form – it will help assessing the obligation later on. For instance, if in a permit the competent authority puts only limit values according to the current By-law on water pollution, such as chemical oxygen demand (COD), sulphure (S^-) phenol, zinc (Zn), fish bioexperiment (ZSF), pH, it does not mean that chlorides are not released. If chlorides are released, the operator should report it as well.
b. The PRTR regulation is not connected with the fact of granting a permit with a specific limit value or not – it is for informative purposes. There is no need to put all PRTR substances into the permit.

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[6] Currently the PRTR regulation is not binding for Turkey but it will be once Turkey joins the EU, and probably before, as steps are being taken by the Ministry of Environment and Urbanism to transpose it into national legislation.

c. There is an obligation to report to PRTR only if in a year a threshold value is exceeded – consider the following examples:
    - in 2011 a textile finishing factory released to water 102 kg of Zinc –even if this is the only substance from the Annex II that was above its threshold level (100 kg), it must be reported.
    - in 2012 the same factory released to water 98 kg of Zinc and did not release any other substances from Annex II above their threshold levels, then it does not to have to report.

d. d) Amounts of substances reported can be measured, calculated or estimated – in practice reporting based on measuring emissions in a physical sense can be advisable only for installation that have continuous monitoring systems (incinerators, big power plants) – for textile installations it is much better to calculate releases or to estimate them –measurement results should be regarded as an auxiliary method.

5.2.2 Monitoring of emissions to water and measurement techniques

When speaking about monitoring of emissions to water there are two situations, as mentioned before:

- direct emissions to natural reservoirs (rivers, lakes),
- emissions to a common sewage system (public or private).

They both need monitoring although the second case is usually less strict, however it depends not only on the conditions of the permit but also on the requirements of the owner of the sewage system. Here the approach that should be used for granting permits will be presented.

1. Monitoring oflevels of pollutants in wastewater.

This is a typical measurement-based monitoring that has one aim: to check whether the conditions of a permit are fulfilled. If there are binding regulations/laws stating prescriptions on monitoring, its scope and frequency as well as standards for sampling and analytical methods, only a reference to them can be stated in a permit. There is no need to write again the same rules that are already in the law. [7] Regarding who should be responsible for monitoring, it must be emphasized that it is responsibility of both the operator and the competent/inspection authority. This means that an operator has to have self-monitoring or to hire an external, certified company that takes samples and analyzes it. On the other hand, the inspection authority should control and monitor permit conditions in two ways:

- checking monitoring reports sent by the operator,
- carrying out inspections to installations and taking samples on their own.

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[7] Nevertheless it may be an option, it is a matter of choice by the competent authority.

Some considerations on monitoring are the following ones:

- There may be several cases where additional monitoring is needed: i) if a recipient of wastewater is vulnerable to degradation (it has a small capacity for self-treatment of sewage), ii) if an installation is located close to protected areas, iii) during incidents. All of these cases should be taken into account in the application and in the process of granting the permit. If additional monitoring is needed, usually it means that the operator does not only monitor pollutants in wastewater but also the quality of the recipient environment of the wastewater.
- If wastewater is released to a sewage system, during normal working conditions of the installation it is sufficient to take samples twice a year – however an owner of a sewage system may impose on an operator stricter conditions for monitoring but this is beyond the scope of a permit (it is usually in a contract signed by an operator and the owner of the sewage system).
- Choice of analytical method: it is advisable to use methods based on international standards (ISO). Examples for some substances are: i)COD – ISO 15705, ii) Chlorine – ISO 10304-2, iii) Zinc – ISO 8288

These are international standards commonly used in the EU countries. For the parameters for which no international standard exists, methods based on national standards must be used.

- Apart from monitoring parameters in wastewater, it is important to measure water usage and amount and flow of wastewater – this will be important to assess total yearly releases of the pollutants. The more accurate the monitoring the better for the operator – to know precisely how much water is used for a specific process. It is recommended to measure separately water used for production and technological sewage, as water used for people’s consumption can be easily calculated. In case of releases to sewage systems a good estimate of the amount of sewage realeased is to regard as equal to the water consumed (although it is not exact due to losses from evaporation and other losses).

2. Monitoring based on calculation methods and estimations.

This is another part of monitoring that has a slightly different aim than the previous one. While by measuring emissions the goal is to check if an installation is in line with permit conditions, taking enforcement procedures if it is not the case, by using calculations and estimations the goal is to check:

- Whether in the production processes and auxiliary processes BAT are used,
- What are the emission levels in relation to other installations (benchmarking), especially if indicators based on production units are used.

Another important issue is that useful information is obtained if there is a need to report to PRTR.

In the table below some indicators are shown that can be used in this kind of monitoring. Note this is not a closed list and, depending on circumstances additional indicators may be added.

Parameter	Unit
Water used for dyeing	l/kg of product
Water used for rinsing	l/kg of product
COD/BOD/other parameters	g/kg of product
Annual consumption of water	l/year
Percentage of water used from own well	%
Percentage of water recycled from sewage	%

Table 5.2. Indicators which can be used for the monitoring of the emission

Mass balance is commonly used for this kind of monitoring. According to the BREF on the General Principles of Monitoring (2003 - currently under revision), when applying the mass balance to an individual substance (substance 'i'), the equation may be written as:

Input of substance 'i' = Amount of substance 'i' in product +

amount of substance 'i' in waste +

amount of substance 'i' transformed/consumed in process -

amount of substance 'i' generated in process +

accumulation of substance 'i' +

emissions of substance 'i'

5.3 Soil and groundwater.

In normal working conditions for textile industry soil and groundwater pollution should not be an issue. Therefore there is no need to put standards or monitoring requirements in the application and in a permit, as they are stated in the draft By-Law on Integrated Environmental Permits.[8]. However if any industrial incident happens (e.g. uncontrolled spillage of chemicals to soil), monitoring may be imposed by the competent authority. Nevertheless it is difficult to address such potential incidents in the permit as it is hard to foresee what may happen and what parameters released to soil or/and groundwater should be monitored in such cases

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[8] According to the draft By-law on Integrated Environmental Permit periodic monitoring shall be carried out at least once every 5 years for ground water and 10 years for soil, unless such monitoring is based on a systematic appraisal of the risk of contamination.

5.4 Air emissions

As processes used in textile industry are very complex there may appear some emissions that an operator or a competent authority is not aware of, making the assessment of air emissions a challenging task for both. This does not entail automatically a problem as such emissions may be insignificant in comparison with other emissions.[9]

Sources and substances that may be emitted to air are described in Chapter 3 of this guide. In the following some practical considerations for monitoring and the range of substances that should be controlled by granting a permit are presented.

5.4.1 Selection of pollutants and emission levels.

Inclusion of auxiliary emissions in the permit

By auxiliary emissions are understood emissions from processes that are not directly technological ones but are essential for production. In the case of textile industry, a good example are emissions from boilers producing technological steam, emissions from heat setting, drying etc. Generally speaking permits should cover them as they are within the scope of the definition of installation appearing in the By-Law on Integrated Environmental Permits:

“a stationary technical unit or units within which one or more activities listed in Annex I are carried out, and any other directly associated activities on the same site which have a technical connection with the activities listed in this Annex and which could have an effect on emissions and pollution”.

On the other hand, if in a textile IPPC factory there is also a boiler for producing heat for rooms where workers stay, it is in principle not under the scope of the integrated environmental permit. It will be up to the Competent Authority to establish in each case whether such aspect should be included.

Emission levels

Criteria that should be considered for defining levels of emissions:

- Existing emissions standards for pollutants in applicable legislation: If there are such standards, emission levels must be not higher them. In terms of textile installations, this will be the case for example for VOCs from printing processes.[10]
- Will proposed levels of emissions break environmental quality standards (immission levels)? To answer this question a modelling of dispersion of pollutants in the

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[9] Example:the moment when dyeing machines are reloaded - for a short time emissions of steam and dyes appear that are insignificant in comparison with, for example, emissions from a boiler fueled with gas/oil that produces technological steam.

[10] Note that ifan operator wants to include in an application a power plant that is located in the site of the textile installation emission standards will apply to it too.

atmosphere must be done. If environmental quality standards are expected not to be respected, the permit should not be issued. Another possibility is to use some abatement techniques to decrease emission levels and once they are in place, apply again for a permit.

- If the emission levels proposed by the operator are in line with (not higher than) environmental emissions standards, they can be stated in the permit.
- For those pollutants for which there are neither emission standards nor environmental quality standards there are no legal basis to include them in the permit. Usually their emission levels are relatively insignificant. However this may lead to further problems if, for example, a pollutant causes odour nuisances for people living close to an installation (e.g. acetic acid used sometimes in finishing processes).

Typical pollutants

In the table below typical pollutants from the textile industry are presented. Bear in mind that the list is not closed and there is always a possibility that some new substance may appear.

Pollutant	Remarks
CO, CO2, SO2, NOx, dust	All installations burning fossil fuels: boilers, installations for singeing and heat setting, drying
VOCs	Dyeing, printing, coating, laminating, dry cleaning – as they can be manifold it is recommended to use an indicator as total carbon
Formaldehyde	Technological processes: singeing, heat setting, printing
Ammonia	Laminating
Chlor	May be released from bleaching

Table 5.3. Typical pollutants.

5.4.2. Modelling of pollutants into the atmosphere.

The aim of modeling is to check whether proposed levels of emissions will not break environmental quality standards. This work should be a part of the application for a permit and should be done by the operator (often in practice by external consultants hired for this task). There are many dispersion models, most of them based on the Complete Equation For Gaussian Dispersion Modeling. There are many dispersion models such as:

- CALPUFF,
- RIMPUFF,
- AERMOD,

and many others.

Describing them is beyond the scope of this guide so we provide some general remarks that should be considered mainly by the competent authorities while assessing applications:

a. It would be advisable if one kind of dispersion model used all over Turkey could be applied – this would lead to a unified approach. In most EU countries dispersion models are obligatory stated in their regulations;
b. Be critical when assessing indicators of emissions – many consultants tend to lower them so as to present a good picture in the application for a permit; in case of doubt do not hesitate to ask the operator for a justification of this part of the application or to ask for an external expert's/consultant's opinion (for example from the Association of the Textile Industry).It must be remembered that most indicators are based on calculation: for example if we would like to know what amount of pollutants are emitted from printing, we would have to find an indicator based on the amount of printing pasta used and the content of VOCs in it. By multiplying the amount of printing pasta usedin one printing machine and the amount of VOCs contained in itwe obtain an indicator of emission that will be later used for a dispersion model.
c. it is recommendable to have in the office of the Competent Authority a software for dispersion calculation – from time to time it might be used to check the work presented by the operators .

5.4.2 Monitoring of air emissions.

When emission standards apply to an installation, a continuous or periodical monitoring is required. Those requirements (frequencies, methods, statistical approach to results) are included in the By-Law on Integrated Environmental Permits so no description of them will be repeated here. However, for some pollutants there may be no legal obligation to carry out measurement of air emissions. This means that monitoring obligations for them must be decided in each permit by the competent authority (of course the operator should propose a scope of monitoring in its application), fullfilling at least the minimum requirements established in applicable legislation.

Monitoring of air emissions does not always mean a physical measurement – in fact, in most cases it is not necessary as most of the environmental impact from the textile sector comes from wastewater discharges. Nevertheless a recommendation for the competent authorities is to require operators to install emitters measuring nozzles to enable the connection of measurement equipment for taking samples of air with emitted pollutants. This should be applicable especially for cases where complaints from settlements close to the installations are expected. With this nozzles an inspection authority can easily check if the limits stated within a given permit are not broken.

As for monitoring based on calculation/estimation, the same principles apply as in the case of monitoring of emissions to water (subsection 5.2.2). The same principles also apply when speaking about PRTR reporting (see end of subsection 5.2.1).

Some additional considerations:

In case of air emissions, apart from monitoring (directly or indirectly) levels of pollutants released to the atmosphere, monitoring of auxiliary parameters might be useful and necessary. For example, moisture or maximum ash content of biomass used as fuel can be difficult to measure, but the measurement may be avoided if there is a certificate issued by providers/producers of the biomass stating the values of those parameters.Such certificates should be in the possession of the operator who may be asked by an Inspection Authority to present them.

5.5 Odour control

At the EU level there is no odour regulation. Therefore each Member Country must apply their own ones. There are no emission limit values for substances causing odour nuisances at EU level, therefore in the permit just some general remarks in addition to the requirements derived from the national By-Law 27692 on the Control of Emissions Causing Odours should be included.

Typical substances causing odour problems are listed in the table below. This is a table from the Chapter 3 of the Textile BREF.

Substance	Possible source
Epsilon-caprolactame	Heat-setting of polyamide **6** and polyamide **6** blends; Paste and powder coating with PA **6** and PA **6**-copolymers
Paraffins, fatty alcohols, fatty acids, fatty acid esters (less odour-intensive substances, but high concentrations)	Heat-setting of grey textiles and inefficiently prewashed textiles
Hydrocarbons	Printing, wetting agents, machine
Aromatic compounds	Carriers
Acetic acid, formic acid	Various processes
Hydrogen sulphide, mercaptans	Sulphur dyeing
Sulphur derivatives	Reducing agents, hot acid cracking in wool scouring mills
Ammonia	Printing (ex urea), coating, non-woven
Acrylates	Printing (ex thickening agents), coating, non-woven processing
Formaldehyde	Easy-care finishing, finishing of non-wovens, permanent flame retardants
Terpene (d limonene)	Solvents, machine cleaners
Styrene	SBR polymerisation, styrene addition to SBR compounds
4-Vinylcyclohexene (4-VCH)	SBR- polymerisation (4-VCH is a dimer of butadiene that is formed during SBR-polymerisation)
Butadiene	Monomere in SBR-polymerisation
4-phenylcyclohexene (4-PCH)	SBR- polymerisation (4-PCH is formed by reaction between styrene and butadiene)
Aldehydes	Singeing
Acroleine	Decomposition of glycerol
Phosphoric acid esters (esp.	Wetting agents, de-aeration agents
Phthalates	Levelling and dispersing agents
Amines (low molecular)	Various processes

Alcohols (octanol, butanol)	Wetting agents, antifoaming agents
Source: [179, UBA, 2001]	

Table 5.3. Typical substances causing odour problems.

By using certain BATs (like for example wet scrubbers or some general mamagement practices like closing tanks with chemicals) odour nuisances can be partially eliminated. A technique called olfactometry is used for measuring odours levels. Other methods may include measuring a concrete substance causing odour problems (e.g. H_2S) but bear in mind that it is often possible that although people smell some substance it is not always in such a concentration that it can be measured by a special equipment. So in practice, the only good way to control odour emissions is to apply BATs because once an installation applies them, it should not cause significant odour problems.

According to the current By-law on odours which came into force in 2012 odours are not part of the permitting system. It focuses on preventive actions, and on how to measure the odour.

5.6 Noise control and monitoring

There are no binding rules for noise monitoring and control neither in the IED nor in the Environmental Noise Directive. In the second one there is a rule stating that local noise issues should be addressed by requiring competent authorities to draw up action plans to reduce noise where necessary and maintain environmental noise quality where it is good. The Directive does not set any limit value, nor does it prescribe the measures to be used in the action plans, which remain at the discretion of the competent authorities.

Therefore the application for the permit and the permit itself will include the information and obligations derived from the fulfillment of the By-Law 26809 on the Assessment and Management of Environmental Noise, for those installations which fall under the scope of that By-Law.

As for methods of noise measurement and monitoring the standards stated in the Annex II of the mentioned By-Law 26809 should be applied, like the following:

- TS ISO 8297: "Acoustics - Determination of sound power levels of multisource industrial plants for evaluation of sound pressure levels in the environment - Engineering method",
- TS EN ISO 3744: "Acoustics - Determination of sound power levels of noise using sound pressure - Engineering method in an essentially free field over a reflecting plane",
- TS EN ISO 3746: 1995 "Acoustics - Determination of sound power levels of noise sources using an enveloping measurement surface over a reflecting plane".

5.7 Ensuring compliance with current and future environmental quality standards

As for current environmental quality standards, it is obvious that, in general, a permit cannot be issued if the exploitation of an installation leads to infringement of environmental quality standards. This means that if for example a working installation causes excessive noise levels in its surroundings, no integrated permit can be issued to it until noise levels are respected.

As for the future environmental quality standards it is important for both competent authorities and operators to check regularly the progress on preparing new legislation. To check developments in the European Union's legislation a useful website is http://ec.europa.eu/environment/index_en.htm

At this website general policies and information on current and coming legislation can be found.

5.8 Plan of environmental monitoring and control

A plan of environmental monitoring and control should be included in each integrated permit. If there are legal requirements for monitoring (such as in case of VOCs emission) it is not necessary to repeat them in a permit – it is sufficient to give a reference to the applicable legislation. For pollutants which have no monitoring requirements stated in national legislation a monitoring plan should be defined.

The most important issue is the monitoring frequency and whether the competent authority will require taking samples and performing measuring of emission levels or using calculation and estimation methods. **For the cases when it is not stated in national legislation**, it should be based on the following criteria:

1. Significance of emissions and emissions impact: if emission levels from technological processes are insignificant in comparison with other emissions such as, for example, emissions from dryers, there is no need to require sample taking methods for them – calculating emissions should be sufficient.
2. Location of an installation – if it located in an industrial zone, the frequency and scope of monitoring might be less strict than for installations located close to living areas.
3. Complaints from society – if there are complaints, it may be necessary to increase monitoring so as to have a solid evidence on whether an installation breaks/does not break the permit's conditions.
4. Recipient of wastewater – if wastewater is discharged to a sewage system and the capacity of a common wastewater treatment plant is large, there is no need to take samples of wastewater more than twice a year. If a recipient has some problems with high concentration of some pollutants, more frequent monitoring may be imposed.
5. Previous accidents and incidents – if there was a leakage to soil, it might be necessary to monitor the state of the soil for some time (usually until the moment where there is no trace of pollution in it)
6. In case of noise monitoring – only if close to an installation there are located protected areas.

Non-routine inspections should also be carried-out in case there are complaints, accidents, incidents and occurrences of non-compliances.

5.8.1 Assessment of compliance with ELVs.

For the case of the textile industry there are usually no problems with the assessment of compliance with ELVs: the only work is to look at the results of monitoring (such as reports of samples analyses, reports of noise measurements, certificates of substances used in the processes, annual or periodical reports from the operator) to say whether they are in line with the ELVs or not. Modelling and calculating, for example, noise emissions is neither a task for the operator nor for the environmental inspector but for laboratory staff. They should prepare a report with the results so the only job for the operator or the inspector should be to check if the values are surpassed or not. It is much more complicated if the factory has its own big power plant to which emission standards apply – then the whole assessment must be based on continuous monitoring and statistical analysis,about which information can be found in the BAT sector guide for Coal Large Combustion Plants.

5.8.2 Sampling and inspection frequencies.

In practice it is necessary to carry out an inspection to a given IPPC installation at least every two years. It must be kept in mind that this period is for not problematic installations working in normal conditions. It may be necessary to inspect some installations even several times per year if they are the problematic ones. By problematic are meant the installations that systematically break their permits' conditions, have problems with compliance with ELVs or those for whom there are a lot of complaints.

Another important issue is whether the competent authority should take samples or measure emissions each time they are on inspection. There is no such need as all sampling and analysis are usually expensive and if installations have their own analysis and reports done by certified laboratories this is really unnecessary. However from time to time or in case of complaints (also if there was noncompliance with ELVs revealed during previous inspections) it is recommendable that inspection authorities take samples and perform analysis by themselves.

5.8.3 Reporting frequency to the Competent Authority and reporting systems to the Competent Authority.

It is common for the operators in EU countries to send reports from monitoring based on sampling and measurements to the competent authority within a month after samples were taken. It enables the latter to acquaint themselves with the results of it and take necessary steps if needed. For example if an operator discharging wastewater to surface waters is obliged to take samples 4 times per year, this means that four reports from him/her should be send to the competent authority. Should an accident or incident happen that may result in negative impact on the environment, authorities must be informed immediately.

As for other methods of monitoring based on calculation/estimation, in most case the operator should provide competent authorities with a yearly report.: According to the "Communication28142 on integrated pollution prevention and control in the textile sector", it is necessary to send to the Competent Authority the Progress Report on Cleaner Production. This is a good solution and can be recommended also for the purpose of this guide as it covers most information that compentent authorities usually require from operators.

It is suggested to cover most of the aspects of the installations' impact on the environment in the report, namely:

- Water, material and energy use,
- Emissions to water and air,

Waste production.It is recommendable to facilitate the process of sending reports through the Internet. This, however, requires the creation of a system and software for competent authorities.

To give some ideas on the content of a report for Competent Authorities within the EU ANNEX IV of the REGULATION (EC) No 1221/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 November 2009 on the voluntary participation by organisations in a Community eco-management and audit scheme (EMAS), repealing Regulation (EC) No 761/2001 and Commission Decisions 2001/681/EC and 2006/193/EC is attached (see Annex III of this guide). Be aware that the Annex IV is just for reference as it applies only for organisations that are EMAS certified. Turkey has not yet transposed this EU Regulation into its national legislation, so for the moment it is not applicable, even though the transposition will have to take place in order for Turkey to become a member of the EU.

For the same purpose the ANNEX III of the Regulation (EC) No 166/2006 of the European Parliament and of the Council of 18 January 2006 concerning the establishment of a European Pollutant Release and Transfer Register (E-PRTR) and amending Council Directives 91/689/EEC and 96/61/EC is attached as well.

Bear in mind the following points:

1. PRTR was created mainly for the purpose of informing society on emission levels from the most significant installations across Europe. It does not say anything on the fact whether emission limit values stated in permits are breached or not. Therefore, regardless of reporting to it, operators are obliged to prepare periodical reports from sampling or yearly reports covering other aspects of monitoring (such as total emission per year).
2. There are no standard patterns for reports and their content across Europe. Therefore each country has its specific regulations. Also, EMAS reporting is only restricted for the companies registered in this system.
3. Some typical content of reports from sampling must be:
   - the date and the place of sampling + GPS data (more common),
   - the time in which sampling took place + conditions of the weather as well as other conditions (e.g. flow of wastewater)
   - themethod of sampling,

- results of sample analysis juxtaposed with emission limit values (this should includethe uncertainty range of themeasurement),
- methods used for the analysis,
- the signature of the persons taking samples and responsible for the result of analysis.

6 EMERGING TECHNIQUES.

6.1 Emerging techniques for the textile sector.

In this chapter techniques under development to solve the environmental problems of activities involving treatment of surfaces with organic solvents are described.

The techniques described below refer to the control of emissions of volatile organic compounds (VOCs) in general, as they constitute one of the main environmental issues derived from the use of organic solvents. In addition to these, emerging techniques also include the new developments in product formulations (paints, dyes, …) and new technologies under development, often parallel to the new formulations, to optimize its application/use.

6.2 Emerging techniques already implemented.

This subsection includes emerging techniques which are already in operation in enterprises and whose effectiveness has been fully tested.

Equipment for the recovery of solvents in fluidised bed

It is used in any place where different kinds of organic solvents are generated. The equipment collects organic solvents with a high purity and efficiency, and in particular the ones which are soluble in water, the chlorinated ones and the CFCs, which are hardly recoverable by conventional systems with fixed bed.

It consists in a multistage adsorption tower and a desorption tower, continuously circulating a bed of activated carbon and thus creating a solvent recovery system. If compared with traditional systems of fixed beds, this equipment ensures a safe and continuous recovery operation, with the following advantages:

- Solvents can be recovered with high purity.
- The cost of maintenance is low.
- A small area for the installation is needed.

Applications are various: printing facilities, painting, cleaning, rubber and plastic, storage of solvents, etc. Nitrogen is used as a desorption gas for the recovery of organic solvents.

ADR system for the recycling of VOCs

The ADR system consists of a VOCs’ adsorber and recycling equipment.

Active carbon is used as adsorption agent, and is mainly used to adsorb the vapors of organic solvents (hydrocarbons) from the waste gases generated in the different plants and facilities. This adsorber can be used for the effluent gas of semiconductors production processes, painting facilities, film manufacturing industries, etc. It does not only work correctly with simple hydrocarbons, but also with halogenated compounds.

Therecovery efficiency depends on the gas concentration, the class of pollutants and temperature of effluent gases. In this case an efficiency of 95% or morecan be reached, specially in cases such as benzene, toluene, xylene and 1,1,1-trichloroethane (99%).

The system requires electricity, a watercooler, cold water, steam and compressed air, but consumption is generally lower than in other techniques. The life of the activated carbon will be longer than 3 years, with a conventional use.

Polymeric adsorbents

It is a technologybased on polymer adsorbents and a microwave desorption process. It has been proven that this technology has a cost which makes it an economically viable alternative with respect to the classic system of granular activatedcoal.

The regenerative steam recovery system has been tested on a wide variety of applications. In its most recent application, this system is being used to remove VOCs generated in the processes of painting sun protection glasses frames.

The polymeric materials can be reactive at low temperatures (less than 177°C), while coal reacts at temperatures exceeding 760°C. The reaction can be accompanied with indirect heating with hot air or nitrogen, or a direct heating with microwaves. The last step is regeneration.

The compounds that can be treated using this technology are:

1. 1,1,1 Trichloroethane	11.-Methyl isobutyl ketone
2. Acetone	12. Methyl tertiary butyl ether
3. Aldehydes	13 Methyl bromide
4. Aliphatic compounds (C4 to C12)	14.-Metilen chloride
5. Benzene	15 Styrene
6. Ethanol	16 Tetrachlorethene
7. Ethyl benzene	17 Toluene
8. Isopropyl	18 Trichloroethane
9. Methanol	19. Vinyl chloride
10. Methyl ethyl ketone	20 Xylene

Recommendations for the Sector

The best ways to solve the problem posed by the emission of volatile organic compounds are common to other sectors. The first possibility and most recommended would be the substitution of raw materials including, in the production process, the adhesives with high content of solids (hot melt), and the water based adhesive. In some cases the quality requirements exceed those offered by these new developments, or the modifications associated with the new alternatives involve heavy investments. Thus, for installations with single solvent raw material, recovery in active carbon as noted in other sectors is an important solution not only of environmental but also financialcharacter (savings of raw materials).

Eco-Smart Rinse

Filter implementation, containing special chemicals, is presented to the market by a brand called Eco-Smart Rinse developed by Rudolf & Duraner Company. This filter application has great contributions both to the environment and enterprises. Usually, after the completion of current reactive dyeing process, a series of washing processes are applied depending on the ratio of dyeing stuff and the construction of the fabric in the process. While some of the washings are done at a very high temperature, overflow rinse which may cause excessive water consumption, is applied at some stages.

Eco-Smart Rinse has been developed by applying special chemicals to the surface of non-woven fabrics. The fabric is passed from the mechanic filter of the dyeing machine and it has the contact with the whole process flotte. The hydrolyzed dyestuff is collected on the fabric, therefore the number of washing cycles is decreased. There is no need for any other additional washing agents while using the technique. Thus the use of chemicals and amount of waste chemicals are reduced. The number of rinsing baths are reduced therefore the technique provides energy and water savings up to 50%. It also provides a decrease in the emission values caused by heating. Moreover, the total time for the whole process will decrease by 40-50%. It will also contribute to the country's economy by providing a capacity increase.

Avitara Group Dyestuffs

Reactive dyeing process using Avitara group dyestuffs has been developed by Hunstman company and been providing various advantages. Usually, during the dyeing process, the washing process is either overflow rinse or hot and washing with soap in the current system. The amount of energy and water consumption is too high during these kinds of washings.

Avitara group dyestuff is able to perform reactive dyeing process at a temperature of 60ºC instead of 80ºC. Lower temperature reduces energy and time consumption. After the dyeing process washing is carried out by a single rinsing bath at a temperature of 60ºC. Therefore, the process does not only provide energy and water savings but also reduces carbon dioxide emission during dyeing and washing processes. On the other hand, there are some disadvantages such as scouring, not to create special colors and not to make any combinations with colors from different color groups.

Replacement of oxidizing chemicals by ozone

The objective of ozonation in the textile sector is the improvement in the quality of textiles treated in its facilities, as well as the reduction of the energy and environmental costs of these facilities, thus increasing profitability and reducing the environmental impact which involves water and energy as well as water pollution caused by their discharges.

To achieve optimum efficiency in the use of ozone, it is essential that the gas is fully dissolved in the water. There are four factors that affect the efficiency of the ozone in this application and that have to do with the ability of dissolution of gas in water: the contact time between both, the pressure of the gas, the mixing method and the temperature of the water.

With appropriate technology, water is taken and mixed with the ozone through a venturi tube in a contact column (reactor). Well treated water passes then to a pressurized tank and keeps recirculating within the reactor until the moment in which the washing system demands water.

It reduces the consumption of hot water: By increasing the concentrations of oxygen in the water used for washing andpromoting the action of detergents, high temperaturesare not necessary to achieve an optimum cleaning. In fact, one can wash with cold watergetting better results than those obtained with hot water withoutozone.

*It reduces the consumption of chemicals:*Because, in addition to increasing its potential as detergent through the oxygenation of water, ozone opens the fibers of fabrics, favouring the penetration in thefabrics of detergents. The disinfectant and oxidizing power of ozone makes theuse of chlorine (bleach)-based bleaching agentsunnecessary.Products used to balance the pH of the waterare not needed either, as the ozone keeps it close to the neutral values.

It reduces the time/number of washes: As detergents are more effective in the presence of ozone, the same cleaning is achieved in a shorter time. It can reduce the time of conventional washing a 33% approximately.

It reduces the time/number of rinses: Due to the use of fewer chemicals in the washing process, there is a smaller deposit of residues in the tissues, so that the number of rinses can be reduced by one or two , reducing also the centrifugation and dryingtime.

Minimizing water consumption: By reducing or even eliminating phases of the washing process, the final amount of water used is much smaller. In fact, the reduction in water consumption is the most notable feature of ozonation.

It eliminates the problem of discharges and waste: Thanks to ozone, at the end of the washing cycle, the residual water is free of any kind of microbiological contamination, with a near neutral pH and very small amounts of chemicals.

It increases the lifetime of the tissues: By reducing the temperature of washing, the amount of chemical used, wash cycles and rinses and the drying times (all of them factors that damage the tissues) the lifetime of the tissues is increased. In fact, when the washing is done with ozone, a great reduction in the accumulation of fibers in the filters of the dryers takes place. The increase in the lifetime of the tissues with ozone is 25-50%.

*It improves the working conditions:*By being able to work without high temperatures and reducing washing and drying times and the consumption of chemicals, the working conditions improve substantially .

Comparison of consumption in processes.

	Traditional	**Ozone**
Washing time	45 minutes	28 minutes
Cold Water	Yes	35% - 40% less

	Traditional	Ozone
Hot Water	Yes	No
Ozonized Water	No	Yes
Alkali	Yes	55% less
Detergent	Yes	50% less
Bleach	Yes	No
Colour protector	Yes	No
Neutralizer (acid)	Yes	No
Softener- bactericidal	Yes	No

Table 6.1. Comparison of consumption in processes.

Comparison of cleaning technologies

	Currently	Ozone (O_3)
1. Soften the fabric to allow the penetration of the same.	Hot Water	Ozone
2. Elimination and decomposition of dirt.	Alkali (pH 13 – 14)	Ozone starts the decomposition of dirt, increasing the pH up to 8.5-9.0
3. Catch dirt.	Softener	Softener
4. Bactericidal and bleaching.	Oxidant	Ozone
5. Neutralize pH (= 7.5).	Acid	Not necessary
6. Offset the reaction of alkali and acid in the tissue.	Fabric softener	Not necessary

Table 6.2. Comparison of cleaning technologies

Other advantages of the system of washing with ozone with direct injection are:

- The whitening degree increases, reaching approximately above 20%.
- The shrinkage is reduced by a 21%.
- Tensile strength is increased over 20%.
- The degree of polymerization after 100 washes is 65% higher.

The Spanish company "Jeanología" is working with this technique and obtaining very good results, especially in blue jeans.

6.3 Emerging techniques under development.

In this subsection are included emerging techniques under development which are in a testing phase on small scale, and who are not yet implemented on an industrial scale, but whose preliminary results are proving to be promising.

Membrane technologies

The key element of this process is the innovative membrane material used to separate organic vapors from the air or other inert gases. The membrane is a composite of three layers rolled into spiral modules. The gas enters with organic vapors that are permeable to the membrane and passes through the spiral into aninner pipe. The air flows through the surface of the membrane and leaves,creating a flow of air. To achieve adequate capacity ensuring the required degree of separation, modules are connected in series or in parallel flow distributors.

Systems with membranes are suitable for treating gaseous streams containing more than 5,000 p.p.m (in volume). The cost increases in proportion to the flow that enters, but is relatively independent of the concentration of organic vapours.

This is a technology which has just been released and is in full expansion in research for new applications. For the time being applications implemented have been in processes that include chemical reactors, cooling, sterilization, sterilization in hospitals, organic vapour recovery.

Use of supercritical fluids as a solvent in the process of dyeing

The use of supercritical fluids as a solvent during the impregnation of active substances or the dyeing process has great economic and ecological advantages. The dyeing with supercritical CO_2 (CO_2-SC) has the following associated advantages:

It avoids the use of water during the process and thereby, it reduces the generation of polluting discharges.

It does not require the use of other chemicals so that the unused coloring or impregnation agents can be recovered for reuse.

This technology is currently under development, being very interesting its application in the textile sector in combination with in the food sector, applying this technology to packaging so that it acquires properties which can increase the lifetime of the food contained in them.

Wet-Laid technology

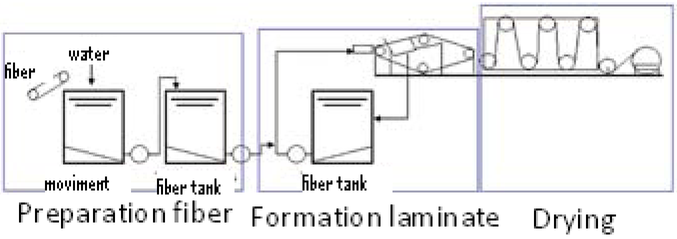
This technology is based on obtaining of non-tissue in a wet environment and its main advantagesare the absence of chemicals and the reuse of water used during the process.

With this technology, the waste obtained in the stages of spinning, weaving and finishing, is used as raw material. The use of this waste minimizes the generation of waste.

In general, the process consists of the following stages:

1. Diffusion of fibers in water.
2. Continuous formation by filtration of the non-tissue on a mesh.
3. Consolidation, drying and organization of non-tissue in batches.

Image: AITEX



Due to the wide variety of textile materials in fiber form that can be used in wet-laid process for manufacturing nonwoven fabrics, these materials may find application in various fields: construction, sound insulation, filtration, composites, cosmetics, medical-healthcare sector, etc.

The following are some of the possible applications of nonwoven fabrics developed by Wet-Laid technology depending on the nature of the material:
Wood pulp: used as a blend with other fibers to reduce costs and improve the structure of the nonwoven.
Hemp>packaged meat, tea bags, vacuum cleaner bags, adhesive plaster for medical care.
Cotton >Absorbent products for medical and personal care.
Aramids >technical panels.
Sisal > Single-use tissues. Products for medical and personal care.
Polyester >medical purposes, adhesive plasters.
Rayon >wipes for medical care, feeding-related filters.
Nylon >interlinings for clothing.

Polyolefins > filters, heat thermofixedfabrics.
Glass >roofs, floors, capacitors and batteries.
PVA >binder fiber or replacement for rayon.
Vinyon >Tea bags and other applications requiring heat-sealing.

AITEX (a Spanish textiles technology institute) has a Wet-Laid pilot plant with a width of approximately 500 mm production and a tilt of 20 °. It can also work at a production rate of 1-10 m / min.

The following table summarizes the emerging techniques described in this Chapter:

EMERGING TECHNIQUES	**New technologies (already implemented)**	**New technologies (under development)**
Equipment for the recovery of solvents in fluidised bed	**X**	
ADR system for the recycling of VOCs	**X**	
Polymeric adsorbents	**X**	
Eco-Smart Rinse	**X**	
Avitara Group Dyestuffs	**X**	
Replacement of oxidizing chemicals by ozone	**X**	
Membrane technologies		**X**
Use of supercritical fluids as a solvent in the process of dyeing		**X**
Wet-Laid technology		**X**

Table 6.2. Emerging techniques.

7 GLOSSARY OF TERMS

Adsorbable Organic Halogens (AOX)	A measure of the adsorbable organically bound halogens in water. The analytical test consists in adsorbing the organic substances contained in the water sample on activated charcoal (halogen-free). The charcoal is then eluted with sodium nitrate solution to completely remove chloride ions (non-organically bound halogen). Afterwards, the charcoal is burned in a stream of oxygen and the resultant hydrogen chloride is quantitatively determined. Only chlorine, bromine and iodine (not the ecologically important fluorine compounds) are determined with this analytical method. Bromine and iodine are calculated as Cl. The analytical values are expressed as AOX in: mg Cl/l of water or mg Cl/g of substance.
Aquatic toxicity	A measure of the effects of a given pollutant on aquatic life. The most common parameters are: IC_{10} = inhibition concentration of bacterial growth (10 % inhibition). Concentrations above the IC_{10} value may strongly affect the efficiency of a biological treatment plant or even completely poison the activated sludge. EC_{50} = lethal concentration (50 % mortality). It is used for fish and represents the water concentration at which a given substance causes the mortality of 50 % of the population. EC_{50} = effect concentration (50 % effect). It is used for particularly sensitive organisms such as daphnia and algae. The level of aquatic toxicity of a given pollutant is defined as follows: highly toxic: <0.1 mg/l very toxic: 0.1-1 mg/l toxic: 1.0 -10 mg/l moderately toxic: 10-100 mg/l non toxic: >100 mg/l.
Biochemical Oxygen Demand (BOD)	A measure of the oxygen consumed by bacteria to biochemically oxidise organic substances present in water to carbon dioxide and water. The higher the organic load, the larger the amount of oxygen consumed. As a result, with high organic concentrations in the effluent, the amount of oxygen in water may be reduced below acceptable levels for aquatic life. BOD tests are carried out at 20 °C in dilute solution and the amount of oxygen consumed is determined after 5, 7 or, less commonly, 30 days. The corresponding parameters are called BOD_5, BOD_7 and BOD_{30}. The analytical values are usually expressed in: mg 0_2/l (effluent) or mg 0_2/g (substance).
Biodegradability	A measure of the ability of an organic substance to be biologically oxidised by bacteria. It is measured by BOD tests (OECD tests 301 A to F) and relates to the biodegradation mechanisms taking place in biological waste water treatment works. It is usually expressed in % (of the substance).
Bioeliminability	A measure of the ability of an organic substance to be removed from the

	effluent as a consequence of all elimination mechanisms thar take place in a biological plant (including biodegradation). It is measured by the bio-elimination test OECD 302 B, which determines the total effect of all elimination mechanisms in a biological treatment plant: - Biodegradation (measured over a long period – up to 28 days – in order to account for he biodegradation of substances that necessitate the development of specially acclimatised bacteria capable of digesting them) - Adsorption on activated sludge - Stripping of volatile substances - Hydrolysis and precipitation processes. It is usually expressed in % (of the substance).
Bleaching agent	The active substance providing the bleaching effect. The bleaching agent is formed/ produced by activating the bleach
Bleach	The formulation used in the bleaching process.
Chemical Oxygen Demand (COD)	A measure of the amount of oxygen required to chemically oxidise organic and inorganic substances in water. COD tests are carried out at ca. 150 °C in the presence of a strong oxidant (usually potassium dichromate). To evaluate the oxygen consumption, the amount of chromium VI reduced to chromium III is determined and the obtained value is converted into oxygen equivalent. The analytical values are usually expressed in: mg 0_2/l (effluent) or mg 0_2/g (substance).
Dye	The formulation (commercial product) containing the dyestuff together with other dyeing auxiliaries
Dyestuff	The colouring agent in the dye formulation: a planar molecule which contains chromophoric group(s) capable of interacting with light.
Finishing	This term can address both the sequence of wet treatments that are carried out to give the fibre the required colour and final properties, and any specific operation to apply functional finishes (easy-care, anti-felting, mothproofing agents, etc.).
Fixation rate	Ratio of the dye fixed on the fibre to the total dye applied.
Fixation efficiency	Ratio of the dye fixed on the fibre to the dye exhausted from the bath.
Liquor ratio	Weight ratio between the total dry material and the total liquor within a batch machine. So, for example, a liquor ratio of 1:10 means 10 litres of water per 1 kg of textile material (or 101/kg).
Make-up	Generic term used in the textile industry to name the different forms in which a textile material can exist. Examples are floe, yam, woven and knitted fabric.
Scouring	Removal of foreign impurities from textiles. In the case of wool, this term can address both the removal of the grease and dirt present on raw wool (wool scouring process) and the removal of spinning oils and residual contaminants from yam or fabric in the wet treatments that are

	carried out before the dyeing process.
Texturised fibres	Filament yams that have undergone a special treatement aimed at giving the fibre a greater volume and surface interest than the conventional yam of the same fibre.
Top	A continuous untwisted strand or sliver of wool fibres.

Abbreviations and acronyms

Acronym/ abbreviation	Explanation
AC	Cellulose acetate
AOX	Adsorbable organic halogens
APEO	Alkyl phenol ethoxylates
BAT	Best available techniques
BOD	Biochemical oxygen demand
BREF	BAT reference document
CA	Cellulose acetate
CMC	Carboxymethyl cellulose
CO	Cotton
COD	Chemical oxygen demand
CT	Cellulose triacetate
cu	Cupro
CV	Viscose
DAF	Dissolved air flotation
EDTA	Ethylenediamine tetraacetate
EL	Elastane
ELV	Emission Limit Value
EPER	European Pollutant Emission Register (defined in Council Decision 2000/479/EC)
E-PRTR	European Pollutant Release and Transfer Register (defined in Regulation 166/2006)
ETAD	Ecological and Toxicological Association of the Dyestuffs manufacturing industry
EVA	Ethylen vinyl acetate
IED	Industrial Emissions Directive
MoEU	Ministry of Environment and Urbanization
PA	Polyamide
PAC	Acrylic
PBT	Poly(butylene terephthalate)
PER	Perchloroethylene
PES	Polyester
PET	Poly(ethylene terephthalate)
POP	Persistent organic pollutants
PP	Polypropylene
PTT	Polytrimethylene terephthalate
REACH	Registration, Evaluation, Authorisation and Restriction of Chemical substances - European Community Regulation on chemicals and their safe use (EC 1907/2006)
SBR	Styrene-butadiene rubber
SVHC	Substance of very high concern
TOC	Total Organic Carbon
VOC	Volatile organic compounds

ANNEX I. CHECK-LISTS TO BE USED IN THE ASSESSMENT OF THE PERMIT APPLICATION

CONTENTS OF THE PERMIT APPLICATION FILE				
	DESCRIPTION		CHECK	
PROJECT REPORT	Owner of the company	Name of the company	1	☐
		Full address	2	☐
		VAT number	3	☐
		Main activity	4	☐
	Operator (if is different from the owner)	Name of the company	5	☐
		Data of the contact person (in each work centre)	6	☐
		Full address	7	☐
		VAT number	8	☐
		Main activity	9	☐
	Description of the installation and technical characteristics	Number of work centres	10	☐
		Register number of industrial establishments	11	☐
		National Classification of Economic Activities (NACE)	12	☐
		Total number of workers	13	☐
		Investments targeted to environmental improvements.	14	☐
		Organization chart	15	☐
		UTM coordinates	16	☐
		Activity of Annex I of the By Law	17	☐
		Main activity and others	18	☐
		Nominal production/treatment capacity and size	19	☐
		Planned date for commencing and completion of building activities (for new installations)	20	☐
		Planned date for starting operation (for new installations)	21	☐
		Operational time of the installation	22	☐
	Description of the production process	Production process description, with a schematic flow chart divided into phases.	23	☐
		Description of the phases	24	☐
		Operational hours in each phase	25	☐
		The methods of operation (continuous or discontinuous)	26	☐
		Description of the equipment and the techniques used, specifying which of them are considered as Best Available Techniques (BAT)	27	☐
	Detailed description of the natural resources, raw and auxiliary materials and products	Energy consumption: use of fuel for heat and steam generation and for transport inside the enterprise not including use of fuel for production of electricity or combined power and heat, use of heat and steam from external suppliers, use of electricity, use of fuel for production of electricity and heat -power plants and boiler houses. Measures to increase energy efficiency.	28	☐
		Water: quantity of water used in the process, intake of surface, ground and marine water –detailed description of intake, and indication of the cases of supply of water from outside or re-circulated	29	☐
		Raw materials: list and quantities of raw materials, indicating hazardous or non-hazardous character	30	☐
		Auxiliary materials: list and quantities of auxiliary materials, indicating hazardous or non-hazardous character	31	☐
		Products and by-products: list of output products and by-products, types and quantity generated of each of them, per hour, day or year.	32	☐

CONTENTS OF THE PERMIT APPLICATION FILE

T	DESCRIPTION			CHECK	
PROJECT REPORT	Environmental emissions and controls	Air quality	Modelization requirements	33	☐
			Plan for monitoring of immisions	34	☐
		Air: Channelled emissions:	Description of the emission points	35	☐
			Requirements and technical conditions of the focus (including operational hours)	36	☐
			Gaseous effluents generated (air flow, temperature and pollutants emitted and their amounts)	37	☐
			Abatement equipment, specifying which ones are BAT	38	☐
			Plan for Monitoring and Control	39	☐
		Air: Non channelled emissions	Description of the emission points	40	☐
			Pollutants emitted	41	☐
			Abatement equipment, specifying which ones are BAT	42	☐
			Plan for Monitoring and Control	43	☐
		Noise	Description of sources (location and characterization)	44	☐
			Acoustic study	45	☐
			Abatement measures, specifying which ones are BAT	46	☐
			Plan for Monitoring and Control	47	☐
		Waste water	Description of the flow (including discharging points) and the associated process (industrial, sanitary, rainwater or other discharges)	48	☐
			Requirements and technical conditions of discharging points	49	☐
			Description of pollutants and emitted amounts	50	☐
			WWTP (specifying BAT)	51	☐
			Monitoring and control (sampling points)	52	☐
		Hazardous waste	Production (amounts) and characterization (classification according EWC and labelling)	53	☐
			Storage conditions	54	☐
			Prevention on pollution measures (specifying BAT)	55	☐
			Waste management (inside/offside treatment)	56	☐
			Plan for minimization of waste	57	☐
		Non hazardous waste	Characterization (classification, amounts and labelling)	58	☐
			Prevention on pollution measures (specifying BAT)	59	☐
			Waste management (inside/offside treatment)	60	☐
		Packaging waste	Characterization	61	☐
			Plan for minimization of waste	62	☐
		Soil and groundwater protection	Safety measures for storage, specifying BAT	63	☐
			Systems of drainage or collection of potentially polluted waters.	64	☐
			Plan for monitoring and control	65	☐
		Not normal operation conditions	Situations when not normal operation will take place. Characterization	66	☐
			Measures which will be taken to minimize environmental impact in these not normal conditions	67	☐
			Description of operation under emergency situations	68	☐
			Measures to be taken upon definite cessation of activities	69	☐
ADDITIONAL INFORMATION	Non-technical summary of the details specified in the foregoing paragraphs			70	☐
	Environmental Impact Assessment (EIA) Report (for new installations, article 11 By Law 26939)			71	☐
	Development plans and landscape planning report			72	☐
	SEVESO report (classification of the installation according to applicable legislation on control of major-accident hazards involving dangerous substances)			73	☐
	Identification of the information which the applicant deems to be confidential under the provisions in force			74	☐
	Any other documentation evidencing compliance with the requirements under the applicable environmental legislation including, where applicable, the legislation on			75	☐

CONTENTS OF THE PERMIT APPLICATION FILE			
	DESCRIPTION	**CHECK**	
	obligatory security or insurance required under the applicable environmental legislation		
	The baseline report, that shall contain the information necessary to determine the state of soil and groundwater contamination so as to make a quantified comparison with the state upon definitive cessation of activities	76	☐
	Receipt of the fees paid by the operator	77	☐

BREF SECTIONS TO BE TAKEN INTO ACCOUNT TO ESTABLISH THE PERMIT'S CONDITIONS, AND CORRESPONDENCES WITH THE BATS MENTIONED IN THE COMMUNICATION 28142 OF THE MINISTRY OF ENVIRONMENT AND URBANISM

The sections indicated below in the middle column correspond by default to the BREF Document for Textile Industry. Where there is reference to other relevant BREF Documents, their name is explicitly indicated.The last column shows the sections in the "Communication 28142 on integrated pollution prevention and control in the textile industry" which are related to the subjects mentioned in the first column. For some operations, there are techniques in the decree which are not included in the BREF.

SUBJECT		BREF SECTION	MoEU's Communication 28142
Generic BAT for the whole sector			
1	Management	4.1.1, 4.1.2?, 5.1	Sections A.1 and A.2
2	Use of chemicals	4.1.3, 5.1	Sections A.2.2.3–A.2.2.5, B.2.19, B.2.8, B.2.13.1, B.2.16.2
3	Selection of raw materials	4.3, 5.1	A.3
4	Water and energy management	4.1.4, 4.1.5, 5.1	Sections B.2.20.2,, B.2.2.3, B.2.20, A.4
5	Waste management	5.1	A.1 and F
BATs for specific operations			
6	Pretreatment	4.5, 5.2.2	Section B.2.1, B.2.2, B.2.3, B.2.4
7	Dyeing	4.6, 5.2.2	Section B.2.5, B.2.6, B.2.7, B.2.8, B.2.9, B.2.10, B.2.11, B.2.12 C.1
8	Printing	4.7, 5.2.2	Section B.2.13, B.2.14, B.2.15
9	Finishing	4.8, 5.2.2	Section B.2.16, B.2.17, B.2.18, B.2.19 C.2,C.3 and C.4
10	Washing	4.9, 5.2.2	Section B.2.20
11	Wool scouring	4.4, 5.2.1	Section B.1 and C.4.9
12	Use of less hazardous chemicals in pretreatment, dyeing, finishing,	4.1.3, 5.1	Section A.2.2

SUBJECT		BREF SECTION	MoEU's Communication 28142
	printing, washing		
13	Waste water treatment and sludge disposal	4.10, 5.3	Section D.2, D.5.4, D.7.3, D.3
HORIZONTAL ISSUES			
14	Emission monitoring and reporting	BREF on General Principles of Monitoring, Chs. 2, 4, 5, 7, 8	Section E

ANNEX II: COMPARATIVE LIST OF LIMIT VALUES FOR POLLUTANTS OF WASTE WATERS DISCHARGED DIRECTLY TO SURFACE WATER BODIES STATED IN POLISH AND TURKISH LEGISLATION, AND IN ONE PARTICULAR SPANISH CASE, WHICH APPLY TO TEXTILE INSTALLATIONS

As an orientative example, 2 tables are shown below, who compare ELVs stated in Polish and Turkish legislation for wastewater-related parameters, in the case of direct discharges to surface water bodies (river, lake, etc). Also, the ELVs for the discharges of a particular textile installation of Spain are shown (in Spain there are no universal values for direct discharges to surface water bodies, instead of that the Competent Authority, as a function of the quality standards established for the water body which will receive the discharge, establishes which parameters should be controlled, and which ELVs should be respected for those parameters by the installation).

According to the Polish requirements, the parameters concerning the quality of the discharged sewage have to be selected individually from a predetermined list of parameters (table 1) in every single case. Thus, the number of parameters is not predefined and is established for each plant individually. Moreover, depending on the particular circumstances of the installation, the Competent Authority may impose stricter ELVs than the ones shown in table 1, even though usually the values of table 1 are the ones applied.

Table 1 shows ELVs for 24 h-average measurements, while Table 2 shows ELVs for 2 h-average measurements. In Poland ELVs are established for 24 h-average measurements, but not for 2 h-average measurements, so in Table 2 are shown only the Spanish example and the values stated in Turkish legislation.

Table 1 : ELVs for 24 h-average measurements:

No.	**Name of the parameter**	**Unit**	**ELV for industrial waste water**								
			Polish legislation	**Parameters and ELVs from a particular Spanish textile installation**	**Turkish legislation**						
					Flock, Yarn Production and Treatment	**Woven Fabric Treatment etc**	**Cotton Textiles etc.**	**Wool Scouring, Treatment, (Woven) Textile etc.**	**Knitted Fabric Treatment etc.**	**Carpet Treatment etc.**	**Synthetic Textile Treatment etc.**
1.	Temperature	°C	35								
2.	pH		6,5 - 9	5,5 – 9,5	6-9	6-9	6-9	6-9	6-9	6-9	6-9
3.	Suspended solids	mg/l	35	60	-	100	120	300		120	
4.	Settleable Solids	ml/l	0,5	0,5							
5.	Biochemical oxygen demand (BOD_5)	mg O_2/l	25	25							
6.	Chemical oxygen demand (COD)	mg O_2/l	125	125	240	300	200	300	200	200	300
7.	Total organic carbon (TOC)	mg C/l	30								
8.	Ammonium nitrogen	mg	10	7	-	-	-	-	-	-	
9.	Nitrate nitrogen	mg NNO_3/l	30	15							
10.	Nitrite nitrogen	mg NNO_2/l	1								

No.	Name of the parameter	Unit	ELV for industrial waste water								
			Polish legislation	**Parameters and ELVs from a particular Spanish textile installation**	**Turkish legislation**						
					Flock, Yarn Production and Treatment	**Woven Fabric Treatment etc**	**Cotton Textiles etc.**	**Wool Scouring, Treatment, (Woven) Textile etc.**	**Knitted Fabric Treatment etc.**	**Carpet Treatment etc.**	**Synthetic Textile Treatment etc.**
11.	Total nitrogen	mg N/l	30[11]								
12.	Total phosphorus	mg P/l	10[12]	8							
13.	Chlorides	mg Cl/l	1.000	250							
14.	Sulphites	mg SO_3/l	1		-	-	-	-	-		
15.	Sulphates	mg SO_4/l	500	250							
16.	Sodium	mg Na/l	800								
17.	Potassium	mg K/l	80								
18.	Total iron	mg Fe/l	10								
19.	Aluminium	mg Al/l	3								
20.	Antimony	mg Sb/l	0,3								
21.	Arsenic	mg As/l	0,1								
22.	Barium	mg Ba/l	2								
23.	Beryllium	mg Be/l	1								
24.	Boron	mg B/l	1	2							
25.	Zinc	mg Zn/l	2								10
26.	Tin	mg Sn/l	2								
27.	Chromium^{+6}	mg Cr/l	0,5								
28.	Total chromium	mg Cr/l	0,5		1	1	1	1	1	1	
29.	Cobalt	mg Co/l	1								
30.	Copper	mg Cu/l	0,5								
31.	Molybdenum	mg Mo/l	1								
32.	Nickel	mg Ni/l	0,5								
33.	Lead	mg Pb/l	0,5								
34.	Selenium	mg Se/l	1								
35.	Silver	mg Ag/l	0,1								
36.	Thallium	mg Tl/l	1								
37.	Titan	mg Ti/l	1								
38.	Vanadium	mg V/l	2								
39.	Available chlorine	mg Cl2/l	0,2								
40.	Total chlorine	mg Cl2/l	0,4		-	-	-	-	-	-	
41	Free cyanide	mg CN/l	0,1								
42.	Cyanide	mg CN/l	5								
43.	Fluoride	mg F/l	25								
44.	Thiocyanate	mg CNS/l	10								
45.	Sulphides	mg S/l	0,2		1						
46.	Formaldehyde	mg/l	2								
47.	Acrylonitrile	mg/l	20								
48.	Phenols (phenol index)	mg/l	0,1		-	0,5			0,5		0,5
49.	Insecticides of the group of chlorinated hydrocarbons	µg/l	0,5								
50.	Insecticides based on organophosphorus and carbamates compounds	µg/l	10								
51.	Caprolactam	mg/l	10								
52.	Anionic surfactants	mg/l	5	2							
53.	Non-ionic surfactants	mg/l	10								
54.	The sum of anionic and non-ionic surfactants	mg/l	1								
55.	Substances extracable with chloroform[13]	mg/l	50		-	-	-	100	-	-	
56.	Petroleum hydrocarbons	mg/l	15								
57.	Polycylic aromatic hydrocarbons BTX (benzene, toluene, xylene)	mg/l	0,1								
58.	Adsorbable organic halogens (AOX)	mg Cl/l	1,0								

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[11] Average annual amount

[12] Average annual amount

[13] In the Turkish legislation it is described as “oil and grease”

No.	Name of the parameter	Unit	ELV for industrial waste water								
			Polish legislation	Parameters and ELVs from a particular Spanish textile installation	Turkish legislation						
					Flock, Yarn Production and Treatment	Woven Fabric Treatment etc	Cotton Textiles etc.	Wool Scouring, Treatment, (Woven) Textile etc.	Knitted Fabric Treatment etc.	Carpet Treatment etc.	Synthetic Textile Treatment etc.
59	Sulphure (S^{-2})	mg/l			-	-	-	-	-	-	-
60	Fish bioexperiment (ZSF)	-			3	3	3	3	3	3	2
61	colour	(Pt-Co)			260	260	260	260	260	260	260

Table 2: ELVs for 2 h-average measurements:

No.	**Name of the parameter**	**Unit**	**ELV for industrial waste water**							
			Parameters and ELVs from a particular Spanish textile installation	**Turkish legislation**						
				Flock, Yarn Production and Treatment	**Woven Fabric Treatment etc**	**Cotton Textiles etc.**	**Wool Scouring, Treatment, (Woven) Textile etc.**	**Knitted Fabric Treatment etc.**	**Carpet Treatment etc.**	**Synthetic Textile Treatment etc.**
1.	pH		5,5 – 9,5	6-9	6-9	6-9	6-9	6-9	6-9	6-9
2.	Suspended solids	mg/l	60		140	160	400	-	160	
3.	Settleable Solids	ml/l	0,5							
4.	Biochemical oxygen demand (BOD_5)	mg O_2/l	25							
5.	Chemical oxygen demand (COD)	mg O_2/l	125	350	400	250	400	300	300	400
6.	Ammonium nitrogen	mg	7	5	5	5	5	5	5	
7.	Nitrate nitrogen	mg NNO_3/l	15							
8.	Total phosphorus	mg P/l	8							
9.	Chlorides	mg Cl/l	250							
10.	Sulphites	mg SO_3/l		1	1	1	1	1	1	
11.	Sulphates	mg SO_4/l	250							
12.	Boron	mg B/l	2							
13.	Zinc	mg Zn/l								12
14.	Total chromium	mg Cr/l		2	2	2	2	2	2	
15.	Total chlorine	mg Cl2/l		0,3	0,3	0,3	0,3	0,3	0,3	
16.	Phenols (phenol index)	mg/l			1			1	1	1
17.	Anionic surfactants	mg/l	2							
18.	Substances extracable with chloroform	mg/l		10		10	200	10	10	
19.	Sulphures (S^{-2})	Mg/l		1	1	0,1	0,1	0,1	0,1	0,1
20.	Fish bioexperiment (ZSF)	-		4	4	4	4	4	4	3
21.	Colour	(Pt-Co)		280	280	280	280	280	280	280

ANNEX III: EXAMPLES OF REPORTING REQUIREMENTS STATED IN EU LEGISLATION (EMAS AND E-PRTR REGULATIONS)

In this Annex are shown 2 annexes of 2 EU Regulations related to environmental reporting requirements. These 2 Regulations (EMAS Regulation 1221/2009/EC and E-PRTR Regulation 166/2006/EC) have not yet been transposed into the Turkish environmental legislation, so they are not an obligation.

Nevertheless, in the coming years, when the EMAS Regulation will be transposed into the Turkish legislation, those Turkish companies who will want to get an EMAS certificate will have to satisfy the reporting requirements listed in the annex of that Regulation which is shown below.

Similarly, when the E-PRTR Regulation will be transposed into the Turkish legislation, the Environmental Competent Authority will have to provide to the European Commission the data shown in the other annex shown below, of all activities which fall under the scope of the E-PRTR Regulation. That scope includes all the activities falling under the scope of the IED. Thus, most probably, the Turkish Environmental Competent Authority will request to the activities falling under the scope of the E-PRTR Regulation those data listed in the E-PRTR annex shown below.

ANNEX IV of the REGULATION (EC) No 1221/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 November 2009 on the voluntary participation by organisations in a Community eco-management and audit scheme (EMAS):

ENVIRONMENTAL REPORTING

A. Introduction

Environmental information shall be presented in a clear and coherent manner in electronic form or in printed form.

B. Environmental statement

The environmental statement shall contain at least the elements and shall meet the minimum requirements as set out below:

(a) a clear and unambiguous description of the organisation registering under EMAS and a summary of its activities, products and services and its relationship to any parent organisations as appropriate;

(b) the environmental policy and a brief description of the environmental management system of the organisation;

(c) a description of all the significant direct and indirect environmental aspects which result in significant environmental impacts of the organisation and an explanation of the nature of the impacts as related to these aspects (Annex I.2);

(d) a description of the environmental objectives and targets in relation to the significant environmental aspects and impacts;

(e) a summary of the data available on the performance of the organisation against its environmental objectives and targets with respect to its significant environmental impacts. Reporting shall be on the core indicators and on other relevant existing environmental performance indicators as set out in Section C;

(f) other factors regarding environmental performance including performance against legal provisions with respect to their significant environmental impacts;

(g) a reference to the applicable legal requirements relating to the environment;

(h) the name and accreditation or licence number of the environmental verifier and the date of validation.

The updated environmental statement shall contain at least the elements and shall meet the minimum requirements as set out in points (e) to (h).

C. Core indicators and other relevant existing environmental performance indicators

1. Introduction

Organisations shall report, both in the environmental statement and the updated environmental statement, on the core indicators insofar as these relate to the direct environmental aspects of the organisation and other relevant existing environmental performance indicators as set out below.

The reporting shall provide data on actual input/impact. If disclosure would adversely affect the confidentiality of commercial or industrial information of the organisation where such confidentiality is provided for by national or Community law to protect a legitimate economic interest, the organisation may be permitted to index this information in its reporting, e.g. by establishing a base line year (with the index number 100) from which the development of the actual input/impact would appear.

The indicators shall:

(a) give an accurate appraisal of the organisation's environmental performance;

(b) be understandable and unambiguous;

(c) allow for a year on year comparison to assess the development of the environmental performance of the organisation;

(d) allow for comparison with sector, national or regional benchmarks as appropriate;

(e) allow for comparison with regulatory requirements as appropriate.

2. Core indicators

(a) Core indicators shall apply to all types of organisations. They focus on performance in the following key environmental areas:

(i) Energy efficiency;

(ii) Material efficiency;

(iii) Water;

(iv) Waste;

(v) Biodiversity; and

(vi) Emissions.

Where an organisation concludes that one or more core indicators are not relevant to its significant direct environmental aspects, that organisation may not report on those core indicators. The organisation shall provide justification to that effect with reference to its environmental review.

(b) Each core indicator is composed of:

(i) a figure A indicating the total annual input/impact in the given field;

(ii) a figure B indicating the overall annual output of the organisation; and

(iii) a figure R indicating the ratio A/B.

Each organisation shall report on all 3 elements for each indicator.

(c) The indication of the total annual input/impact in the given field, figure A, shall be reported as follows:

(i) on Energy efficiency

- concerning the "total direct energy use", the total annual energy consumption, expressed in MWh or GJ,

- concerning the "total renewable energy use", the percentage of total annual consumption of energy (electricity and heat) produced by the organisation from renewable energy sources,

(ii) on Material efficiency

- concerning the "annual mass-flow of different materials used" (excluding energy carriers and water), expressed in tonnes,

(iii) on Water

- concerning the "total annual water consumption", expressed in m3,

(iv) on Waste

- concerning the "total annual generation of waste", broken down by type, expressed in tonnes,

- concerning the "total annual generation of hazardous waste" expressed in kilograms or tonnes,

(v) on Biodiversity

- concerning the "use of land", expressed in m2 of built-up area,

(vi) on Emissions

- concerning the "total annual emission of greenhouse gases", including at least emissions of CO2, CH4, N2O, HFCs, PFCs and SF6, expressed in tonnes of CO2 equivalent,

- concerning the "total annual air emission", including at least emissions of SO2, NOx and PM, expressed in kilograms or tonnes,

In addition to the indicators defined above, an organisation may use also other indicators to express the total annual input/impact in the given field;

(d) The indication of the overall annual output of the organisation, figure B, is the same for all fields, but is adapted to the different types of organisations, depending on their type of activity, and shall be reported as follows:

(i) for organisations working in the production sector (industry), it shall indicate the total annual gross value-added expressed in million euro (EUR Mio) or total annual physical output expressed in tonnes or, in the case of small organisations the total annual turnover or number of employees;

(ii) for organisations in the non-production sectors (administration/services), it shall relate to the size of the organisation expressed in number of employees.

In addition to the indicators defined above, an organisation may use also other indicators to express its overall annual output.

3. Other relevant environmental performance indicators

Each organisation shall also report annually on its performance relating to the more specific environmental aspects as identified in its environmental statement and, where available, take account of sectoral reference documents as referred to in Article 46.

D. Public availability

The organisation shall be able to demonstrate to the environmental verifier that anybody interested in the organisation's environmental performance can easily and freely be given access to the information required above under points B and C.

The organisation shall ensure that this information is available in (one of) the official language(s) of the Member State, in which the organisation is registered, and if applicable in (one of) the official language(s) of those Member States, in which sites covered by the corporate registration are located.

E. Local accountability

Organisations registering under EMAS may wish to produce one corporate environmental statement, covering a number of different geographic locations.

As the intention of EMAS is to ensure local accountability, organisations shall ensure that the significant environmental impacts of each site are clearly identified and reported within the corporate environmental statement.

ANNEX III of the Regulation (EC) No 166/2006 of the European Parliament and of the Council of 18 January 2006 concerning the establishment of a European Pollutant Release and Transfer Register (E-PRTR):

Format for the reporting of release and transfer data by Member States to the Commission

Reference year	
Identification of the facility	
Name of the parent company Name of the facility Identification number of facility Street address Town/village Postal code Country Coordinates of the location River basin district[1] NACE-code (4 digits) Main economic activity	

Production volume (optional) Number of installations (optional) Number of operating hours in year (optional) Number of employees (optional) Text field for textual information or website address delivered by facility or parent company (optional)		
All Annex I activities of the facility (according to the coding system given in Annex I and the IPPC code where available)		
Activity 1 (main Annex I activity) Activity 2 Activity N		
Release data to air for the facility for each pollutant exceeding threshold value (according to Annex II)		Releases to air
Pollutant 1 Pollutant 2 Pollutant N	M: measured; Analytical Method used C: calculated; Calculation Method used E: estimated	T: Total in kg/year A: accidental in kg/year
Release data to water for the facility for each pollutant exceeding threshold value (according to Annex II)		Releases to water
Pollutant 1 Pollutant 2 Pollutant N	M: measured; Analytical Method used C: calculated; Calculation Method used E: estimated	T: Total in kg/year A: accidental in kg/year
Release data to land for the facility for each pollutant exceeding threshold value (according to Annex II)		Releases to land
Pollutant 1 Pollutant 2 Pollutant N	M: measured; Analytical Method used C: calculated; Calculation Method used E: estimated	T: Total in kg/year A: accidental in kg/year
Off-site transfer of each pollutant destined for waste-water treatment in quantities exceeding threshold value (according to Annex II)		
Pollutant 1 Pollutant 2 Pollutant N	M: measured; Analytical Method used C: calculated; Calculation Method used E: estimated	in kg/year
Off-site transfers of hazardous waste for the facility exceeding threshold value (according to Article 5)		
<u>Within the country</u> : For Recovery (R)	M: measured; Analytical Method used C: calculated; Calculation Method used E: estimated	in t/year
<u>Within the country</u> : For Disposal (D)	M: measured; Analytical Method used C: calculated; Calculation Method used E: estimated	in t/year
<u>To other countries:</u> For Recovery (R) Name of the recoverer Address of the recoverer Address of actual recovery site receiving the transfer	M: measured; Analytical Method used C: calculated; Calculation Method used E: estimated	in t/year

<u>To other countries:</u> For Disposal (D) Name of the disposer Address of the disposer Address of actual disposal site receiving the transfer	M: measured; Analytical Method used C: calculated; Calculation Method used E: estimated	in t/year
Off-site transfer of non-hazardous waste for the facility exceeding threshold value (according to Article 5)		
For Recovery (R)	M: measured; Analytical Method used C: calculated; Calculation Method used E: estimated	in t/year
For Disposal (D)	M: measured; Analytical Method used C: calculated; Calculation Method used E: estimated	in t/year
Competent authority for requests of the public: Name Street address Town/village Telephone No Fax No E-mail address		

[1] according to Article 3(1) of Directive 2000/60/EC of 23 October 2000 establishing a framework for Community action in the field of water policy

ANNEX IV: LIST OF POLLUTANTS WHICH ACCORDING TO THE E-PRTR REGULATION HAVE TO BE REPORTED WHEN SURPASSING CERTAIN EMISSION THRESHOLDS

The E-PRTR Regulation 166/2006/EC has not yet been transposed into the Turkish environmental legislation, so it implies currently no obligations for the operators.

Nevertheless, in the coming years, when the E-PRTR Regulation will be transposed into the Turkish legislation, the Environmental Competent Authority will have to provide to the European Commission the data shown in Annex III, of all activities which fall under the scope of the E-PRTR Regulation. That scope includes all the activities in the textile sector who have a production capacity exceeding 10 T/day in operations of dyeing, bleaching or mercerization.

In this Annex are shown the substances that may be necessary to be reported to the PRTR Register. This register contains the information (most of which is available to the public) of the emissions and waste transfers outside of the site of all those industrial activities falling under the scope of the E-PRTR Regulation, for the cases when those emissions or waste transfers surpass the thresholds shown in the table below. The thresholds are established by the European Commission (they should not be confused with the emission limit values established in the applicable environmental legislation), and when the emission of a certain substance notified by a certain installation surpasses the corresponding threshold, it is made available to the public once the value notified is validated by the Competent Authority.

As explained in section 5.2.1 of Chapter 5 of this guide, the parameters and pollutants to be notified are the following ones:

a. releases to air, water and land of any pollutant specified in Annex II (of the Regulation 166/2006) for which the applicable threshold value specified in Annex II (of the Regulation 166/2006) is exceeded;
b. off-site transfers of hazardous waste exceeding 2 tonnes per year or of non hazardous waste exceeding 2000 tonnes per year, for any operations of recovery or disposal with the exception of the disposal operations of land treatment and deep injection referred to in Article 6 of the Regulation, indicating with "R" or "D" respectively whether the waste is destined for recovery or disposal and, for transboundary movements of hazardous waste, the name and address of the recoverer or the disposer of the waste and the actual recovery or disposal site;
c. off-site transfers of any pollutant specified in Annex II (of the Regulation) in waste water destined for waste-water treatment for which the threshold value specified in Annex II (of the Regulation), column 1b is exceeded.

The E-PRTR Register simply contains the data on total annual emissions and waste transfers generated by the most polluting industrial activities, either at national or european level.

The aspects which are not under the scope of the E-PRTR Register are the following:

- The E-PRTR Register does not inform about the degree of fulfillment of the legislation by the installations.
- The public information thresholds indicated in the table below are NOT emission limit values.
- The E-PRTR Register does not include any assessment about the possible risks for human health or environmental impacts which may be derived by the emissions reported.

Preliminary explanatory notes to the table below:

The CAS number of the pollutant means the precise identifier in Chemical Abstracts Service.

Column ”Thresholds for releases”: If the threshold in a given sub-column (air, water or land) is exceeded, reporting of releases or, for pollutants in waste water destined for waste-water treatment, transfers to the environmental medium referred to in that sub-column is required with respect to the facility in question.

A hyphen (-) indicates that the parameter in question does not trigger a reporting requirement.

An asterisk (*) indicates that, for this pollutant, the release threshold in column (1)(a) is to be used rather than a manufacture, process or use threshold.

A double asterisk (**) indicates that, for this pollutant, the release threshold in column (1)(b) is to be used rather than a manufacture, process or use threshold.

No	CAS number	Pollutant	Thresholdforreleases (column1)		
			toair (column1a) kg/year	towater (column1b) kg/year	toland (column1c) kg/year
1	74-82-8	Methane(CH_4)	100.000	- (2.b)	-
2	630-08-0	Carbonmonoxide(CO)	500.000	-	-
3	124-38-9	Carbondioxide(CO_2)	100.000.000	-	-
4		Hydro-fluorocarbons(HFCs)(3)	100	-	-
5	10024-97-2	Nitrousoxide(N_2O)	10.000	-	-
6	7664-41-7	Ammonia(NH_3)	10.000	-	-

No	CAS number	Pollutant	Thresholdforreleases (column1)		
			toair (column1a) kg/year	**towater (column1b) kg/year**	**toland (column1c) kg/year**
7		Non-methanevolatileorganic compounds(NMVOC)	100.000	-	-
8		Nitrogenoxides(NO_x/NO_2)	100.000	-	-
9		Perfluorocarbons(PFCs)(4)	100	-	-
10	2551-62-4	Sulphurhexafluoride(SF_6)	50	-	-
11		Sulphuroxides(SO_x/SO_2)	150.000	-	-
12		Totalnitrogen	-	50.000	50.000
13		Totalphosphorus	-	5.000	5.000
14		Hydrochlorofluorocarbons (HCFCs)(5)	1	-	-
15		Chlorofluorocarbons(CFCs)(6)	1	-	-
16		Halons(7)	1	-	-
17	7440-38-2	Arsenicandcompounds(asAs)(8)	20	5	5
18	7440-43-9	Cadmiumandcompounds(asCd)(8)	10	5	5
19	7440-47-3	Chromiumandcompounds(asCr)(8)	100	50	50
20	7440-50-8	Copperandcompounds(asCu)(8)	100	50	50
21	7439-97-6	Mercuryandcompounds(asHg)(8)	10	1	1
22	7440-02-0	Nickelandcompounds(asNi)(8)	50	20	20
23	7439-92-1	Leadandcompounds(asPb)(8)	200	20	20
24	7440-66-6	Zincandcompounds(asZn)(8)	200	100	100
25	15972-60-8	Alachlor	-	1	1
26	309-00-2	Aldrin	1	1	1
27	1912-24-9	Atrazine	-	1	1
28	57-74-9	Chlordane	1	1	1
29	143-50-0	Chlordecone	1	1	1
30	470-90-6	Chlorfenvinphos	-	1	1
31	85535-84-8	Chloro-alkanes,C_{10}-C_{13}	-	1	1
32	2921-88-2	Chlorpyrifos	-	1	1
33	50-29-3	DDT	1	1	1
34	107-06-2	1,2-dichloroethane(EDC)	1.000	10	10
35	75-09-2	Dichloromethane(DCM)	1.000	10	10
36	60-57-1	Dieldrin	1	1	1
37	330-54-1	Diuron	-	1	1
38	115-29-7	Endosulphan	-	1	1
39	72-20-8	Endrin	1	1	1
40		Halogenatedorganiccompounds(asAOX)(9)	-	1.000	1.000
41	76-44-8	Heptachlor	1	1	1
42	118-74-1	Hexachlorobenzene(HCB)	10	1	1
43	87-68-3	Hexachlorobutadiene(HCBD)	-	1	1
44	608-73-1	1,2,3,4,5,6- hexachlorocyclohexane(HCH)	10	1	1
45	58-89-9	Lindane	1	1	1
46	2385-85-5	Mirex	1	1	1
47		PCDD+PCDF(dioxins+furans)(asTeq)(10)	0,0001	0,0001	0,0001
48	608-93-5	Pentachlorobenzene	1	1	1
49	87-86-5	Pentachlorophenol(PCP)	10	1	1
50	1336-36-3	Polychlorinatedbiphenyls(PCBs)	0,1	0,1	0,1
51	122-34-9	Simazine	-	1	1
52	127-18-4	Tetrachloroethylene(PER)	2.000	10	-
53	56-23-5	Tetrachloromethane(TCM)	100	1	-
54	12002-48-1	Trichlorobenzenes(TCBs)(allisomers)	10	1	-
55	71-55-6	1,1,1-trichloroethane	100	-	-
56	79-34-5	1,1,2,2-tetrachloroethane	50	-	-
57	79-01-6	Trichloroethylene	2.000	10	-

No	CAS number	Pollutant	Thresholdforreleases (column1)		
			toair (column1a) kg/year	towater (column1b) kg/year	toland (column1c) kg/year
58	67-66-3	Trichloromethane	500	10	-
59	8001-35-2	Toxaphene	1	1	1
60	75-01-4	Vinylchloride	1.000	10	10
61	120-12-7	Anthracene	50	1	1
62	71-43-2	Benzene	1.000	200 (as BTEX)$^{(11)}$	200 (as BTEX)$^{(11)}$
63		Brominateddiphenylethers(PBDE)(12)	-	1	1
64		NonylphenolandNonylphenolethoxylates(NP/NPEs)	-	1	1
65	100-41-4	Ethylbenzene	-	200 (as BTEX)$^{(11)}$	200 (as BTEX)$^{(11)}$
66	75-21-8	Ethyleneoxide	1.000	10	10
67	34123-59-6	Isoproturon	-	1	1
68	91-20-3	Naphthalene	100	10	10
69		Organotincompounds(astotalSn)	-	50	50
70	117-81-7	Di-(2-ethylhexyl)phthalate(DEHP)	10	1	1
71	108-95-2	Phenols(astotalC)(13)	-	20	20
72		Polycyclicaromatichydrocarbons(PAHs)(14)	50	5	5
73	108-88-3	Toluene	-)	200 (as BTEX)$^{(11)}$	200 (as BTEX)$^{(11)}$
74		Tributyltinandcompounds (15)	-	1	1
75		Triphenyltinandcompounds (16)	-	1	1
76		Totalorganiccarbon(TOC)(as totalCorCOD/3)	-	50.000	-
77	1582-09-8	Trifluralin	-	1	1
78	1330-20-7	Xylenes(17)	-	200 (as BTEX)$^{(11)}$	200 (as BTEX)$^{(11)}$
79		Chlorides(astotalCl)	-	2.000.000	2.000.000
80		Chlorineandinorganiccom- pounds(asHCl)	10.000	-	-
81	1332-21-4	Asbestos	1	1	1
82		Cyanides(astotalCN)	-	50	50
83		Fluorides(astotalF)	-	2.000	2.000
84		Fluorineandinorganiccom- pounds(asHF)	5.000	-	-
85	74-90-8	Hydrogencyanide(HCN)	200	-	-
86		Particulatematter(PM_{10})	50.000	-	-
87	1806-26-4	OctylphenolsandOctylphenolethoxylates	-	1	-
88	206-44-0	Fluoranthene	-	1	-
89	465-73-6	Isodrin	-	1	-
90	36355-1-8	Hexabromobiphenyl	0,1	0,1	0,1
91	191-24-2	Benzo(g,h,i)perylene	-	1	-

(1) Unless otherwise specified any pollutant specified in this Annex shall be reported as the total mass of that pollutant or, where the pollutant is a group of substances, as the total mass of the group.

(2) A hyphen (—) indicates that the parameter and medium in question do not trigger a reporting requirement.

(3) Total mass of hydrogen fluorocarbons: sum of HFC23, HFC32, HFC41, HFC4310mee, HFC125, HFC134, HFC134a, HFC152a, HFC143, HFC143a, HFC227ea, HFC236fa, HFC245ca, HFC365mfc.

(4) Total mass of perfluorocarbons: sum of CF4, C2F6, C3F8, C4F10, c-C4F8, C5F12, C6F14.

(5) Total mass of substances including their isomers listed in Group VIII of Annex I to Regulation (EC) No 2037/2000 of the European Par- liament and of the Council of 29 June 2000 on substances that deplete the ozone layer (OJ L 244, 29.9.2000, p. 1). Regulation as amended by Regulation (EC) No 1804/2003 (OJ L 265, 16.10.2003, p. 1).

(6) Total mass of substances including their isomers listed in Group I and II of Annex I to Regulation (EC) No 2037/2000.

(7) Total mass of substances including their isomers listed in Group III and VI of Annex I to Regulation (EC) No 2037/2000.

(8) All metals shall be reported as the total mass of the element in all chemical forms present in the release.

(9) Halogenated organic compounds which can be adsorbed to activated carbon expressed as chloride.

(10) Expressed as I-TEQ.

(11) Single pollutants are to be reported if the threshold for BTEX (the sum parameter of benzene, toluene, ethyl benzene, xylenes) is exceeded.

(12) Total mass of the following brominated diphenylethers: penta-BDE, octa-BDE and deca-BDE.

(13) Total mass of phenol and simple substituted phenols expressed as total carbon.

(14) Polycyclic aromatic hydrocarbons (PAHs) are to be measured for reporting of releases to air as benzo(a)pyrene (50-32-8), benzo(b)fluo- ranthene (205-99-2), benzo(k)fluoranthene (207-08-9), indeno(1,2,3-cd)pyrene (193-39-5) (derived from Regulation (EC) No 850/2004 of the European Parliament and of the Council of 29 April 2004 on persistent organic pollutants (OJ L 229, 29.6.2004, p. 5)).

(15) Total mass of tributyltin compounds, expressed as mass of tributyltin.

(16) Total mass of triphenyltin compounds, expressed as mass of triphenyltin.

(17) Total mass of xylene (ortho-xylene, meta-xylene, para-xylene).

ANNEX V: DETERGENTS

Definition:

A detergent is a product specifically designed to wash textiles and other substrates through a process that involves detergency phenomena.Its main component are the surfactants, but it may contain additional components such as adjuvants (substances which reinforce the action of surfactants) and additives.Washing results are the outcome of the combined properties and effects of all components. Typical compounds used as detergents/wetting agents are the following ones:

Class	Examples of products available on the market	Bio-degradability (1)	Bio-eliminability (2)
Non - ionic	Alcohol and fatty alcohols ethoxylates	>90 %	80-85 %
	Fatty acids ethoxylates	>90 %	80-85 %
	Alkylphenol ethoxylates (APEOs)	˜60 %	54 – 58 % (toxic metabolites)
	Fatty amines ethoxylates	60 – 80 %	72 – 73 %
Anionic	Alkyl sulphonates	>98 %	
	Alkyl aryl sulphonates	>98 %	
	Alkyl sulphates	>98 %	
	Dialkylsulphosuccinates	>98 %	
	Alkyl carboxylates (e.g. sodium palmitate, -stearate)	>98 %	
	Sulphated alkanolamides	n.d.	

Notes:
(1) OECD-test 301 E: 301 E MODIFIED OECD SCREENING TEST
(2) OECD-test 302 B: determining ready biodegradability

Potential environmental impact:

It is considered thatthe most important factorto assess the toxicological potentialof differentsurfactantsis the difference inbiodegradabilitybetween them.It is generally acceptedthat chemicalswith a linear molecular chainare sufficientlybiodegradabletomeet the requirementsof legislation, while that is not the case for chemicals with a branched molecular chain.There is for examplesome uncertainty regardingthe biological effectsofnonionic surfactants,especiallyalkyl phenolethoxylates(APEO).

Some of the chemicals which often form part of detergents and that have a considerable environmental impact are the following:

- Many surfactants give rise to environmental concerns due to their poor biodegradability, their toxicity (including that of their metabolites) and their potential to act as endocrine disrupters. Concerns currently focus on alkylphenol ethoxylates (APEO) and in particular on nonylphenol ethoxylates (NPE), which are often contained in the formulations of detergents and many other auxiliaries (e.g. dispersing agents, emulsifiers, spinning lubricants).

- Alkylphenol ethoxylates are themselves believed to be endocrine disruptors and to cause feminisation of male fish. More importantly, however, they produce metabolites which are believed to be many times more potent as endocrine disruptors than the parent compounds. The most potent of these are octyl- and nonylphenol. Nonylphenol is listed as a priority hazardous substance under OSPAR and the EC Water Framework Directive, which means that any discharge needs to be gradually reduced to zero.

There are also detergents in the discharged water, which contribute to the increase of the chemical oxygen demand of the effluent. The detergent is recycled via the grease recovery/dirt removal loop. As a result, low efficiency in this recovery system is associated with higher amounts of detergent in the effluent. Compared to the chemical oxygen demand attributable to wax, dirt, etc., the detergents can be considered minor contributors to water pollution, but this is not the case when harmful surfactants such as alkylphenol ethoxylates are used as detergents.

Methods to determine the amount of detergents contained in waste waters:

D7065 – 06

Standard Test Method for Determination of Nonylphenol, Bisphenol A, p-tert-Octylphenol, Nonylphenol Monoethoxylate and Nonylphenol Diethoxylate in Environmental Waters by Gas Chromatography Mass Spectrometry.

D7485 – 09

Standard Test Method for Determination of Nonylphenol, p-tert-Octylphenol, Nonylphenol Monoethoxylate and Nonylphenol Diethoxylate in Environmental Waters by Liquid Chromatography/Tandem Mass Spectrometry.

D7742 – 11

Standard Practice for Determination of Nonylphenol Polyethoxylates (NPnEO, $3 \leq n \leq 18$) and Octylphenol Polyethoxylates (OPnEO, $2 \leq n \leq n \leq 12$ in Water by Single Reaction Monitoring (SRM) Liquid Chromatography/ Tandem Mass Spe.

OECD-test 301 E

301 E MODIFIED OECD SCREENING TEST. Standard Methods for the Examination of Water and Wastewater, 12th ed, Am. Pub. Hlth. Ass., Am. Wat. Poll. Control Fed., Oxygen Demand, P 65 (1965).

OECD-test 302B

Method OECD 302 B for determining ready biodegradabilityand ISO Standard 6060 (1986). Water Quality-Determination of Chemical Oxygen Demand.

ANNEX VI: ENVIRONMENTAL LEGISLATION RELATED TO PERMITTING CURRENTLY APPLICABLE TO THE SECTOR

- Su Kirliliği Kontrolü Yönetmeliği (Resmi Gazete Tarihi : 31.12.2004 | Sayısı : 25687)

- Yeraltı Sularının Kirlenmeye ve Bozulmaya Karşı Korunması Hakkında Yönetmelik (Resmi Gazete Tarihi : 07.04.2012 | Sayısı : 28257)

- **Hava Kalitesi Değerlendirme ve Yönetimi Yönetmeliği** (Resmi Gazete Tarihi : 06.06.2008 | Sayısı : 26898)

- **Sanayi Kaynaklı Hava Kirliliğinin Kontrolü Yönetmeliği** (Resmi Gazete Tarihi : 03.07.2009 | Sayısı : 27277)

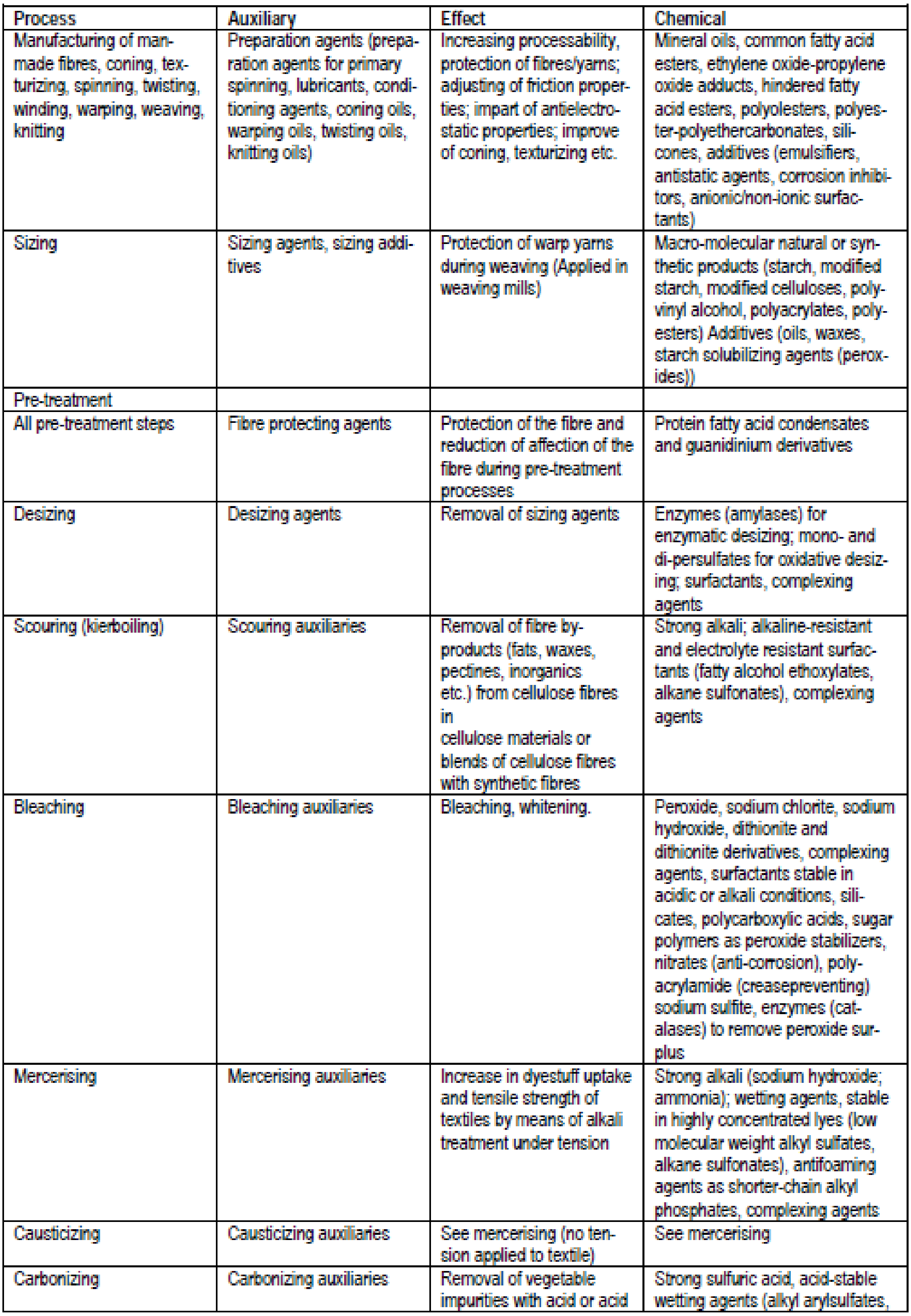
- **Tehlikeli Atıkların Kontrolü Yönetmeliği** (Resmi Gazete Tarihi : 14.03.2005 | Sayısı : 25755)

- **Kokuya Sebep Olan Emisyonların Kontrolü Yönetmeliği** (Resmi Gazete Tarihi : 04.09.2010 | Sayısı : 27692)

- **Çevresel Gürültünün Değerlendirilmesi ve Yönetimi Yönetmeliği** (Resmi Gazete Tarihi : 04.06.2010 | Sayısı : 27601)

- Tekstil Sektöründe Entegre Kirlilik Önleme ve Kontrol Tebliği **(Resmi Gazete Tarihi : 14.12.2011 | Sayısı : 28142)**

ANNEX VII: Overview on the most important auxiliaries and basic chemicals, their technological effect, and their chemical composition used along the textile chain (annex prepared within a German BMU GIZ Project with Thailand)



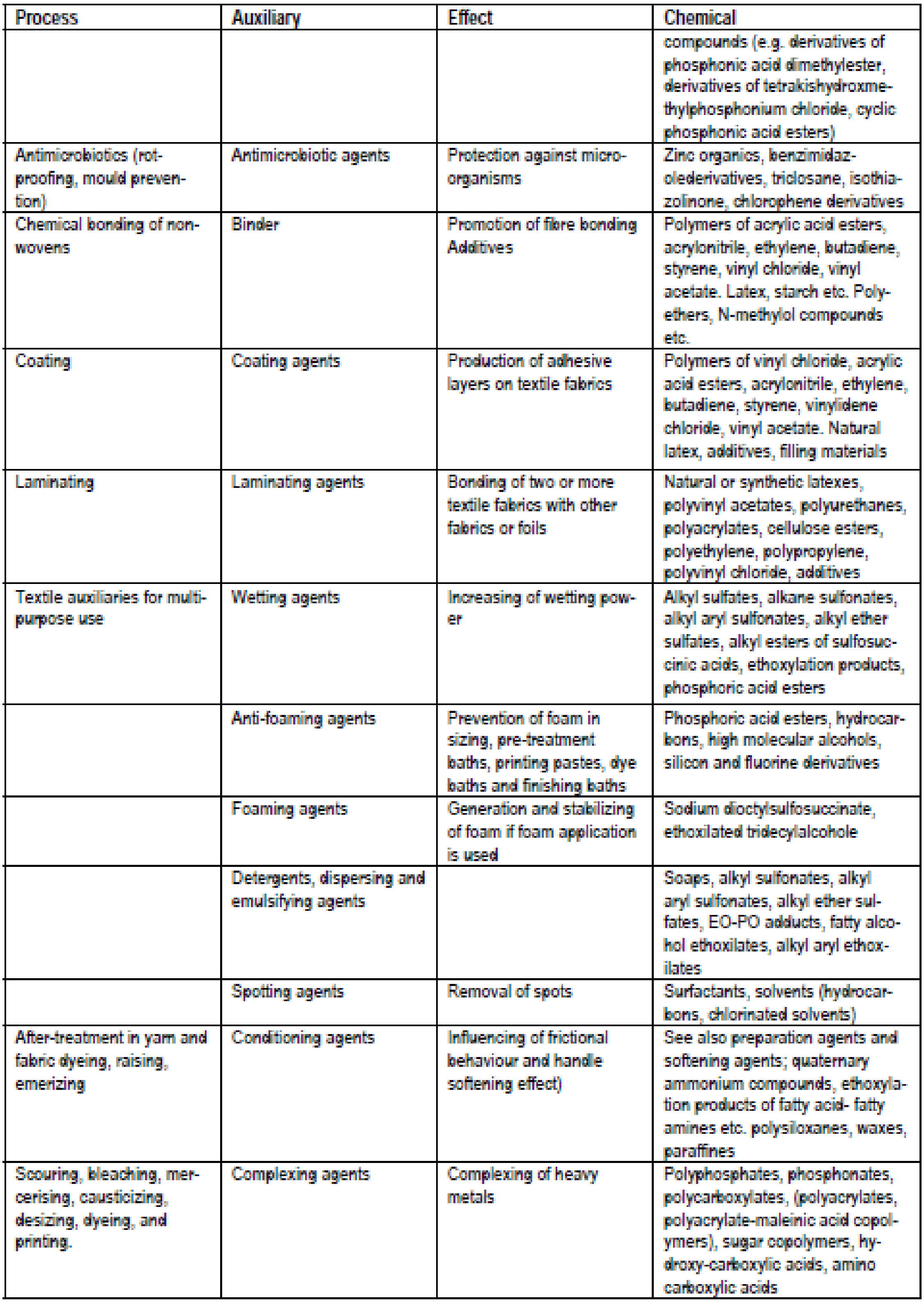
Process	Auxiliary	Effect	Chemical
Manufacturing of man-made fibres, coning, texturizing, spinning, twisting, winding, warping, weaving, knitting	Preparation agents (preparation agents for primary spinning, lubricants, conditioning agents, coning oils, warping oils, twisting oils, knitting oils)	Increasing processability, protection of fibres/yarns; adjusting of friction properties; impart of antielectrostatic properties; improve of coning, texturizing etc.	Mineral oils, common fatty acid esters, ethylene oxide-propylene oxide adducts, hindered fatty acid esters, polyolesters, polyester-polyethercarbonates, silicones, additives (emulsifiers, antistatic agents, corrosion inhibitors, anionic/non-ionic surfactants)
Sizing	Sizing agents, sizing additives	Protection of warp yarns during weaving (Applied in weaving mills)	Macro-molecular natural or synthetic products (starch, modified starch, modified celluloses, polyvinyl alcohol, polyacrylates, polyesters) Additives (oils, waxes, starch solubilizing agents (peroxides))
Pre-treatment			
All pre-treatment steps	Fibre protecting agents	Protection of the fibre and reduction of affection of the fibre during pre-treatment processes	Protein fatty acid condensates and guanidinium derivatives
Desizing	Desizing agents	Removal of sizing agents	Enzymes (amylases) for enzymatic desizing; mono- and di-persulfates for oxidative desizing; surfactants, complexing agents
Scouring (kierboiling)	Scouring auxiliaries	Removal of fibre by-products (fats, waxes, pectines, inorganics etc.) from cellulose fibres in cellulose materials or blends of cellulose fibres with synthetic fibres	Strong alkali; alkaline-resistant and electrolyte resistant surfactants (fatty alcohol ethoxylates, alkane sulfonates), complexing agents
Bleaching	Bleaching auxiliaries	Bleaching, whitening.	Peroxide, sodium chlorite, sodium hydroxide, dithionite and dithionite derivatives, complexing agents, surfactants stable in acidic or alkali conditions, silicates, polycarboxylic acids, sugar polymers as peroxide stabilizers, nitrates (anti-corrosion), polyacrylamide (creasepreventing) sodium sulfite, enzymes (catalases) to remove peroxide surplus
Mercerising	Mercerising auxiliaries	Increase in dyestuff uptake and tensile strength of textiles by means of alkali treatment under tension	Strong alkali (sodium hydroxide; ammonia); wetting agents, stable in highly concentrated lyes (low molecular weight alkyl sulfates, alkane sulfonates), antifoaming agents as shorter-chain alkyl phosphates, complexing agents
Causticizing	Causticizing auxiliaries	See mercerising (no tension applied to textile)	See mercerising
Carbonizing	Carbonizing auxiliaries	Removal of vegetable impurities with acid or acid	Strong sulfuric acid, acid-stable wetting agents (alkyl arylsulfates,

Process	Auxiliary	Effect	Chemical
		salts	alkane sulfonates, fatty alcohol ethoxylates)
Optical bleaching	Fluorescent brighteners	Whitening	Stilbene, pyrazoline or benzeneazole derivatives
Dyeing/Printing			
Dissolving of dyestuffs	Dyestuff solubilising and hydrotropic agents	Promotion of the dissolution of dyestuffs in water	Alcohols, polyols, fatty alcohol ethoxylates, esters
Dissolving of dyestuffs	Dispersing agents; protective colloids	Promotion of the formation and stability of dyestuff and pigment dispersions	Naphthalene sulfonic acid formaldehyde condensates, naphthaline sulfonates, lignosulfonates, fatty alcohol ethoxilates, alkylsulfonates, alkylaryl sulfonates, polyacrylates
Exhaust dyeing, padding processes	Wetting agents De-aeration agents	Increase of wetting capacity of the dye liquors; improve of dye penetration in padding processes; increase of dye absorption	Alkyl sulfates, alkane sulfonates, alkylaryl sulfonates, salts of sulfosuccinic acid esters, fatty alcohol ethoxilates, alcohols of higher valence, phosphoric acid esters, hydrocarbons, sequestring agents
Levelling	Retarding agents Migration agents Compensating agents Penetrating agents	Promotion of an even distribution of dyestuffs in the textiles	Alkyl -, alkyl aryl -, alkyl amine - and alkyl aryl amine ethoxylates, fatty acid esters and amides, fatty acid ethoxilates, fatty acid condensates, sulfonated PES-derivatives, polyvinyl pyrrolidone, quaternary ammonium salts, alkyl sulfates, alkyl aryl sulfonates
Exhaust dyeing (esp. PES, PES/WO)	Carriers	Acceleration of dye absorption, dye diffusion esp. for PES and PES/WO dyeing	Aromatic hydrocarbons, chlorinated aromatic compounds, benzoic acid esters (benzylbenzoate) phthalic acid esters, alkyl phthalimides, alkylphenolethoxilates
Skein dyeing of piece goods	Crease preventing agents	Crease preventing esp. during skein-dyeing of piece goods	Polyglykolethers, polyamide, polyacrylates, fatty alcohol ethoxilates, phosphoric acid esters, fatty acid esters
Exhaust dyeing	Dyestuff protecting agents, boildown protecting agents	Protection of dyestuffs during application from destruction by foreign matters with a reducing effect	Buffers and/or oxidizing substances (nitrobenzene sulfonate), urea, alkylaryl sulfonates
Padding	Padding auxiliaries Antimigration agents Antifrosting agents Wet pick-up increasing substances	Prevention of undesired migration of dyestuffs in or onto the textile. Prevention of frosting effects in pad-steam processes. Increase of dye yield in reactive pad batch processes.	Polyacrylates, polyacryl amides, EO/PO-adducts, alkyl phosphates, alkyl aryl ether sulfates, alginates, polyacrylates, EO/PO-adducts, guar derivatives, polyacrylamide polymers and copolymers. Foaming surfactants as ethylene oxide adducts. Polyacrylates, EO/PO adducts, alkyl aryl ether sulfates.
Continuous dyeing, printing	Fixing acceleration for continuous dyeing and printing	Acceleration of dye fixation and diffusion, increase of dyestuff yield	Aromatic ethers, fatty acid ethoxylates, polyglycols
After-treatment	After-treatment agents for fastness improvement	Improve of rubbing fastness, wet fastness and light fastness	Soaping after-treatment with detergents or dye-affinitive polymers.

Process	Auxiliary	Effect	Chemical
			Cationic fixing agents for direct and reactive dyes (polyquaternary ammonium compounds, cationic formaldehyde condensates. Polysulfonates for improvement of polyamide dyeing with anionic dyestuffs. Reducing agents for PES. Heterocyclic compounds to improve light fastness (benzophenone, benzotriazole, benztriazine derivatives) Organic copper compounds resp. benzophenones for improvement of light fastness of PA resp. PES
Soaping after-treatment with detergents or dye-affinitive polymers. Cationic fixing agents for direct and reactive dyes (polyquaternary ammonium compounds, cationic formaldehyde condensates. Polysulfonates for improvement of polyamide dyeing with anionic dyestuffs. Reducing agents for PES. Heterocyclic compounds to improve light fastness (benzophenone, benzotriazole, benztriazine derivatives) Organic copper compounds resp. benzophenones for improvement of light fastness of PA resp. PES	Bonding agents (also for pigment dyeing)	Fixing of inorganic and organic pigments onto the textiles(pigment printing)	Film-forming substances (styrene butadiene copolymers, polyacrylates, acrylate copolymers, polyurethane
Printing paste manufacturing	Thickeners	Adjusting of viscosity required in printing pastes	Alginates, galactomannanes, modified starch, polyacrylates, polysaccharide combinations, additives, esp. mineral oils
Printing paste manufacturing	Emulsifier	Dispersion of the pigments in the printing paste	Alkylarylethoxilates (APEO), fatty alcohol ethoxilates, isopropanol, Nmethylpyrrolidone
Pigment printing	Fixation agents	Crosslinking of bonding agents	Melamine derivatives, urea formaldehyde condensates
Printing	Agents to remove printing thickeners	Removal of printing thickeners	Alkylamine ethoxilates, fatty acid ethoxilates, fatty alcohol ethoxilates
Printing	Printing and edge adhesives	Printing adhesives fasten the goods to be printed onto the printing blanket Edge adhesives (edge stiffening agents) for the hardening of edges, so that they do not role up in case of treatment in broad	Water-soluble adhesives (starch, starch derivatives, vegetable gum, polyvinyl alcohol, polyvinylcaprolactam, polyacrylate etc.). Water-insoluble compounds (polyvinyl acetate, polyacrylic acid esters).

Process	Auxiliary	Effect	Chemical
		form (also used in pre-treatment and dyeing)	Polyvinyl alcohol, polyvinyl chloride, polyacrylic acid esters, polyvinyl acetate
Dyeing and printing	Oxidizing agents	Oxidizing of reduced forms of vat dyes, leucoester, vat dyes, and sulfur dyes Stripping (removal) of dyes and auxiliaries from the fibre	Peroxo compounds, sodium perborate, sodium persulfate, sodium chromate, salts of mnitrobenzene sulfonic acid, bromite, sodium chlorite
Dyeing and printing	Reducing agents	Reduction of vat and sulfur dyes in order to transform them into the water soluble form Removal of dispersion dyes (reductive after-treatment) Destroy of dyes in case of faulty dyeing (stripping)	Vat Dyes: sodium dithionite, sulfinic acid derivatives Sulfur dyes: sodium sulfide, sodium dithionite, glucose and mixtures thereof. Sodium dithionite, thiourea dioxide. Sodium dithionite, sodium or zinc formaldehyde sulfoxylates, thiourea dioxide
Discharge printing	Discharging agents Discharging assistants	Discharging agents are printed onto a pre-dyed textile material for the destruction of the dyes and thus cause a pattern	Reducing and oxidizing agents (see above) Anthraquinone derivatives
Dyeing, resist printing	Resist agents	Reduced or completely prevention of dyeing/printing	Dyeing: inorganic salts, tannins, alkyl aryl -, aryl-, alkane sulfonates, aromatic sulfonates, anionic or polyanionic compounds Printing: aluminium and tin salts, alkali compounds
Dyeing and printing with mordant dyes	Mordants	Improvement of dye affinity of the fibre	Quaternary ammonium compounds, Al-, Cr-, Fe-salts
Dyeing, colour correction	Brightening agents	Partial removal of the dye already absorbed and fixed	Polyvinylpyrrolidone, polyglycol ether, cellulase, alkyl aryl sulfonates, alkyl amine ethoxylates, reducing agents and oxidizing agents
Dyeing, fibre protection	Fibre-protective agents	Prevention or reduction of damage to the fibre during dyeing, finishing	Protein hydrolysates, polyglycol ether, protein fatty acid condensates, lignosulfonates, formaldehyde eliminating products (urea derivatives), guanidine derivatives
Dyeing in general	pH-regulators, acids and alkali dispensers	Adjust/control pH	Organic acids, esters, buffering salts
Dyeing in general	Salts	Increase of substantivity for reactive and direct dyes; levelling effect on acid dyes etc.	Sodium chloride, sodium sulfate etc.
Dyeing in general	Acids/alkali	Adjust pH	Organic acids (mainly acetic acid, formic acid, oxalic acid), inorganic acids (sulfuric acid, hydrochloric acid); sodium hydroxide, ammonia (in water), sodium carbonate
Finishing			
Optical brightening	Fluorescent brighteners	See pre-treatment	
Easy-care	Agents for the improvement of crease and shrink resistance	Increase of crease recovery and/or dimensional stability of textile materials	Dimethylolurea and dimethylolurea-derivatives, 1,3-dimethylol-4,5 dihydroxyethylene urea and –

Process	Auxiliary	Effect	Chemical
	Additives Catalysts		derivatives, melamine derivatives, carbamates, cyclic urea compounds. Polyethylene dispersions, silicone emulsions. Metal or ammonium salts and preparations of acids or alkalis.
Handle	Handle imparting agents		
	Weighting agents	Increase the basic weight of textiles	Pigments (kaolin, talcum); soluble compounds (urea, glycerine, salts)
	Filling and stiffening agents	Impart of a full handle and increase of stiffness (bending modulus)	Polyacrylates, polyvinyl acetate, polyurethane, polyvinyl alcohol, ethylenevinylacetatecopolymers, starch, modified starch
	Softening agents	Impart of a soft handle	Fatty acid condensation products, alkanolamides, waxes, paraffines, polysiloxanes, polyethylene, quaternary ammonium compounds
Anti-electrostatic	Anti-electrostatic agents	Prevention of electrostatic charging	Ethoxylation products of fatty acids, alkane sulfonates, alkyl aryl sulfonates, phosphoric acid esters, quaternary ammonium compounds, alkylamine oxides
Repellents	Water repellents	Impart of a water-proof finish	Fluorocarbon resins, polysiloxanes, paraffins together with aluminium, zirconium and chromium compounds,
	Oil repellents	Impart of an oil-repellent finish	Fluorocarbon resins
	Soil repellents	Improve of soil repellent properties and removal of impurities	Polysiloxanes, fluorocarbon resins
	Soil release agents	Improve of soil release from textiles	Fluorocarbon resins, polyacrylates, fatty acidcondensation products, polyurethane
Felting	Felting agents (animal fibres)	Promotion of felting during the milling operation	Fatty alcohol ethoxilates, alkyl sulfonates, fatty acid condensation products
Anti-felting	Anti-felting agents (animal fibres)	Reducing of shrink during washing	Reducing or oxidizing agents, chlorocyanurate, polysiloxane, polyurethane, polyamideepoxide copolymers
Lustre	Lustring agents	Impart or increase of lustre (with or without connection to a mechanical treatment)	Emulsions of paraffins, waxes, polyolefins, polyglycols or polysiloxanes
	Delustring agents	Reduction of lustre	Pigments
Non-slip, ladderproof	Non-slip, ladderproof, anti-snag agents	Reduction of the slipping of various yarn systems and of ladders in knitwear. Prevention of snags in hosiery and other ready-made goods of continuous filament yarns	Modified silicic acid, polyvinyl acetate, copolymers, acrylatestyrol copolymers
Flame resistance	Flame retardants	Reduction of inflammability and combustibility	Inorganics (e.g. ammonium salts), antimony trioxide in combination with halogenated synergists (chloroparaffins, brominated compounds), reactive P-organic



Process	Auxiliary	Effect	Chemical
			compounds (e.g. derivatives of phosphonic acid dimethylester, derivatives of tetrakishydroxmethylphosphonium chloride, cyclic phosphonic acid esters)
Antimicrobiotics (rot-proofing, mould prevention)	Antimicrobiotic agents	Protection against micro-organisms	Zinc organics, benzimidazolederivatives, triclosane, isothiazolinone, chlorophene derivatives
Chemical bonding of non-wovens	Binder	Promotion of fibre bonding Additives	Polymers of acrylic acid esters, acrylonitrile, ethylene, butadiene, styrene, vinyl chloride, vinyl acetate. Latex, starch etc. Polyethers, N-methylol compounds etc.
Coating	Coating agents	Production of adhesive layers on textile fabrics	Polymers of vinyl chloride, acrylic acid esters, acrylonitrile, ethylene, butadiene, styrene, vinylidene chloride, vinyl acetate. Natural latex, additives, filling materials
Laminating	Laminating agents	Bonding of two or more textile fabrics with other fabrics or foils	Natural or synthetic latexes, polyvinyl acetates, polyurethanes, polyacrylates, cellulose esters, polyethylene, polypropylene, polyvinyl chloride, additives
Textile auxiliaries for multi-purpose use	Wetting agents	Increasing of wetting power	Alkyl sulfates, alkane sulfonates, alkyl aryl sulfonates, alkyl ether sulfates, alkyl esters of sulfosuccinic acids, ethoxylation products, phosphoric acid esters
	Anti-foaming agents	Prevention of foam in sizing, pre-treatment baths, printing pastes, dye baths and finishing baths	Phosphoric acid esters, hydrocarbons, high molecular alcohols, silicon and fluorine derivatives
	Foaming agents	Generation and stabilizing of foam if foam application is used	Sodium dioctylsulfosuccinate, ethoxilated tridecylalcohole
	Detergents, dispersing and emulsifying agents		Soaps, alkyl sulfonates, alkyl aryl sulfonates, alkyl ether sulfates, EO-PO adducts, fatty alcohol ethoxilates, alkyl aryl ethoxilates
	Spotting agents	Removal of spots	Surfactants, solvents (hydrocarbons, chlorinated solvents)
After-treatment in yarn and fabric dyeing, raising, emerizing	Conditioning agents	Influencing of frictional behaviour and handle softening effect)	See also preparation agents and softening agents; quaternary ammonium compounds, ethoxylation products of fatty acid- fatty amines etc. polysiloxanes, waxes, paraffines
Scouring, bleaching, mercerising, causticizing, desizing, dyeing, and printing.	Complexing agents	Complexing of heavy metals	Polyphosphates, phosphonates, polycarboxylates, (polyacrylates, polyacrylate-maleinic acid copolymers), sugar copolymers, hydroxy-carboxylic acids, amino carboxylic acids

Anionic surfactants

Anionic surfactants commonly used in textile processing are:

- sulphates (e.g. alcohol ethoxysulphates, alkanolamides sulphates, sulphated vegetable oils)
- sulphonates (e.g. alkylbenzene sulphonates, sulphonated vegetable oils, naphthalene sulphonates, ligninsulphonates)
- alkyl ether phosphates
- carboxylates (fatty acid condensation products, alkali salts of fatty acids).

The linear, more biodegradable compounds are the most commonly used (e.g. alkylbenzene sulphonates, fatty alkyl sulphates, etc.). Examples of recalcitrant anionic surfactants are the common lignin sulphonates and condensation products of naphthalene sulphonic acid with formaldehyde, which are widely used as dispersants for vat, sulphur and disperse dyes.

Anionic surfactants have several advantages: they are good oil emulsifiers and dye dispersants, they are excellent wetting agents and they are not expensive. In turn, they generate high levels of foam, and sulphate surfactants can be sensitive to calcium and magnesium.

Cationic surfactants

Cationic surfactants are relatively uncommon in textile processing. One example is quaternary ammonium compounds (salts) used as retarders for cationic dyes, which are water-soluble recalcitrant substances. Cationic surfactants have by far the highest toxicity of all classes of surfactants.

Amphoteric surfactants

Amphoteric surfactants are not widely used in the textile industry. Their main advantage is the fact that they can be used in alkaline and acidic media and in combination with either cationic or anionic surfactants.

Quaternary ammonium compound derivatives are very rarely applied, while other lowtoxicity types are increasing in use. Examples are:

- betaine derivatives

- imidazolines

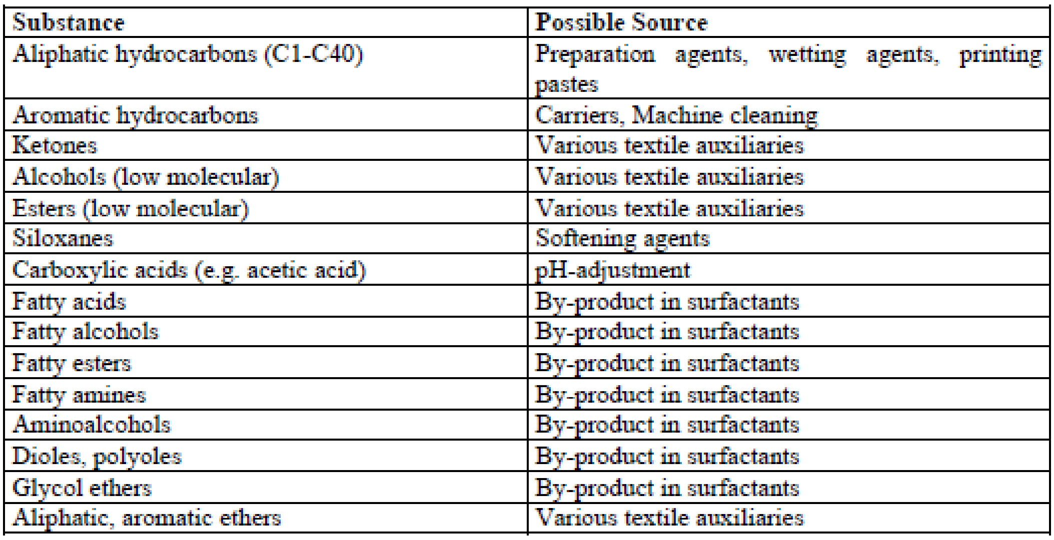
- modified fatty amino ethylates (they have very good emulsifying and dissolving capacity for removing oligomers in the reductive cleaning of polyester fibres).

Amphoteric surfactants are expensive and their use is required only in specialised situations where wide ranges of compatibility are needed.

ANNEX VIII: Typical substances in the off-gas (annex prepared within a German BMU GIZ Project with Thailand)

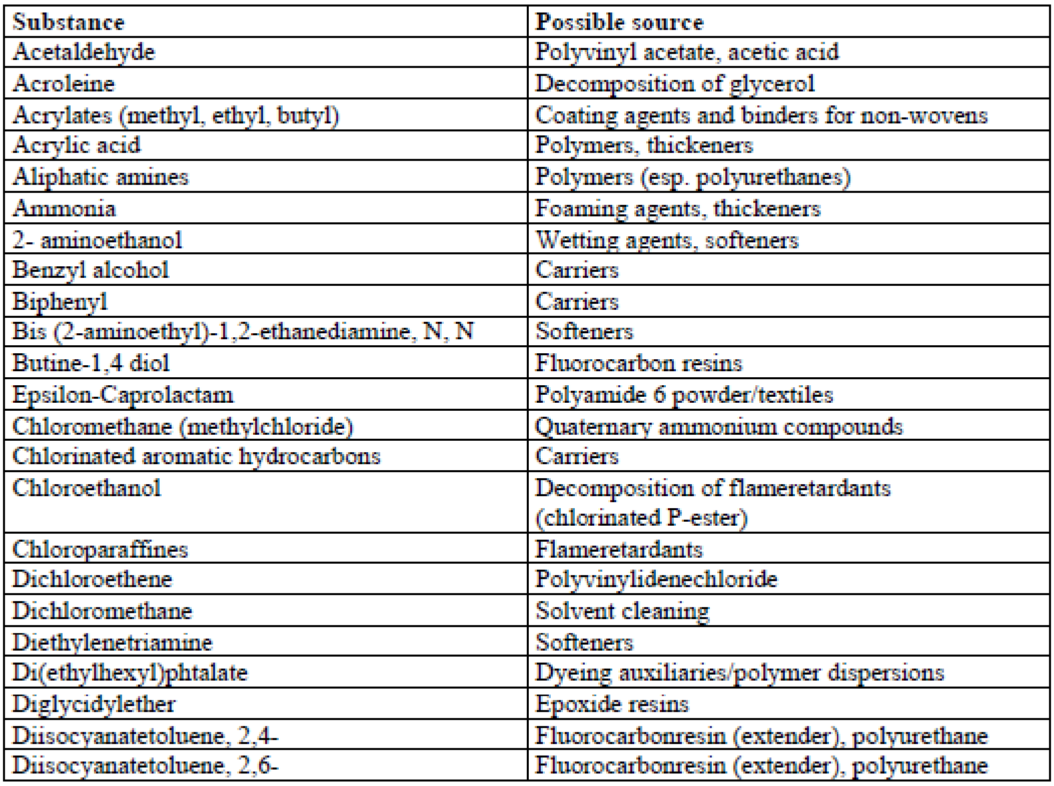
Off-gas in textile finishing can be loaded with various chemical substances. Depending on their volatility the active ingredients in auxiliaries, impurities and by-products in the formulations as well as reaction products of these substances are to be detected in the off-gas. The following tables give an overview on the most important substances to be detected in finishing, printing, and coating processes.

The classification concerning less respectively more dangerous properties follows German and European legislation.



Substance	Possible Source
Aliphatic hydrocarbons (C1-C40)	Preparation agents, wetting agents, printing pastes
Aromatic hydrocarbons	Carriers, Machine cleaning
Ketones	Various textile auxiliaries
Alcohols (low molecular)	Various textile auxiliaries
Esters (low molecular)	Various textile auxiliaries
Siloxanes	Softening agents
Carboxylic acids (e.g. acetic acid)	pH-adjustment
Fatty acids	By-product in surfactants
Fatty alcohols	By-product in surfactants
Fatty esters	By-product in surfactants
Fatty amines	By-product in surfactants
Aminoalcohols	By-product in surfactants
Dioles, polyoles	By-product in surfactants
Glycol ethers	By-product in surfactants
Aliphatic, aromatic ethers	Various textile auxiliaries

Table 1: Substances with less dangerous properties which may be present in waste gas



Substance	Possible source
Acetaldehyde	Polyvinyl acetate, acetic acid
Acroleine	Decomposition of glycerol
Acrylates (methyl, ethyl, butyl)	Coating agents and binders for non-wovens
Acrylic acid	Polymers, thickeners
Aliphatic amines	Polymers (esp. polyurethanes)
Ammonia	Foaming agents, thickeners
2- aminoethanol	Wetting agents, softeners
Benzyl alcohol	Carriers
Biphenyl	Carriers
Bis (2-aminoethyl)-1,2-ethanediamine, N, N	Softeners
Butine-1,4 diol	Fluorocarbon resins
Epsilon-Caprolactam	Polyamide 6 powder/textiles
Chloromethane (methylchloride)	Quaternary ammonium compounds
Chlorinated aromatic hydrocarbons	Carriers
Chloroethanol	Decomposition of flameretardants (chlorinated P-ester)
Chloroparaffines	Flameretardants
Dichloroethene	Polyvinylidenechloride
Dichloromethane	Solvent cleaning
Diethylenetriamine	Softeners
Di(ethylhexyl)phtalate	Dyeing auxiliaries/polymer dispersions
Diglycidylether	Epoxide resins
Diisocyanatetoluene, 2,4-	Fluorocarbonresin (extender), polyurethane
Diisocyanatetoluene, 2,6-	Fluorocarbonresin (extender), polyurethane

Substance	Possible source
N,N-Dimethylacetamide	Fibre solvent (m-aramide)
Dioxane, 1,4-	Surfactants (ethoxilated products)
Diphenylmethane-2,4 diisocyanate	Extender, polyurethane
Diphenylmethane-4,4' diisocyanate	Extender, polyurethane
Dipropylenetriamine	Softeners
Acetic acid-(2-ethoxiethyl)-ester	Softeners/fluorocarbonresins
Ethoxyethanol	Softeners/fluorocarbonresins
Ethanedialdehyde (glyoxal)	Crosslinkers
Ethylenediamine	Softeners
Fluoroorganics, lowmolecular	Fluorocarbon resins
Formaldehyde	Crosslinkers, conservation agent, stenter off-gas
Formic acid	Various textile auxiliaries
Hexamethylendiamine	Polycondensationproducts
Hexamethylenediisocyanate	Fluorocarbon resins, polyurethane
Hexanone, 2-	Fluorocarbon resins
Hydrogen chloride	Catalyst
Isocyanatomethyl-3,5,5-trimethylcyclohexyl-Isocyanate,3	Fluorocarbon resins, polyurethane
N-Methylpyrrolidon	Fibre solvent (m-aramides), machine cleaning
N-alkylmorpholine	Non wovens coating
Oxalic acid	Bleaching auxiliary
Tetrachloroethene	Dry cleaning
Thiourea	Dyeing auxiliary
Triethylamine	Special crosslinkers
Tricresylphosphate	Flameretardants
Trimethylphosphate	Flameretardants
Tin derivatives, organic, inorganic	Fluorocarbon resins, Hydrophobing agents, biocides
Vinylacetate	Polyvinyl acetate

Table 2: **Substances with more dangerous properties which may be present in waste gas**

Substance	Possible source
Arsenic trioxide/antimonytrioxide	Flameretardants
Dimethylsulfate	Quaternary ammonium compounds
Ethylenimine	Flameretardants
Acrylonitrile	Polymer dispersions
1,3-Butadiene	Polymer dispersions
2-Vinylcyclohexen	Polymer dispersions
Epichlorohydrine	Polycondensation products
1,2-Epoxypropane (propyleneoxide)	Surfactants (propoxilated products)
2,3-Epoxy-1-propanol	Some antistatics
Ethyleneoxide	Surfactants (ethoxilated products)
Vinylchloride	Polymer dispersions (PVC)
Acrylamide	Reactive polymers, flameretardants
Butanoneoxime	Fluorocarbon resins, polyurethanes
Pentachlorophenol	Pesticides
Propyleneimine	Flame retardants and polyurethane crosslinker
N-vinylpyrrolidon	Polyvinylpyrrolidone dispersions

Table 3: **Substances with cancerogenic properties which may be present in waste gas**

Overview on single substances in emissions of processes in Germany in finishing processes

Note: To obtain this emission level generally the application to emission optimized finishing recipes is necessary!

Single substance	Source	Chemical description of auxiliary	classification according to TA Luft	Emission factor [g Substance/kg Textile]	Mass flow [kg/h]	Machine
1,3-Butadiene	Coating	k.A.	5.2.7.1.1 Kl. III	0,42 mg/m^{3}N 0,75 mg/m^{3}N	1,4 g/h 2,0 g/h	Pre-dryer Main dryer No ARA
1,3-Butadiene	Cotton	-	5.2.7.1.1 Kl. III	0,2 mg/m^{3}N	0,5 g/h	Singe with scrubber (burner emission)
2,4-TDI	Flame coating	Polyurethane	5.2.5 Kl. I	1,83 mg/m^{3}N 4,57 mg/m^{3}N	0,0049 0,0122	Process 1 Process 2 No ARA
2,6-TDI	Flame coating	Polyurethane	5.2.5 Kl. I	2,85 mg/m^{3}N 3,59 mg/m^{3}N	0,0076 0,0096	Process 1 Process 2 No ARA
4-Vinyl-Cyclohexene	Coating	k.A.	5.2.5 Kl. I	1,8 mg/m^{3}N 3,3 mg/m^{3}N	0,003 0,011	Pre-dryer Main dryer ARA
4-Vinyl-Cyclohexene (2)	Synthetic Latex	Butadiene-Copolymer	5.2.5 Kl. I	0,0085	0,011	After WRG
Acetyl aldehyde	Aramide fibre	-	5.2.5 Kl. I	0,016 0,058	0,006 0,021	Process 1 Process 2 No ARA
Acetyl aldehyde (2)	Cotton fibre	-	5.2.5. Kl. I	0,4 mg/m^{3}N	0,001	Singe with scrubber
Acryl amide	Schaumbeschichtung	Acryl-Copolymer	5.2.7.1.1 Kl. II	< EG (0,0021)	< EG (2,62 g/h)	After WRG
Acryl amide	Migrationsinhibitor	Polyacrylamid	5.2.7.1.1 Kl. II	< EG (0,0003)	< EG (0,36 g/h)	After WRG
Acryl nitrile	Coating	k.A.	5.2.7.1.1 Kl. II	< EG (0,008 mg/m^{3}N) 0,71 mg/m^{3}N	< EG (0,017 g/h) 1,8 g/h	Pre-dryer Main dryer No ARA
Acryl nitrile (2)	PAN fibre	-	5.2.7.1 Kl. II	20,7 mg/m^{3}N	22,1 g/h	Singe
Acrylic acid	Thickener Flame retardant	Acrylic acid, Acrylic amide copolymer Antimon-trioxide -Dispersion on acrylate basis	5.2.5 Kl. I	< EG; 0,003	< EG; 0,002	Raw gas before ARA
Benzene	Coating	k.A.	5.2.7.1.1 Kl.III	0,046 mg/m^{3}N 0,64 mg/m^{3}N	0,15 g/h 1,7 g/h	Pre-dryer Main dryer No ARA
Benzene (2)	-	-	5.2.7.1.1 Kl.III	0,005	0,001 g/h	After WRG; (emission probably caused due to bad adjusted burner)
Benzene (3)	Foam coating	Copolymer	5.2.7.1.1 Kl. III	0,00099	1,25 g/h	After WRG
Benzene (4)	Flame coating	Polyurethane	5.2.7.1.1 Kl. III	0,52 mg/m^{3}N 0,86 mg/m^{3}n	8,7 g/h 13,7 g/h	Machine 1 Machine 2 No ARA
Bis-(2-Ethylhexylphthalat)	Carrier	-	5.2.5 Kl. I	0,0036	0,0022	No ARA
Bis-(2-Ethylhexylphthalat) (2)	Finishing		5.2.5 Kl. I	0,016 0,0018	0,0067 0,0022	Process 1 Process 2 After WRG
Butanonoxime	Oil repellent (Extender)	Fluorocarbon resin	5.2.5 Kl. I	< EG (0,03)	< EG (0,007)	No ARA

Single substance	Source	Chemical description of auxiliary	classification according to TA Luft	Emission factor [g Substance/kg Textile]	Mass flow [kg/h]	Machine
Butanonoxime (2)	Oil repellent agent (Extender)	Fluor0carbon resin	5.2.5 Kl. I	0,46 0,97 0,28	0,073 0,154 0,049	Process 1 Process 2 Process 3 No ARA
Butanonoxime (3)	Oil repellent (Extender)	Fluorocarbon resin	5.2.5 Kl. I	0,07	0,014	After WRG
Crotonaldehyde	Aramide fibre	-	5.2.5 Kl. I	0,0034	0,0013	No ARA
Cyan hydrogen	Flame coating	Polyurethane	5.2.4 Kl. II	9,5 mg/m^{3}N 25,6 mg/m^{3}N	160 g/h 408 g/h	Process 1 Process 2 No ARA
Cyan hydrogen (2)	Flame coating	Polyurethane	5.2.4 Kl. II	4,03 mg/m^{3}N 10,98 mg/m^{3}N	10,77 g/h 29,37 g/h	Process 1 Process 2 No ARA
Dibutylphthalate	Carrier	-	5.2.5 Kl. I	0,0119	0,0072	No ARA
Dichlorethane	Flame coating	Polyurethane	5.2.7.1.1 Kl. III	< EG (0,017 g/m^{3}N)	< EG (0,29 g/h)	Process 1 No ARA
Dimethylacetamid	Aramid fibre	-	5.2.7.1.3	0,160 0,84	0,059 0,312	Process 1 Process 2 No ARA
Dimethylformamide	Aramide fibre	-	5.2.7.1.3	0,0017	0,0006	No ARA
Dimethylphthalate	Carrier	-	5.2.5 Kl. I	0,037	0,0078	No ARA
Ethanolamine	Wetting agent	Modificated fat alcohol ethoxilate	5.2.5 Kl. I	< EG (0,03)	< EG (0,007)	No ARA
Methacroleine	Cotton fibre	-	5.2.5 Kl. I	0,3 mg/m^{3}N	0,001	Singe with scrubber
n-Butylacrylate	Flame retarding agent		5.2.5 Kl. I	< EG (0,0005)	< EG; (0,0003)	Raw gas before ARA
n-Butylacrylate	Coating agent	Polyacrylate	5.2.5 Kl. I	0,0003	0,00010	No ARA
Octamethyl-cyclo-tetrasiloxane	Plasticiser	Polysiloxane	5.2.5 Kl. I	0,051 0,018 0,0037	0,020 0,013 0,0033	Process 1 Process 2 Process 3 No ARA
Phenol	Coating	k.A.	5.2.5. Kl. I	< EG (0,2 mg/m3N) 0,8 mg/m^{3}N	< EG (0,01) 0,003	Pre-dryer Main dryer No ARA
Resorcin	Coating	k.A.	5.2.5 Kl. I	< EG (0,6 mg/m^{3}N) 2,4 mg/m^{3}N	< EG (0,001) 0,0051	Pre-dryer Main dryer No ARA
Tetrachlorethylene	Carry over from dry chleaning	Tetrahloro e-thylene	5.2.5 Kl. I	0,35 0,263	0,094 0,056	Process 1 Process 2 No ARA
Tetrachlorethylen (2)	Carry over by dry cleaning	Tetrachloro e-thylen	5.2.5 Kl. I	0,29 0,18	0,127 0,116	Process 1 Process 2 No ARA
n-Tributylphosphate	Coating	k.A.	5.2.5 Kl. I	< EG (0,3 mg/m^{3}N) 5,7 mg/m^{3}N	< EG (0,001) 0,012	Pre-dryer Main dryer No ARA
Triethylamine (1)	Agent for bonding of fibre and yarn	PU-Dispersion	5.2.5 Kl. I	< EG (0,07)	< EG (0,029)	No ARA
Triethylamine (2)	Silk finishing agent	PU-Dispersion	5.2.5 Kl. I	0,17 < EG (0,012)	0,037 <EG (0,003)	Raw gas Cleaned gas
Urotropine			5.2.5 Kl. I	< EG (0,4 mg/m^{3}N) 19,2 mg/m^{3}N	< EG (0,001) 0,041	Pre-dyer Main dryer No ARA
Vinyl acetate	Griffgebendes Mittel	Polyvinylacetat	5.2.5 Kl. I	< EG (0,0012)	< EG (0,00046)	No ARA

ARA = Exhaust gas cleaning unit
K.A. = No information available
EG = Limit of detection
WRG = After heat exchanger in waste gas

ANNEX IX: Overview on Waste in Textile Installations (annex prepared within a German BMU GIZ Project with Thailand)

Fibre waste

During the treatment of fibres before spinning, e.g. carding and finishing of fibres, untreated natural and man-made fibres arise.

Classification of waste:

04 02 21 waste from unprocessed textile fibres

Notes on recycling, utilization and disposal:

Waste fibre which has not been treated with chemicals can be returned to the production process or used in other processes (e.g. plant fibres can be used for cellulose production).

Otherwise, incineration or disposal to landfill, as a rule, together with municipal waste.

Yarn, cloth waste and sub-standard products

This waste comprises fibres and cloth that has already been treated (e.g. with spinning oil, coatings).

Classification of waste:

04 02 22 waste from processed textile fibres

Notes on recycling, utilization and disposal:

After treatment (e.g. washing) partial return to the production processes or use in other processes (e.g. cellulose production, cleaning rags, cleaning wool).

Otherwise, incineration or disposal to landfill, as a rule, together with municipal

Composite materials and carpet

Yarn and fabric that has already been coated (e.g. impregnation, flame-retardancy), laminated with man-made coating (e.g. waterproof material), or fixed with adhesives should be classified as composite material.

Classification of waste:

04 02 09 waste from composite materials (impregnated textile, elastomer, plastomer)

Notes on recycling, utilization and disposal:

Can be used in brickworks (as swelling agent).

Otherwise, incineration or disposal to landfill, as a rule, together with municipal waste.

Textile waste, cutting rests and sub-standard products

During textile production, fabric rests, which are coated or impregnated or uncoated, arise.

Classification of waste:

04 02 09 wastes from composite materials (impregnated textile, elastomer, plastomer)

04 02 22 wastes from processed textile fibres

Notes on recycling, utilization and disposal:

04 02 09: Can be used in brickworks (as swelling agent).

04 02 22: After treatment (e.g. washing) partial return to the production processes or use in other processes (e.g. cellulose production, cleaning rags, cleaning wool).

Otherwise incineration or disposal to landfill, as a rule, together with municipal waste

Untreated natural and man-made fibre waste

This waste arises during the treatment and manufacture of fibres or yarn, e.g. during combing of wool and finishing for spinning.

Classification of waste:

04 02 21 wastes from unprocessed textile fibres

Notes on recycling, utilization and disposal:

Return to the production process or use in other processes (e.g. plant fibres can be used for cellulose production).

Otherwise incineration or disposal to landfill, as a rule, together with municipal waste.

Grease, wax and dirt from washing and rinsing stages

Separated waste such as wool grease, salt, plant matter and soil arise in washing and rinsing baths, that are normally recycled. Sometimes, waste from wool washing processes is contaminated with pesticides and from cotton washing processes with herbicides.

Classification of waste:

04 02 10 organic matter from natural products (for example grease, wax) (the rule)

04 02 19* sludge from on-site effluent treatment containing dangerous sub-stances (exception)

Notes on recycling, utilization and disposal:

Wool grease is a valuable raw material and can be used, for example, in the cosmetics industry. In addition, the mixed sludge (grease, soil, salt) can be used in brick-works as swelling agent.

Otherwise, incineration, or if the organic content is low, disposal to landfill. If it does not contain dangerous substances, together with municipal waste.

Distillation residue, waste containing solvents

Fibres and textiles are sometimes washed with solvents (e.g. perchloroethylene). The solvents are recycled and sometimes reprocessed on-site. Distillation residue arises during this recycling process.

Classification of waste:

14 06 04* sludges or solid wastes containing halogenated solvents

14 06 05* sludges or solid wastes containing other solvents

Notes on recycling, utilization and disposal:

At present there are no known viable treatment processes.

Incineration in Hazardous Waste Incineration (HWI).

Spent adsorbents

When washing with solvents the extracted air is cleaned in activated carbon filters which have to be regularly renewed or regenerated.

Classification of waste:

19 01 10* spent activated carbon from flue-gas treatment

Notes on recycling, utilization and disposal:

Laden activated carbon filters can be regenerated and reused.

Otherwise, incineration.

Dyes and pigments from dyeing of textiles

Dye and pigment residue from the use of dye-baths, from the cleaning of machines and pipe work as well as out-of-date dyes and pigments. Especially during the dyeing of wool, metal compound dyes, which contain chrome and other metals, are used.

Classification of waste:

04 02 16* dyestuffs and pigments containing dangerous substances

04 02 17 dyestuffs and pigments other than those mentioned in 04 02 16

Notes on recycling, utilization and disposal:

Dye and pigment residue can be recycled to some extent.

Otherwise, incineration, or if the organic content is low, disposal to landfill. If it does not contain dangerous substances, together with municipal waste.

Dyes and pigments from fabric printing

Unused dyes and printing pastes from printing processes, sub-standard products and cleaning processes as well as out-of-date dyes.

Classification of waste:

04 02 16* dyestuffs and pigments containing dangerous substances

04 02 17 dyestuffs and pigments other than those mentioned in 04 02 16

Notes on recycling, utilization and disposal:

Dye and pigment residue can be recycled to some extent.

Otherwise, incineration, or if the organic content is low, disposal to landfill. If it does not contain dangerous substances, together with municipal waste.

Waste from finishing

During functional finishing, various substances are used. In particular, the waste from coating and laminating processes (e.g. man-made resin) may contain solvents. In addition, during these finishing stages, solvents (e.g. perchloroethylene) are required as carriers to support the coating processes.

Waste arises as production residue, from cleaning processes and as sub-standard products.

Classification of waste:

04 02 14* wastes from finishing containing organic solvents

04 02 15 wastes from finishing other than those mentioned in 04 02 14

Notes on recycling, utilization and disposal:

At present there are no known viable treatment processes.

Incineration (waste containing organic solvents), otherwise disposal to landfill. If it does not contain dangerous substances, it can be disposed of with municipal waste.

Note: In the textile industry, finishing covers a large number of treatment processes. If these were all considered in depth, waste would have to be classified in almost every waste category. Here, only waste from functional finishing has been classified.

Condensate containing oil

During the drying of fibres and textiles, condensate is produced which may contain grease from impurities in the fibrous material. As a rule, the condensate is treated in on-site waste water treatment plants.

Classification of waste:

13 08 02* other emulsions

Notes on recycling, utilization and disposal:

At present there are no known viable treatment processes.

Treatment in Chemical/physical and biological treatment (CPT) plants to separate the water phase. This can then be fed into the sewage system.

Sludges from waste water treatment

Precipitation sludges arise during precipitation and flocculation of waste water, as a rule, following the biological stage. They are mainly mineral and may contain heavy metals.

With on-site biological waste water treatment, sludges, that are mainly laden with organic matter, are produced.

Classification of waste:

04 02 19* sludges from on-site effluent treatment containing dangerous sub-stances (predominantly precipitation sludge)

04 02 20 sludges from on-site effluent treatment other than those mentioned in 04 02 19 (predominantly sludges from the biological stage)

Notes on recycling, utilization and disposal:

At present there are no known viable treatment processes.

Incineration (organic sludges), or disposal to landfill (precipitation sludges). If they do not contain dangerous substances, together with municipal waste.

Concentrate

Especially while reprocessing washing water, oil and greasy concentrate from membrane systems may arise.

Classification of waste:

19 02 07* oil and concentrates from separation

Notes on recycling, utilization and disposal:

At present there are no known viable treatment processes.

Treatment in CPT plants to separate the water phase. This can then be fed into the sewage system.

Evaporation residue

During the evaporation of waste water from washing raw wool, mixed sludges that contain wool grease, salt, soil and other dirt are produced.

Classification of waste:

04 02 10 organic matter from natural products (for example grease, wax)

Notes on recycling, utilization and disposal:

Can be used in brickworks as swelling agent.

Otherwise incineration, as a rule, together with municipal waste.