Ecodesign in the Textile Sector

Unit 02: Textile processes: spinning, weaving, finishing, cut-make-trim.

Paolo Ghezzo. paolo.ghezzo@centrocot.it

With this unit, students will be able to:

– Know main processes in the supply chain.
– Know main issues on environmental impacts of fabrics and cloth supply chain
– Know main databases for applying Best Practice in design with environmental awareness

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2.1. Introduction

The textile industry in its complex generates products range between the widest and most structured in the manufacturing world, for this reason, the textile sector, constituted both by big groups and many PMI, it is fragmented and heterogeneous, and it is one of the longest and most complex supply chain of the manufacturing industry.

The textile industry is therefore composed of a big number of subsectors that cover the entire production cycle, from the production or the harvest of the rough fibers, as described in Unit 01, to final goods.

This Unit begins where the last one ends, with the overview of the raw fibers, and it continues analyzing the transformation processes to obtain the final product, especially it deal the environmental issue of the semi-finished production chain.

This Unit analyzes the production processes of consumer goods, addressing in particular the environmental implications of the production chain of semi-finished products.

The Unit provides a basis for designing more responsible textiles and fashion and to guide production processes towards the adoption of production criteria with low environmental impact.

In addition, this Unit will describe the Best Available Techniques, offering suggestions to the company regarding the improvement of processes in compliance with European standards.

With reference to the complex world of the textile sector, in this Unit attention is paid to the various processing phases, which can be simplified, in the perspective of a linear process, as for how it is represented in table 2.1, with:

- spinning and weaving;
- enoblelling and finishing;
- the packaging of the final products or articles.

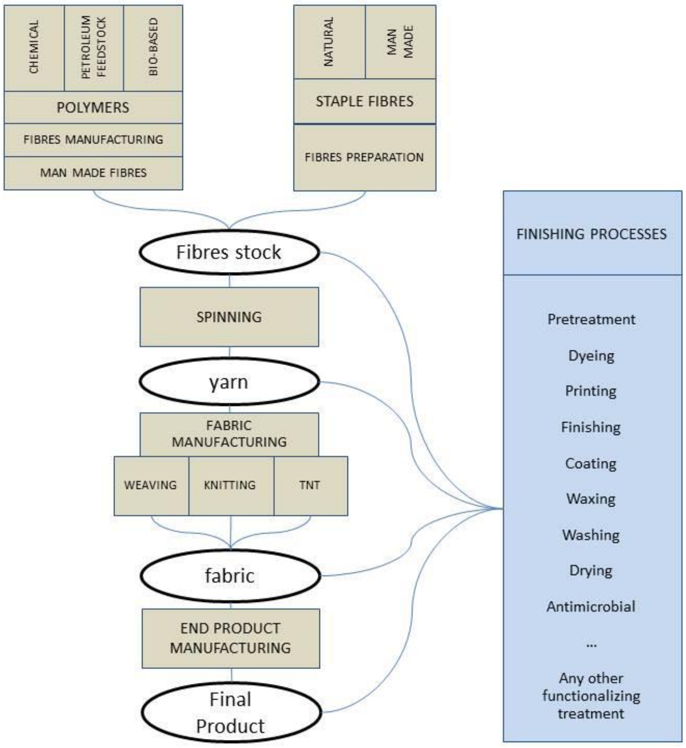

Table 2.1 common supply Chain of Textile Sector

The complexity of the sector can be simplified as a resulting from the sum of two main components, linked together with a double string and they interact with a reciprocal relationship:

- the variety of possible manufacturing processes, each of which is characterized by technical, chemicals and production aspects, and, consequently, also by aspects linked to environmental sustainability;

- the variety of possible materials, which they are characterized by specific properties and performances sought, these aspects and these different necessities can demand or exclude certain processes.

The table 2.2 summarizes the potential materials flows by stages, on the textile sector.

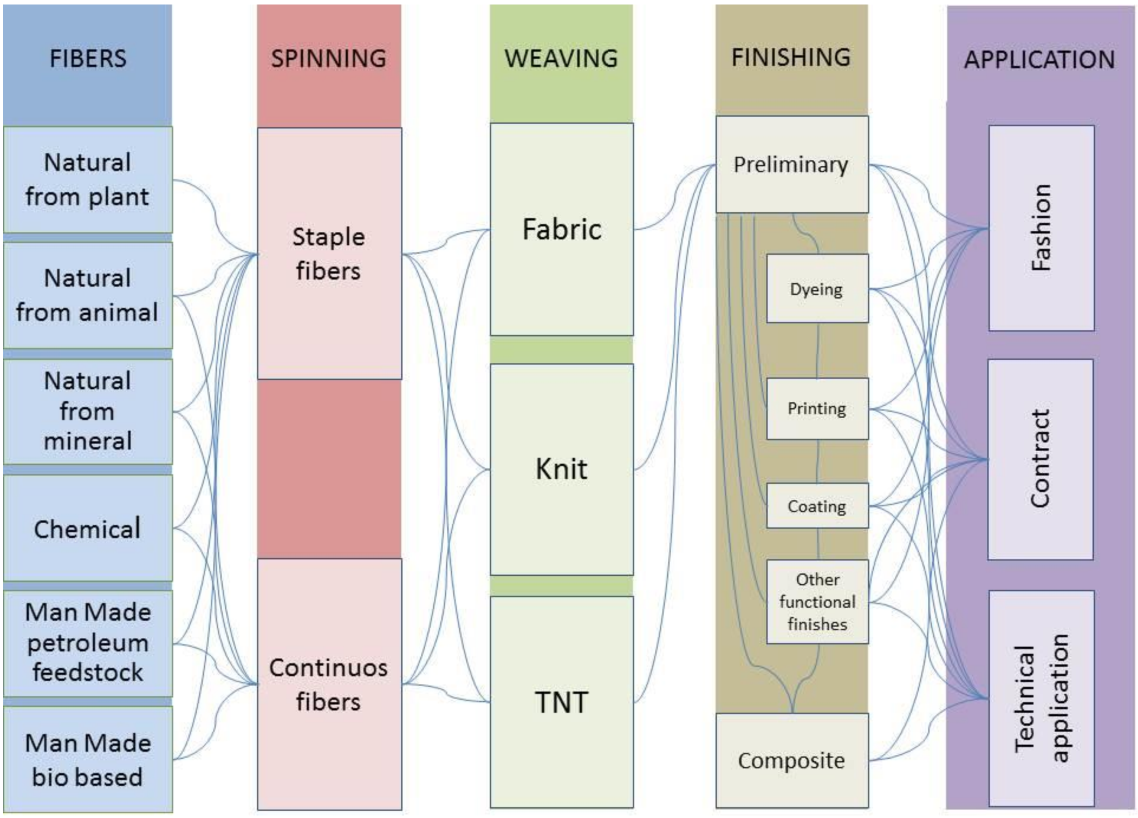

Table 2.2 diagram of material flows on Textile Sector

The main question, when designing products, is whether the use of special finishing processes can lead to a significant reduction in the environmental impacts of final products, both in economic terms and in terms of environmental balance.

As we will see in detail, each of the treatments available has costs in terms of possible pollutants and in terms of water and energy consumption. During the design phase, these issues should be well considered, referring both to available databases and to the availability of new products and technologies to be used to reduce possible environmental burdens.

2.2. Production and storage of rough materials

Raw natural materials usually are delivered to the mills in bales; they are stored and registered before bringing them to the production phase.

Basic chemicals, i.e. acids, alkalis and mass auxiliary chemicals are normally stored in a specific area, with the proper precautions for the security/safety. For some components, such as high-value and moisture-sensitive products or other factors (e.g. dyes and pigments), they are transferred directly to the preparation area ("color kitchen"). These components are generally powdery, so color kitchens are normally equipped with suction and filtration systems to ensure the health of workers and safety in general.

2.3 Spinning and Weaving

Spinning and weaving processes are mainly mechanical processes, and their most significant environmental impacts imply energetic and water consumption, generation of solid waste, dust and noise. If we consider the overall lifecycle of a textile product (look at Unit 06) they don't constitute a great environmental impact, especially because the use of auxiliary or chemical agents is reduced, if not in some cases it can be zero. In order to optimize production processes, auxiliaries are utilized as lubricants, oils, waxes or paraffin, size batches or stabilizers. These are then eliminated in the early stages of the finishing with scouring and specific washing.

2.3.1 Spinning: Man-Made fibres

Man-made fibers are typically extruded into continuous filaments (primary spinning), which can be used as they arise, undergo processing and finishing processes (such as ironing, twisting, texturing, dyeing, functionalizing finishing), or cut into staple (fragments of a defined length) to be blended and spun with natural fibers spinning in their traditional spinning processes.

Three principal methods for the production of the primary spinning are:

- melt spinning: the polymer is melted in a melt-extruder. The liquid is forced through the spinneret opening under pressure and cooled by a jet of air to form the filament. the melting process is suitable for thermoplastic fibers such as polyester, polyamide, polyolefins (e.g. polypropylene) and glass fiber;
- dry spinning: the polymer is firstly dissolved in a solvent and then it is extruded through a spinneret into a chamber of heated air or gas where the solvents evaporate 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 and then it is forced under pressure through the spinneret into a liquid bath in which the polymer is insoluble. As the solvent is dissipated the fiber 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 washing. Wet spinning is usually used to produce viscose and acrylic fibers.

At this point two ways are available:

1. use the produced continuous yarns, intervening eventually on the "form" in meaning of section of the fiber, or even additional treatments;
2. cut in length the fibers (staple fiber), to use the fibers in the traditional spinning of the discontinuous fibers, like cotton and wool. This second way is the most common to produce yarns blended with natural fibers, thanks to the "similarity" of the length of the singular fibers.

The most relevant environmental aspects related to the spinning processes for Man-Made fibers are the energy consumption and the use of chemical agents.

These indeed can be applied in various phases, in addition to the primary spinning, the secondary spinning, in relation to the processes to be carried out (i.e. winding, twisting, warping, etc.…). Therefore safety procedures are included to avoid the risk of wastewater pollution and gaseous emissions, in particular in the case of the production of the continuous fibers for the knitted fabric and the production of elastomeric fibers.

2.3.2 Spinning: natural or staple fibers

Natural fibers are derived from animal and plant sources and do not require the synthesis process seen for Man-made fibers. Before the proper process of manufacturing, fibers need to be washed and prepared, in order to remove the residues of the external elements and dirt. In some cases this phase is the most impactful of the entire spinning cycle, so we are going to do a fast overview of these themes:

Wool:

After the sheep shearing the wool is opened and dusted, and then scoured in order to remove the pollute and the excess grease on the fiber, with baths over 40°C, which is the melting temperature of the grease swint by dissolution, emulsification of the and suspension of dirt. These baths then require specific purification treatments to eliminate the load of potentially polluting substances before they leave the plant. Subsequently, the bleaching involves the use of hydrogen peroxide and formic acid or acetic acid in the bowl.

Other possible treatments include mothproofing treatment, with a synthetic pyrethroid insecticide and acetic acid or formic acid, and the sterilization with formaldehyde.

It is therefore evident that the wool preparation processes are characterized by a significant use of chemicals and water. The main environmental issue associated to the wool washing process is emissions to water, solid waste and air emission.

The removal of the contaminants from the fiber can produce waters of unloading, muds or, in case of incineration of these, gaseous emissions. There is the risk to introduce therefore in the environment the following polluting: organic substances, compounds containing sulphur and nitrogen, residues of detergents, auxiliaries and even veterinary medicinal products.

Cotton and bast fibers:

Rough cotton doesn't present big environmental impacts in the preparation: the fibers, supplied in compressed bales are cleaned to remove dirt particles and blended with fibers from different lots in order to guarantee the yarn homogeneity.

With the linen and some similar fibers, the extraction and the cleaning of the fiber of the stalk linen take place in different stages: it may cause wastewater with a high content of organic pollutants from the degradation of pectin and hemicellulose substances present on the fibrous material.

Silk:

For silk production, the silkworm is killed with steam and the filament is unwound directly from the cocoon. The filament resulting is then submitted to pretreatment processes in order to remove the sericin and the silk gum and other organic impurities. This phase uses water and chemicals, which must then be properly treated.

2.3.3 Staple fibres spinning

The spinning of the discontinuous fibers is divided according to the type of fiber because every kind of fiber has its own characteristics, such as length, title, fineness and other aspects. In general, there are two different kinds of processes: the spinning cycle for cotton and the spinning cycle for wool. The wool process in turn distinguishes between combed and carded; the cotton process instead provides for a more articulated series of operations: carding, combing, drawing, roving, spinning, twisting (if required) and winding; and it can be divided into three cycles (carded, combed and open end)

In the spinning processes may be used auxiliary chemical agents and they will have to be removed before the following phases, with the risk of emissions in wastewater or in the air. The main used agents are organic substance (mineral oils), hydrocarbon substances, ethoxylated alkyl phenols and biocides. With synthetic fibers, the amount of chemical agents substantially grows up to a 7% in weight for the elastomeric fibers.

2.3.4 Weaving, Knitting and Non-Woven fabrics

In this phase, conceptually it gets from linear dimension (yarn) to a surface (the fabric).

In the production phase of the fabrics, we can consider weaving, knitting and the production of non-woven fabrics.

These three families have different characteristics and processes, and they produce, consequently products with very different characteristics between them. In this Unit we won't enter in the matter of the available fabrics, it would be too large a field to analyse in a single unit, but we will focus on the most important environmental impacts related to their production, and how to adopt some precautions in the design phase to improve the sustainability.

The environmental impacts associated with the fabric manufacturing processes are fundamentally linked to the energy consumption of the machines and plants and to a reasonable consumption of chemical products that are loaded during the weaving process in order to facilitate the process. For example, in order to optimize the knitwear production it is often used to prepare the yarn with lubrication or waxing. The oil and the wax that remain on the final woven will then be washed during the first finishing treatments, thus generating a polluting load.

Overall the environmental impact of the weaving is higher than the one of the knitting, due to the increased number of production processes and the use of sizeing to strengthen the warp. The sizeing, once it is removed, due it is composed of natural starches or chemical agents, may implicate the pollution of wastewater, so not to impact on the environment chemical agents have to be recovered and neutralized in the wastewater treatment.

Anyway, in the last decades, the textile machinery manufacturers have directed the development of the machines in order to optimize the energetic efficiency, to reduce the consume of the auxiliary products and to reduce gas emissions.

Best practice in yarn and fabric manufacture includes:

- in spinning, ask suppliers to manufacture yarn with readily biodegradable lubricants;
- in knitting, ask suppliers to use water-soluble and biodegradable lubricants as substitutes for mineral oils;
- avoid woven fabrics where PCPs have been added as a size preservative;
- ask suppliers to substitute recyclable sizing agents for natural starches and use 'low add-on techniques' which minimize the amount of size used;

- if recyclable sizing agents are used, check with suppliers that size is recovered and reused;
- if unknown sizing agents are used, check with suppliers that size is removed with efficient techniques such as the oxidative route and ensure adequate effluent treatment;
- ask suppliers to combine scouring and desizing processes with bleaching to save chemicals, energy and water
- use alternative and innovative production processes, characterized by greater efficiency and reduced environmental impact...

Environmental impact can also a through the introduction of innovative production technology such as whole-garment or seamless knitting.

A typical example of the latest practice is seamless knitwear, which is able to create a single garment, three-dimensional, directly from the knitting machine, so it does not need the subsequent cutting and sewing processes. This process can speed up production times (by 30-40 %), reduce costs by eliminating garment packaging and reduce waste production.

2.4 Finishing

In order to become finished products, the fabrics have to go through some finishing processes, which aim at increasing the quality level of the products, at giving them their final identity and at endowing them with particular properties. The finishing processes represent the largest contribution to the environmental impact of the entire textile supply chain, in terms of water, energy and chemical agents consumption.

"Finishing processes" as described in figure 1, for convenience of explanation are described as consecutive to weaving, but actually they can be carried out, individual or just some few specific, in different stages of the production process (as in Unit 06 i.e. in which the "yarn dyed" is a dyeing of the yarn before weaving). Moreover, although spinning and weaving cycle are fairly standardized, the finishing phases involve a combination of processes more fragmented and articulated, as synthetized in table 2.1 and 2.2.

As mentioned, ennobling processes have the highest share of environmental impact, as they require water resources (e.g. for bathroom preparation and washing), energy (used for heating the bathrooms and drying the material) and the use of different chemical agents.

It is therefore mandatory to focus the macro areas in order to provide general indications on how to intervene in the design phase. During this Unit we provide such indications but, given the complexity of the subject, in the case of real production will be necessary to have a constant and continuous dialogue with experts in the specified field and with responsible person (or technician of finishing mills).

As mentioned above, the finishing processes are extremely articulated and diversified, based on the type of finished product to be obtained, the nature of the fiber used and the type of textile used (for example, an orthogonal fabric has different finishes from knitted fabrics, although some may be very similar or even the same).

The main factors influencing the finishing processes are:

- the kind of fiber: natural fibers such as cotton, wool, flax and silk require specific operations and chemical reagents, and their processing is more complex than that of Man-Made fibers. This fact is due to the fact that natural fibers have higher amount of substances that can interfere with later processing. However, Man-made fibers can contain preparation agents, water-soluble synthetic size and soil that needs strong pretreatment to be removed;
- the kind, status, geometry, and dimension of the textile substrates to be treated (flock, yarn, woven, knitted or non-woven fabrics) ;
- the amount of material to be treated, its state (such as if it is yarn or fabrics, or clothes) and the technology available. For example, continuous and discontinuous technologies are both available: for large quantities are more efficient the continuous processes; but for low quantity productions and small batches, discontinuous methods are economically affordable.

For practical reasons, we are going to gather together the processes into macro areas: pretreatments, dyeing and printing, finishings.

2.4.1 Pretreatment

Pretreatment processes are made in order to: remove foreign materials from the fibers; improve their characteristics such as uniformity, hydrophilicity and affinity for dyestuffs and finishing treatments; improve the ability to absorb dyes uniformly (i.e. mercerizing); relax the tensions in synthetic fibers in order to avoid dimensional instability and ripples that could influence the quality and performance of the finished product.

Cotton pretreatment includes various wet operations, usually: desizing, singeing, scouring, mercerizing, caustification, bleaching. Sometimes most of those are often combined together in one single step in order to faster the process and reduce resource consumption. The main environmental impacts associated with cotton pretreatment are related to the use of chemicals and water, energy consumption and emissions.

Desizing is the first step made on fabrics: it is used to remove sizing compounds and dirty results from previous processes. Desizing techniques are different and relate to the kind of sizing agent to be removed, that can be: starch-based sizing agents (water-insoluble sizes); water-soluble sizes; water-soluble and insoluble sizes. Starch-based size is a process based on the enzyme or other chemical treatment in order to be converted into a washable form. Frequently desizing is combined with bleaching in the same bath in order to reduce the number of steps. Water-soluble agents, on the other hand, require a rinsing bath with hot water and sodium carbonate; often the bath is added with some auxiliaries to increase its efficiency. Unfortunately, this step represents one of the most critical with regard to emissions into the environment due to the low biodegradability of compounds present in waste water.

Scouring or boiling-off process is made to extract the impurities present on the raw fibers such as pectins, fat and waxes, proteins, inorganic substances, sizes (when scouring is carried out on woven fabric before desizing), residual sizes and sizing degradation products (when scouring is carried out on woven fabric after desizing). The process is carried out using chemicals similar to those used in the subsequent bleaching process but in more drastic conditions to ensure a sufficiently strong removal effect.

Bleaching is used to produce white fibers and fabrics, or also to enhance brilliance for Man-made fibers; in addition, bleaching is necessary as a preparatory action for dyeing, especially for the most delicate colors, due to the fact that natural fibers, after scouring is still with its own original off-white color (ecru or off-white). Bleaching can be carried out on all kinds of make-ups (yarn, woven and knitted fabric). For cellulosic fibers, the most frequently used are hydrogen peroxide (H2O2); sodium hypochlorite (NaClO); sodium chlorite (NaClO2) are used for cellulosic fibers.

Mercerizing can be adopted on yarns and fabrics and knitted fabrics. Thanks to the action of caustic soda, it allows the swelling of the individual cotton fibers, so that the final effects are better mechanical strength and dimensional stability, greater luster of the cotton and increased absorption of the dyes. The process involves stretching the fabric combined with a bath in a solution of concentrated caustic soda. Although mercerizing baths can be recovered and reused in other preparation treatments, the process still generates a large amount of strong alkali that needs to be neutralized before being discharged into wastewater.

Singeing remove the surface fibers by passing the fabric over a row of gas flames and then immediately into a quench bath to extinguish the sparks and cool the fabric. Singeing is more common on cotton, cotton/PES and cotton /PA substrates. Since it requires only cooling water, singeing has no effect on the effluents, but can produce odors and emissions of dust and organic compounds; odorous substances can be destroyed using catalytic oxidation techniques.

Most environmental concerns are associated with the use of stabilizers due to their low bio-eliminability, and their ability to form very stable complex derivatives. Due to the fact that bleaching with sodium hypochlorite leads to organic halogen compounds, the use of sodium hypochlorite is now limited in Europe .

2.4.2 Dyeing and Printing

Dyeing is applicable to raw material at all stages of manufacture: from before spinning, to yarns, fabrics, and finished garments. So there are different techniques and, there are different dyes classes, due to the extremely different kind of materials. Depending on the condition of the material to be dyed, different dyeing techniques are available which can be alternative or substitutive to each other. In addition, depending on the type of dye, dyeing usually also requires auxiliary chemicals in order to optimize the process. The consumption varies in a range from 2g and 80g of dye for each Kg of finished textile.

Often dyeing requires intensive use of water and energy due to the temperatures needed for the process and the high ratio of liquor volume to weight of the goods to be dyed. After dyeing the unfixed dye and the auxiliary agents used needs to be removed by washing, incrementing so wastewater contaminated with pollutants, and energy consumption.

The dyeing process is therefore particularly intensive in terms of water, energy and chemicals, but in last years, the increasing sensibility regarding environmental issues, introduced lot of legal restrictions, in particularity on UE. This has led to the development of lot of technologies aimed at ensuring a balance between color performances (shades and fastness) and environmental sustainability.

One of the most important challenges in the future will be to maintain the dyeing characteristics (in aesthetic and performance terms) in accordance with environmental sustainability, in particular as regards disposal and bio-degradation of the chlorine/pigment itself.

R&D in the last decades has moved to obtain more stable and more manageable pigments, but pigments still have serious disposal problems. The colorants are difficult to degrade in the system of wastewater treatment and some degradation products are toxic. Some researchers have already been done to reduce the toxic components in the pigments and to produce cleaner and more environmentally friendly products.

Many steps to reduce the impacts of dyeing processes regard contaminated wastewater, and the reduction of toxic chemicals. Some progress has also been made in the chemical formulation of dyes and pigments. But the most important improvements have been achieved by technological developments in dyeing techniques, such as low-water dyeing technique that use conventional wet processing equipment but it eliminates pretreatment and washing-off processes; or the development of techniques to recover, reuse and ‘exhaust' dye baths. Other improved dyeing techniques are: electrochemical dyeing, through an electric current, enables to regenerate a spent dye bath in order to be recycled; techniques to dye substituting water with a super-critical carbon dioxide.

Another field can be the use of natural dyes, from plants, animals or shells: they provide environmental and social benefits like low carbon footprint and switch some work to rural communities, but, even though there is a growing question for natural components of the pigments, there are some difficulties hard to overcome: compared to traditional dyes the range of obtainable colors is considerably less, their resistances are scarce, costs are elevated and, for most of them the cultivation may demand a large area, snatching it from the alimentary production. All of this tends to relegate the turning back to natural dye, to markets niches particularly sensitive to environmentally sustainable, but not very extensive in terms of market volumes.

Furthermore, there isn't certainty that natural dyes are “safer”. Some studies conducted on the topic have detected that starting from natural materials, various toxics and harmful substances have been created during the process, this defeating the intention behind their use.

Despite there are few techniques than dyeing, printing is considered more complex due to there is a wide range of chemical agents such as classes of dyes or pigment, auxiliaries and thickening agents.

Most common processes are flat screen, roller, transfer and inkjet. Each of these techniques has both advantages and disadvantages in terms of production (speed and/or minimum quantity per batch), costs and, last but not least, environmental issues.

Concerning screen printing, impacts can be decreased by reducing print paste losses, reuse rinsing water for cleaning of screens and belts, and avoid PVC and phthalate-based printing formulations, in order to eliminate aromatic solvents, which are harmful if discharged in wastewater.

Moving on to inkjet printing, thanks to the propulsion of tiny droplets of dye or pigment, Ink-jet technology dose dyes on demand, and thus avoid print paste waste; in case of pigmented inks also solvents are avoided, and with them also volatile organic compound emissions, which would be necessary to dilute the dye in traditional processes.

In transfer printing, a particular paper is printed with volatile disperse dyes and then, through a thermal process, the print is transferred to the fabric by sublimation. This technique generates the advantages that avoid waste chemicals, it doesn't require washing-off and so it eliminates wastewater.

2.4.3 Other finishing

In addition to the processes mentioned above, textile products may also be subjected to finishing processes which improve certain specific aspects or bring about new aesthetic or technical properties. These processes involve a wide range of mechanical, chemical or combined techniques.

A largely part of this finishes can be applied in order to add value to the final goods, by reducing further environmental impacts, such as minimize washing launderings or enhanced product durability.

The main question is to assess how involving this treatment effectively will reduce further environmental impacts of final products, in other words, if it is worth the hassle.

Mechanical ones are thus defined because they are based on the use of physical (mechanical and thermal) actions and not on the use of chemical agents. Mechanical finishing includes calendering, a process in which the fabric is passed through heated cylinder pairs that compress and print it (in the case of custom engraving on one of the cylinders). Obviously this principle extends into several possible options, and as a final effect increases the density of the fabric and gives it designs or mounds and embossings.

Instead sanfor is a treatment that gives dimensional stability and it is based on a combined mechanical and thermal action that "forces" the fabric to fall back in warp.

The brushing consists in scratching the surface of the fabric, with rotating brushes that cause the emerging of fibers on the surface of the textile. There are different types of brushings, depending on the kind and the technical solution adopted, the intensity and generally take name based on the aspect that they conferred; someone instead, take the name of the manufacturer's machine. The most common type is the fleece, the sweatshirts, the thinner kind is obtained by carbon brushes, and some examples are the "peach" and the "Lafe".

Other mechanical finishes are available to increase the furry, fluffy or fuzzy aspects.

Considering chemical finishing, on the other hand, it is possible to identify some of the more common ones, such as those that allow to reduce the care and maintenance of finished garments (e.g. hydro- and oleo-repellent) or increase their resistance to different types of damage (e.g. flame retardant).

The most common finishes that reduce the washings of the end product are:

- water or oil repellency is provided by chemical finishings, such as wax coating, or based on perfluorinated chemicals. The latter are currently critical due to their high environmental impact and the process needs to be well calibrated in order to ensure low levels of hazardous agents or to find new alternative techniques;
- dirt resistant finishes by the adoption of water-repellent and oil-repellent principles, as silicone based products for water-soluble stains and synthetic resin

products. In the case of anti-slip finishes, the superficial fiber irregularities are saturated with white and translucent particles in order to make the fiber less affine to the extraneous substances and easier to clean;

- lotus effect: inspired by the lotus leaves that are able to slide the raindrops conveying the particles of dirt, this nanotechnological finishing combines the principle of non-stick and self-cleaning to the textile surfaces forming a subtle wrinkled structure, so the drops of dirt substances slip away;
- anti-mould finishings, especially for cellulosic fabrics, uses antiseptics and bacteriostatic products in order to prevent the growth of moulds grown that can be dangerous for health and create damages on fabric.

Another commonly used finishing is for the conferral of flame retardant properties. It is based on the use of chemical substances containing phosphorus, nitrogen, carbon and halogens capable of interfering with the ignition and propagation of the flame. However, it should be borne in mind that highly efficient substances, such as halogenated substances, have a high impact on the environment, and replacement technologies are therefore being sought and developed.

The most common functionalization finishes are:

- waterproofing: applying a thin film of synthetic resins the fabric becomes waterproof and in some cases also air-proof. Various techniques are available that confer different levels of resistance;
- another class of finishing concerns the protection from pathogens through the adoption of biocide substances such as triclosan, generally used on Nylon and polyester and their mixtures, applicable for coating. Also for this class of finishing in reality there are different techniques, different active ingredients, different stages of the production chain in which they are applicable. Therefore, the range of products is extremely articulated and differentiated also by type of expected performance.

A future treatment that is still under developing is plasma treatment. It is a process that modifies the surface of a fabric by using plasma elements (an ionized gas Effects can be calibrated by changing pressure, temperature, density, and ionization level. Plasma application could provide new economics and environmentally friendly methods for surface finishes such as increasing hydrophilicity; imparting hydro- and oil-repellency; increasing dye affinity and rate of dyeing; anti-felting; increasing dimensional stability; increasing printability; increasing adhesion properties. Currently being studied are processes for the generation of surfaces with the following properties: flame retardant, antistatic, antibacterial, mold resistant, biocompatible, resistant to oxidizing agents, UV and sunlight resistance.

The modifications induced by the plasma treatment have effect on the surface layers of the substrate and do not alter the general physical/mechanical properties of the material. Plasma technologies are considerate as energy-efficient, environmentally friendly and completely dry. As plasma treatment is a dry process, it does not use water or energy for solvent evaporation, and because the process implicates only the surface layers, and so it minimizes the number of chemicals used. Therefore plasma treatment is estimated to have very low environmental impact.

In addition, the use of some innovative and replacement processes can reduce the future environmental impacts of products, for example by reducing the amount of washing required in the use phase, or by increasing the life of the product.

As we have seen in previous processes, even in this case each of the available treatments entails has environmental impacts mainly based on water consumption and the use of chemical products, as well as the use of numerous chemical substances for the production of laminated fabrics, coated fabrics, etc... As mentioned, some products used to impart specific properties involve high environmental risks (perfluorinated, halogenated, etc.), but the alternative products developed so far do not always allow the same levels of performance to be achieved. The safety of textile products will be dealt with in more detail in units 4 and 7.

During the design phase these issues should be well-considered, referring both to available databases and their suppliers to get up-to-date information.

2.5 Cut Make-Trim

The preparation of the finished garments (clothing, furniture, etc.) after the fabric has been produced involves the final packaging process, i.e. all the necessary preparation, cutting and sewing processes. Even this phase is extremely wide and varied, for example, for a tablecloth this phase is simpler than the steps needed to make a tailored suit. There is another level of complexity in the case of composite textiles or technical textiles, due they became similar to mechanical materials, and are designated to further specific applications.

Technical or composite textiles constitute an additional level of complexity, because they are destined to enter other sectors, such as non-traditional machining or forming.

Generally, this operation are manual and do not require large impacts on the environmental, we can arise the most impacts are social and worker-related, most of the large companies carrying out this work are in developing countries due to low labor costs, with impacts related to the transport of raw materials and finished garments.

Each process must be analyzed on the overall characteristics of the product.

2.6 Environmental issues

The most important environmental problems for the textile supply chain are related to the generation of wastewater from chemical substances, water consumption and energy consumption. Emissions into the air, the production of solid waste and the generation of odors have a lesser impact.

Air emissions are relegated to the place where they are produced. There is good documentation on air emissions caused by different specific processes, so it is also possible to have the tools to minimize impacts.

This is not the case for emissions into water. The different waste water streams, from different processes, are mixed and produce a single effluent whose characteristics are the result of a complex combination of factors, especially fibers and residues from the chemical compounds used. In the European Union it is mandatory to treat waste water in order to eliminate the risk of contamination by pollutants, as we will see in detail in Unit 05.

It can be considered useful to identify some confined categories of textile system and to compare the amount of effluent between systems of the same category; it is possible to verify the provided data and to identify the macroscopic differences of the various activities. In the BREF (BAT Reference documents) are included considerations on the input/output for a certain number of categories representative of systems, starting with a detailed description of water (input and waste) and ending with a more specific analysis of the individual processes for which data are available. The most important results about some processes of particular importance are then reported themselves in the latest BREF review.

2.6.1 BAT: key role of good management

In order to achieve the highest level of environmental protection, the 1996 Directive 96/61/EC, also called "IPPC" (Integrated Pollution Prevention and Control), which establishes the general principles governing the obligations of industrial activities in order to take all appropriate preventive measures to ensure a high level of environmental protection, including waste management measures, efficient use of energy resources, and prevention of accidents.

Measures to prevent pollution are described in the Best Available Techniques (BATs), documents which, for each sector of activity, report all useful information in the so-called Brefs (BAT Reference documents) and are constantly updated by the European Commission.

The general practices of good management cover both the training of the employees and the definition of the well-documented procedures for the management of production facilities, the maintenance of the machines, the storage of chemicals and their use, handling, dosage and distribution.

A better knowledge of what is included in a process and what it produces is the essential component for a good management of the processes themselves. This implies, therefore, on the one hand, in-depth knowledge of textile raw materials, chemicals, electricity and/or heat, and water use, and on the other hand, control of emissions to air and water and of the type of waste that is generated.

The monitoring of the input and output of the processes constitutes the starting point to identify the available options and the priorities for improving both environmental and economic performance. The measure to improve the quality and the quantity of the chemicals used includes regular review and a periodic assessment of the formulations, an optimal production planning and the involvement of high-quality water in the wet processes

Systems for the automatic control of the operating parameter (for example temperature, time, chemical input) allow a more accurate control of the entire process for better production, with minimal increase of the chemical products and the auxiliary.

2.7 Overview on recycling and reuse

Recycling means the transformation process finalized to re-integrate the end life products in a new productive process and so extend their life in a new lifecycle.

The "reuse", instead, means the approaches when the end life goods have a lengthening of their lifecycle, without changes on original appearance, or when it enhances a new purpose manner and so the new goods are destined to new markets and new consumers.

There are two macro categories of the product that is being checked in the end-of-life treatment:

- “pre-consumption” regard the textile waste that come from the production of the spun and the woven, from the packaging processes of the items of clothing and retail.
- “post-consumption” when the textile waste arising from disused products because it is consumed or outdated.

The potential for the recovery of post-consumer waste is enormous and is considered not yet complete: the possibilities for recycling are almost unlimited. The end of life fabric could be transformed into a recycled product used in different industrial sectors, for example the production of insulating panels used in the automotive, nautical and furniture industries, producing undoubted advantages both in environmental and economic terms (for the reduction of disposal costs and generating a new value).

The cycles, the technical processes and all the items relating to recycling are focused on Unit 08.