CHEMICALS IN TEXTILE PRODUCTION

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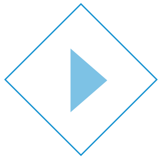
HOW TO USE THIS GUIDE

This guide is interactive. You can navigate onto the next and previous slide using the arrows on your keyboard.

The guide begins with a general overview of chemicals in production, and then examines the specific production stages. Clicking the respective links on the main textile production menu, will take you directly to that section of the guide.

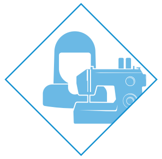
This button will return you to the main textile production process menu



This button will link you to a relevant online video

This button will link you to a relevant web content

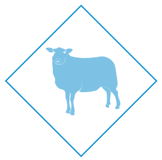
This icons will inform you who/what is at specific risk from exposure to chemicals



Factory workers

Consumers

Environment



Animals

CHEMICALS IN TEXTILE PRODUCTION

Chemicals are a major component of garment and apparel manufacture, from the production and processing of fibres and raw materials, through the fabric and garment assembly, to the transportation of the finished articles. These chemicals can pose a number of threats to the environment, and to the health of both the workers in the industry, and the end consumer.

In order to ensure that products are safe, workers are protected, and to reduce the impact of chemicals on the environment, it is important to have a clear understanding of the basic processes in the textile and garment production stages, and the use and function of chemicals in these processes.

This guide aims to give an overview of the presence and basic functions of chemicals in textile production, to consider the fate of chemicals, and suggest how harmful emissions could be minimised.

It begins with an **overview of chemicals in textile production**, explaining what components make up a chemical formulation, and explain the basic textile chemical flow, into and out of factories.

The **textile production process menu** follows this, where you can easily navigate to specific sections of the document by clicking on the specific parts of the textile production chain.

You are then guided through all stages of textile production, from fibre and yarn production, through fabric construction, and wet processing stages. At each stage the basic processes are explained, along with information on the specific chemicals.

Following this, the **waste water treatment process**, specific to textile wet processing is explained in detail.

Finally, consideration is given to **auxiliary and hazardous chemicals**, with information on their uses, and the associated hazards.

OVERVIEW OF CHEMICALS IN TEXTILE PRODUCTION

The chemicals that are deliberately used in textile processing fall into two broad categories:

Performance Chemicals

These are chemicals that are intended to stay on the final textile product to deliver colour, aesthetics, and performance – such as dyes and performance finishes. It is expected that the majority of any particular chemical that is applied will stay on the textile at the point of sale but, inevitably, some will not fix during application processes and will enter waste streams

Process Chemicals

These are chemicals that are necessary for successful wet processing but they are not intended to stay on the textile product. It is expected that the majority of any process chemical used in a process will enter the waste stream but inevitable, traces may remain on the textile at point of sale

The use of some process chemicals is unavoidable e.g. acids and alkalis to set pH for reactions to take place, and it is necessary to have a specific amount present.

The use of other process chemicals is somewhat optional e.g. the use of fabric lubricants or anti-crease. Sometimes their use is vital and the difference between success and failure, but sometimes their use is often recommended by chemical manufacturers as an insurance policy and may not be essential, Unfortunately the cost of finding out if they are required (i.e. a lost batch of fabric) is a lot more expensive than using them unnecessarily.

Note on chemical choice

Many brands and legislators have strict rules on certain chemicals – meaning that certain chemicals are banned or restricted. It is clear that textile processors should avoid the use of chemicals listed in brand RSL's (restricted substance lists) but they can also make informed choices to reduce the impact of chemicals even when all the chemicals they use are legal and RSL compliant legal/permitted chemicals.

Textile processors may choose 'preferred' chemicals as follows

- Water based (no harmful solvents)
- More easily biodegradable
- Lower toxicity / less harmful (to workers, environment and end consumers)
- Lower impact upstream production (e.g. renewable resources)
- Lower impact upstream (e.g. safer method of chemical manufacture)
- Recyclable

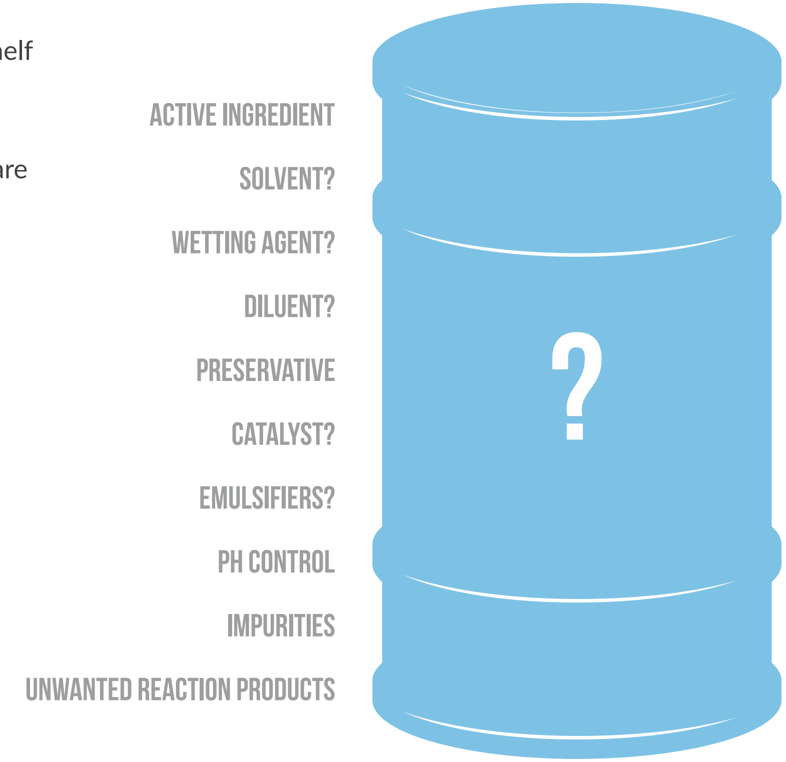
WHAT'S IN A CHEMICAL FORMULATION?

Chemical formulations as purchased from the chemical industry contain active ingredients – the chemicals that are either intended to do a particular task in the process or intended to remain on the textile at point of sale.

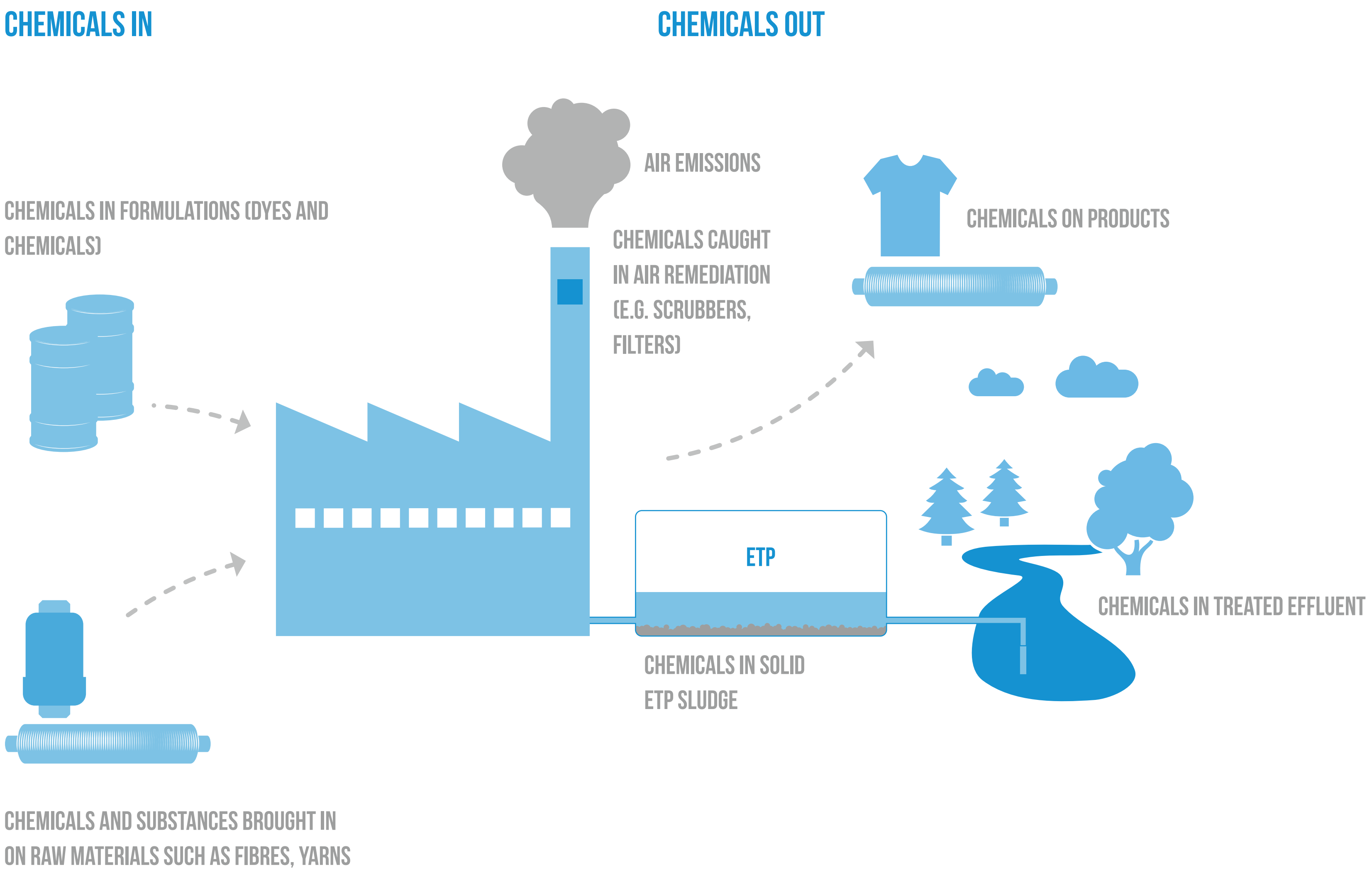
However, commercial formulations will also include additives such as preservatives, buffers, wetting agents, emulsifying agents, stabilisers, solvents, catalysts and inert diluents (to standardise products).

These 'formulation aids' are necessary to ensure the formulation is stable, has good shelf life and that the active gradient can be applied successfully in a given process.

Formulation aids may be found on finished textiles (especially those in performance finishes) but those in dyes, dyeing process chemicals and scouring process chemicals are likely to enter effluent streams.

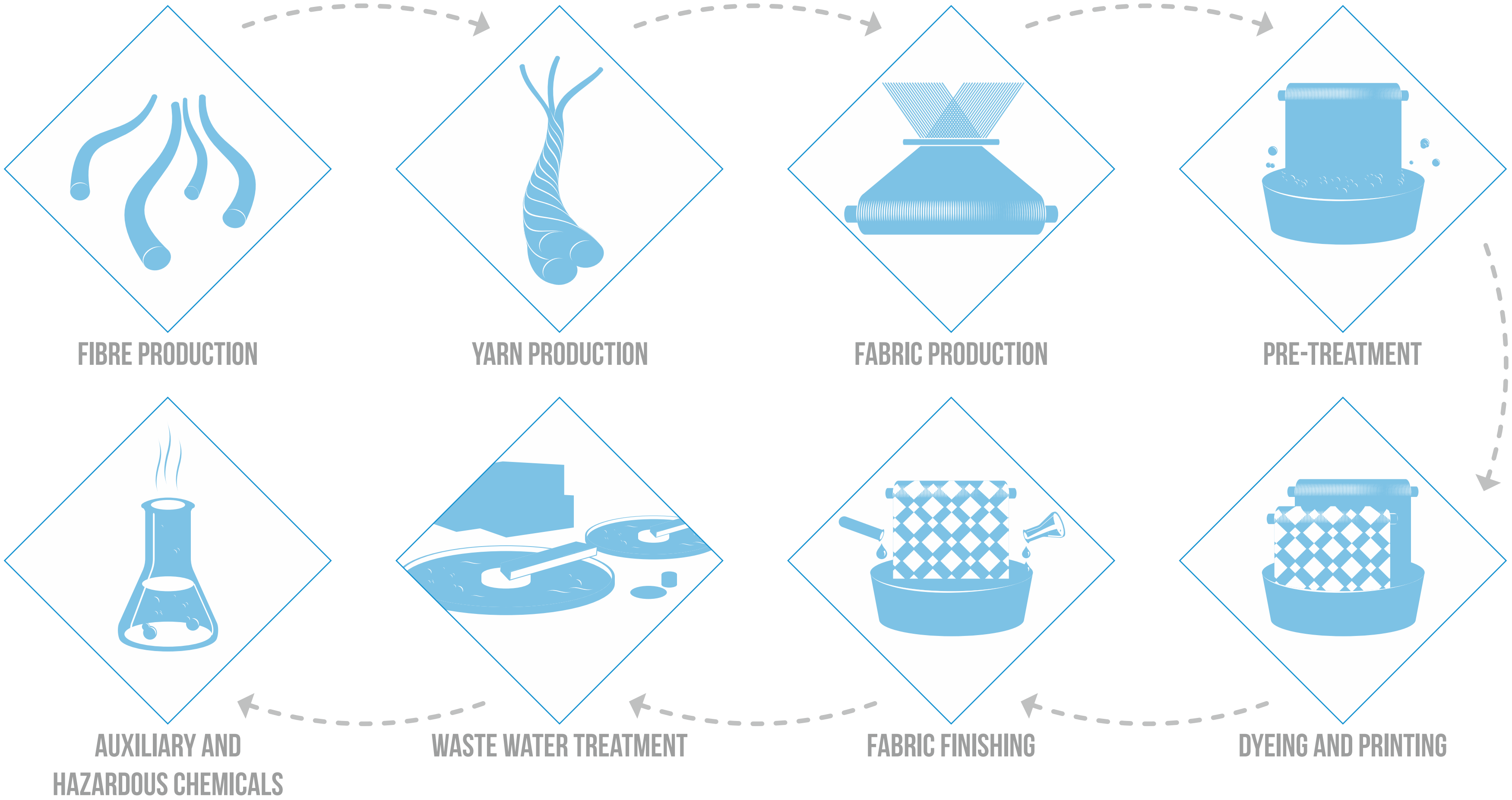


BASIC TEXTILE CHEMICAL FLOW



TEXTILE PRODUCTION PROCESS MENU

Use the icons below to navigate through the guide.



FIBRE PRODUCTION

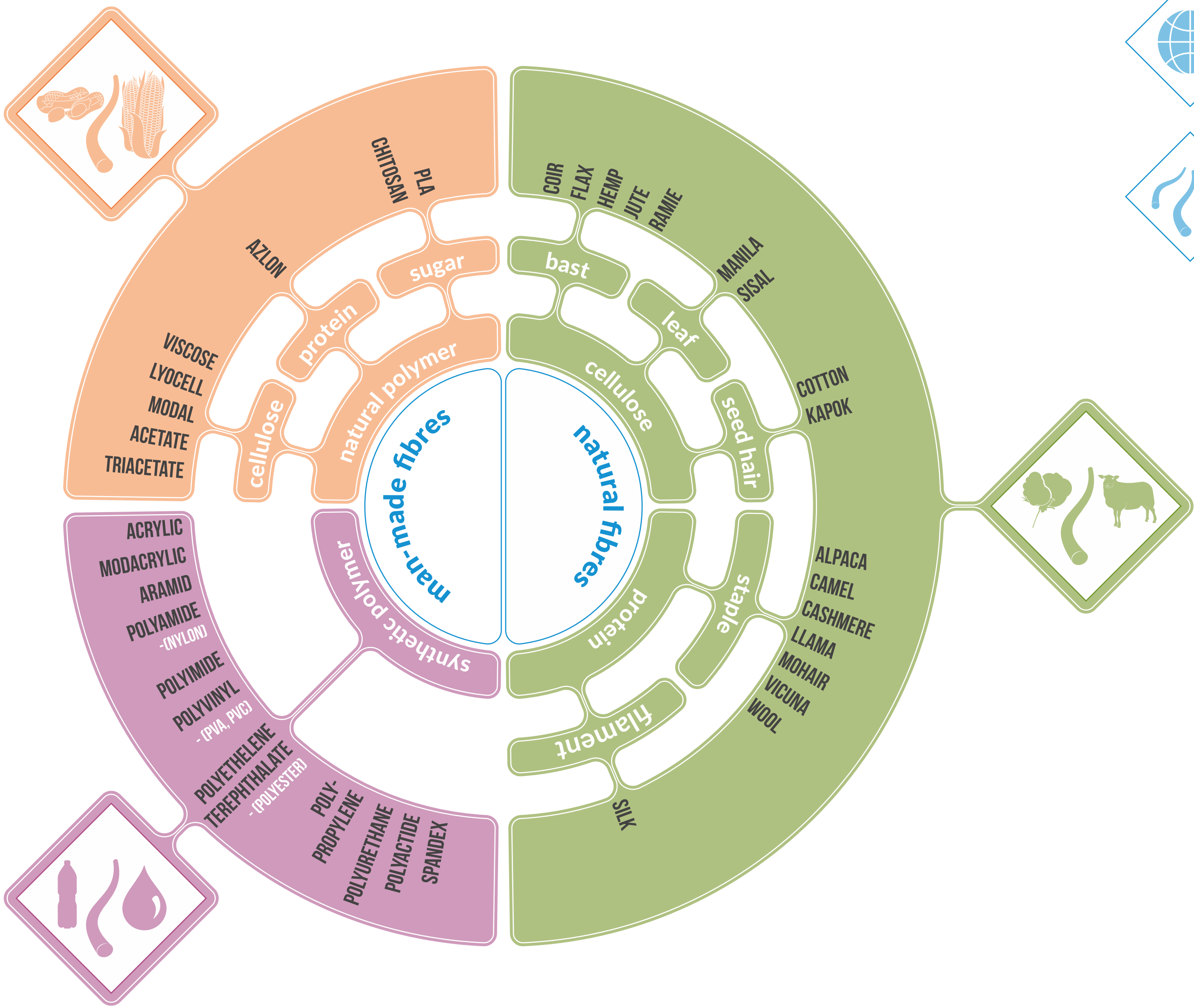
A textile or fabric is a flexible material made up of fibres. These fibres can come from a range of origins and can be classified broadly into three types.

NATURAL FIBRES
(plant or animal)

MAN-MADE FIBRES FROM NATURAL POLYMERS
(usually plant based)

MAN-MADE FIBRES FROM SYNTHETIC POLYMERS
(usually petrochemical based)

Regardless of origin, all fibres are subject to a multitude of chemicals during production and processing.

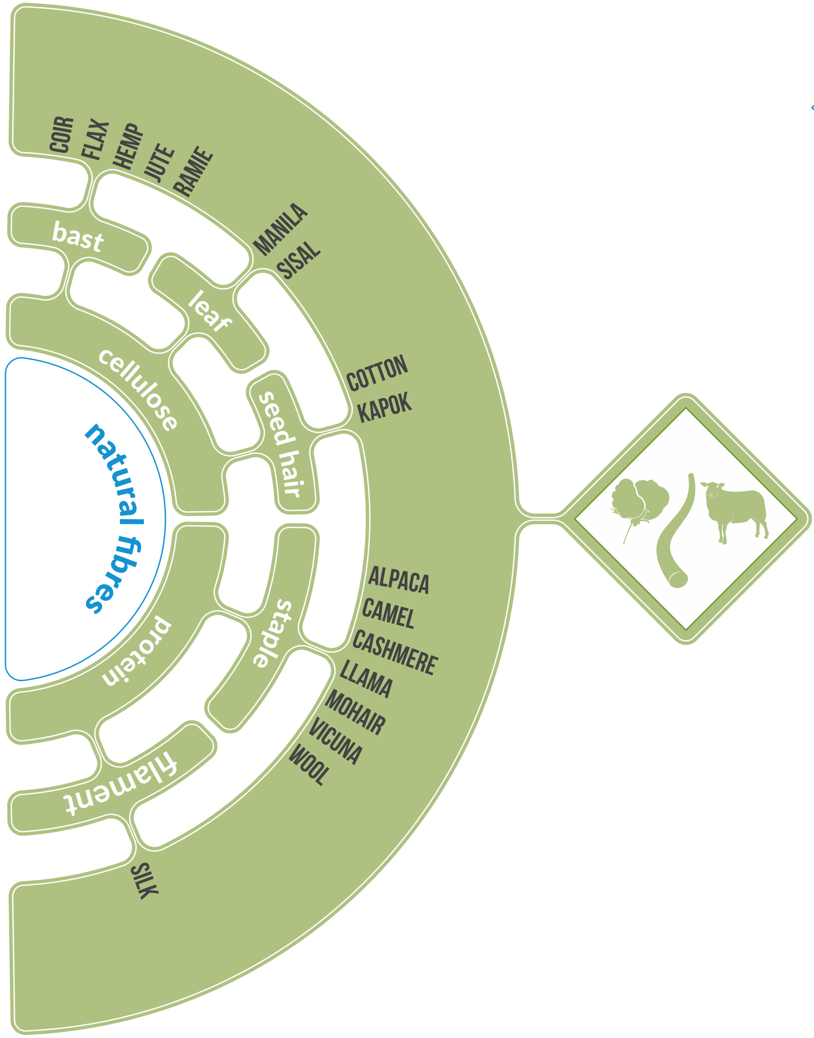


FIBRE PRODUCTION: NATURAL FIBRES

Natural fibres are a class of hair-like materials directly obtainable from

- PLANTS (CELLULOSE)
- ANIMALS (PROTEIN)
- MINERAL SOURCES

The processing of natural fibres is performed predominantly through mechanical means, however, the growing and cultivation of these fibres can be incredibly chemical intensive.



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FIBRE PRODUCTION: CELLULOSE

Fibres can be taken from more or less any plant with an extractable source of cellulose, and are usually harvested from the seed hair, the plant stems (bast fibres), or occasionally, from the leaves.

Natural cellulosic fibres usually come in short, discrete lengths, that are individually separate and distinct called 'staple fibres'.

Staple lengths vary depending of the origin of the fibre and are an important consideration during fibre processing, particularly during spinning.

COTTON SEED FIBRE
STAPLE LENGTH: 2.22 – 3.18 CM

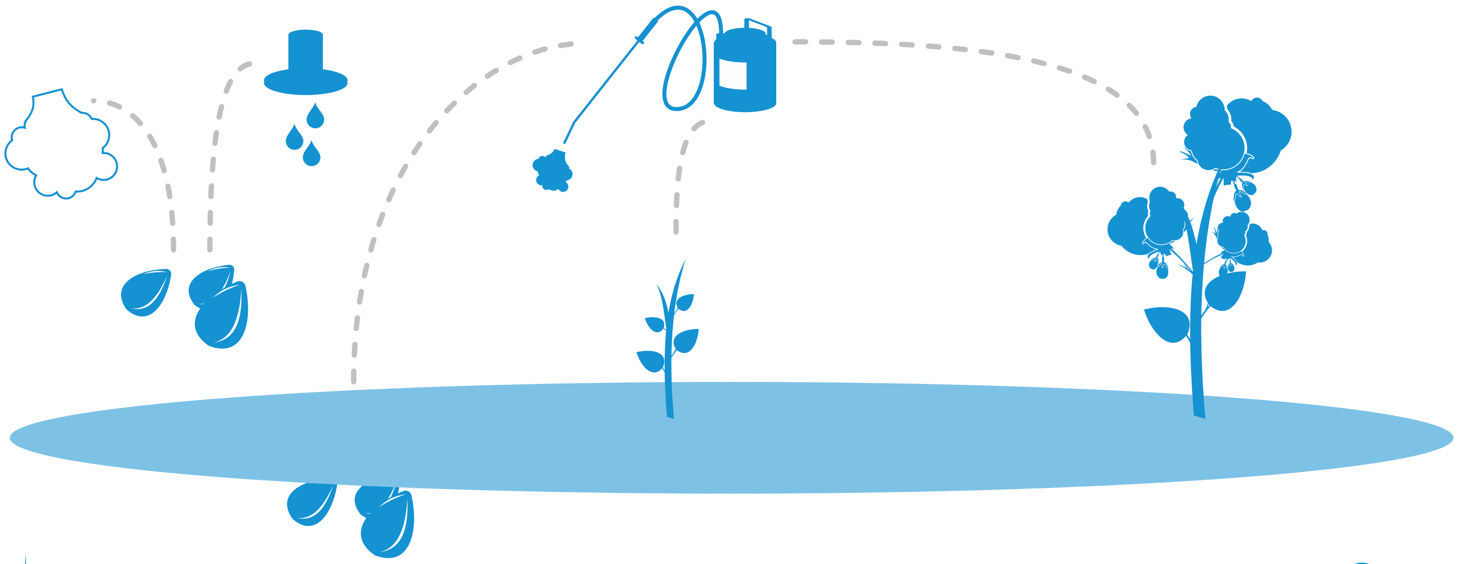
HEMP STEM SHOWING BAST FIBRES
STAPLE LENGTH: AROUND 20CM

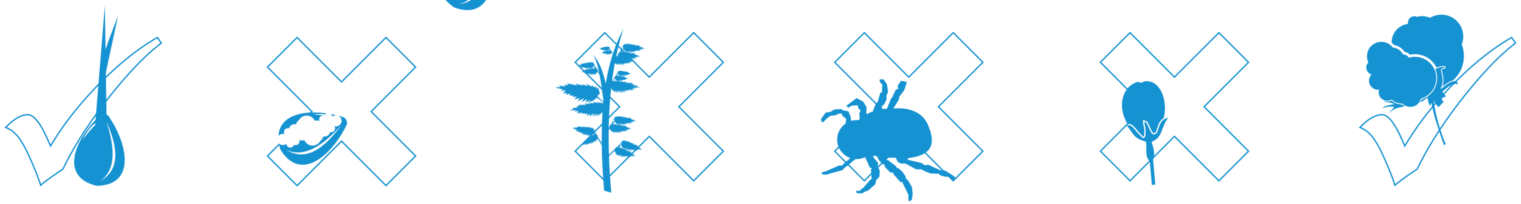
EXTRACTION OF FIBRES FROM PINEAPPLE LEAVES
STAPLE LENGTH: AROUND 20CM

Image credit: Original source unknown, taken from https://textilechapter.blogspot.com/2017/02/cotton-grading-standard-chart.html
Image credit: https://en.wikipedia.org/wiki/Hemp#/media/File:Hanfstengel.jpg
Image credit: Original source unknown, taken from http://iwcpgardeninggroup.blogspot.de/

FIBRE PRODUCTION: CULTIVATION OF CELLULOSE FIBRES

Cultivation of plants where the seed fibres are used, cotton of course being the most prevalent, can be enormously resource intensive, often requiring vast quantities of chemicals, and water.





SEEDS are treated with **fungicides** to control disease during the establishment of a crop, increase productivity of the crop, and to improve the storage life of the harvested plants and produce

PLANTS and fields are regularly heavily treated with **herbicides** to inhibit weed growth, and **insecticides** to control pests, as well as the use of chemical fertilizers to supply nutrients

HARVEST AIDS can be applied to terminate seed growth, open fibre balls, defoliate, or to desiccate the plants, steps that can reduce the trash content and result in less cleaning of the lint at the gin, minimizing fibre damage and maintaining quality.

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Traditional retting process carried out in a river

Example of a retting bath where chemicals can be employed to speed up the process

FIBRE PRODUCTION: RETRIEVAL OF CELLULOSE FIBRES

Fibres from seed hair are ready for processing following harvest, however bast or leaf fibres must firstly be stripped from the stalk, bark or leaf.

For bast fibres this is carried out by ‘retting’ literally meaning ‘rotting’), a process employing the action of micro-organisms and moisture on plants to dissolve or rot away the pectins surrounding the cellulosic fibres. While traditionally performed using dew or water, this makes the process very time intensive and so more modern methods use chemical retting agents such as sodium carbonate, or oxalic acid.

Alternatively, machines can be used to strip off the bark in a mechanical process known as ‘decorticating’, however, this is usually a more appropriate method for leaf fibres.

EXAMPLE OF A DECORTICATING MACHINE

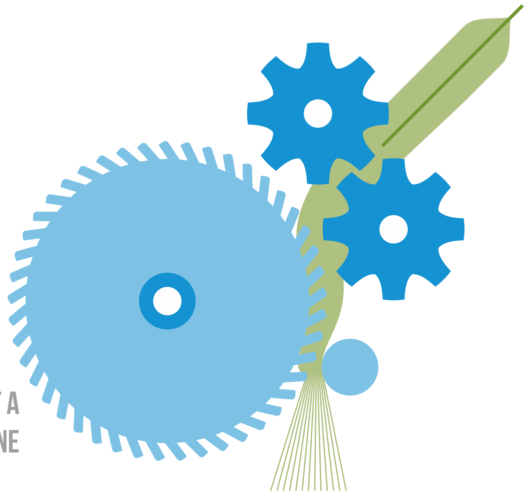


Image credit: Jute products development and export promotion council, http://www.jpdepc.org/about-jute.html
Image credit: Original source unknown, taken from https://textileapex.blogspot.de/2014/12/flax-fibre.html

FIBRE PRODUCTION: PROCESSING OF CELLULOSE FIBRES

Fibres must be processed to prepare them into an appropriate state to be spun into a yarn. These processes are mainly mechanical. The following describes the processing of cotton, however, similar processing steps are undertaken for all short staple cellulosic fibres.

CLEANING AND BLENDING

In the blow room, raw fibres are separated from unwanted debris (leaves, twigs, seeds etc), opened to prevent clumping. Fibres are often blended with different fibre batches to improve uniformity, or with different fibres to improve properties of the final fabric.

CARDING AND COMBING

In this stage, fibres are passed through a series of teeth which removes unwanted short fibres, and untangles bunches and locks of fibres. This also aligns fibres into long strips of parallel fibres are known as 'slivers'.

DRAWING

Slivers then go onto the drawing process, where they are given a slight twist to become rovings, and are repeatedly drawn through rollers to make them thinner and more uniform, in preparation ready for spinning.

1 Fibres being opened in preparation for the blowroom

2 Fibres passing over the teethed rollers of a card

3 Fibre slivers come off the card

4 Slivers being passed between rollers in the typical drawing process

Image credit: Original source unknown, taken from https://www.wotol.com/1-blowroom-rieter-cotton-blowroom/second-hand-machinery/prod_id/59463
Image credit: Columbia Custom Carding, http://www.cccarding.com/Carding.html
Image credit: National Trust, http://www.ntprints.com/image/345623/close-up-of-the-cotton-after-production-on-the-carding-machine-at-quarry-bank-mill-styal

FIBRE PRODUCTION: PROTEIN

Wool is a blanket term used to describe the staple fibres obtained from mammals. Most wool comes from sheep, but can also come from goats (cashmere, mohair), rabbits (angora), and other camelids (camel, llama, vicuna, alpaca). Wool can be incredibly chemical intensive during both production and processing.

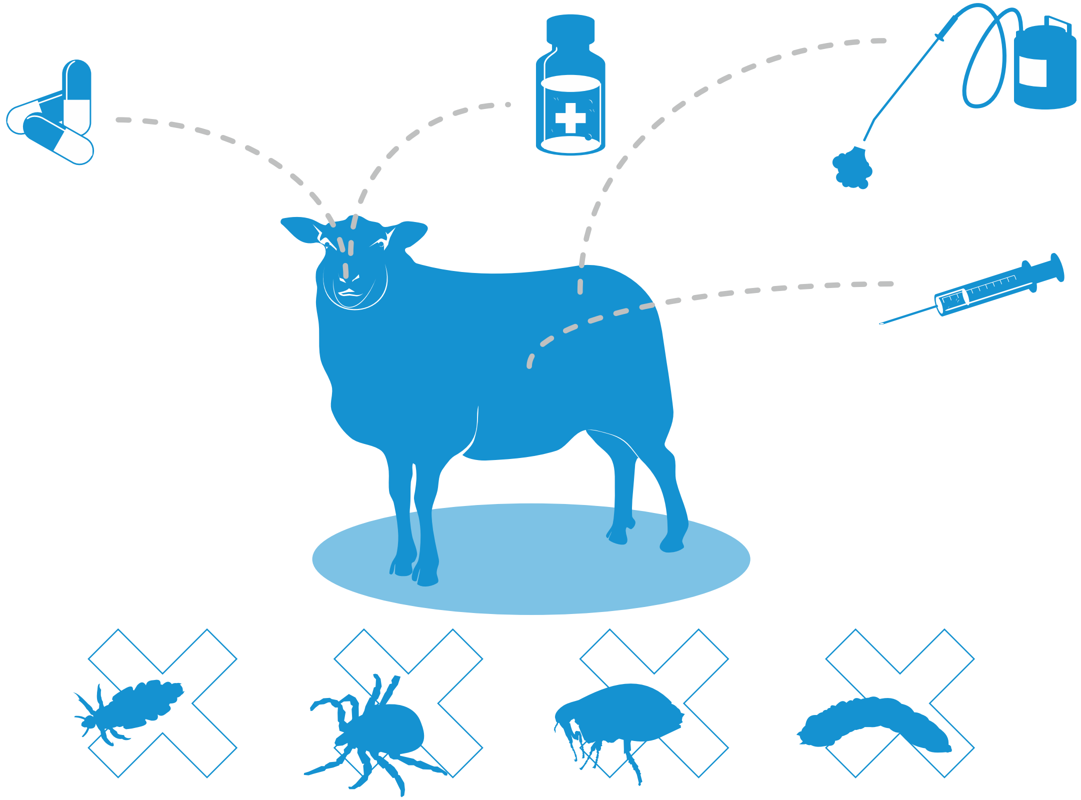
FIBRE PRODUCTION: CULTIVATION OF PROTEIN FIBRES

Growing and Shearing

Wool producing animals are susceptible to a number of pests such as ticks, lice, maggots, and worms, and so **pesticides and insecticides** are widely used on animals to tackle this.

Furthermore, **agricultural antibiotics** can also be given to promote slightly faster growth and to compensate for overcrowded and unhealthy conditions.

Following shearing the animals are often dipped in an **antiseptic solution** to cure and clean any wounds that occur during the shearing process.



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FIBRE PRODUCTION: CULTIVATION OF PROTEIN FIBRES

Normally, around once a year, the animals will be sheared. An experienced shearer will be able to remove the fleece in one piece. Following shearing the fleece must be skirted, a process where dirty and contaminated (unusable) sections are removed.
The wool is then graded on its fibre fineness, length, cleanliness and colour which are important consideration as it usually determines the end use of the wool, with coarser fibres being used for carpets and upholstery, and finer fibres being used for clothing. The quality of the wool is very much determined by the location on the sheep

1 Head and neck wool is inferior in quality, it is often dirty and coarse, and may contain matted lumps

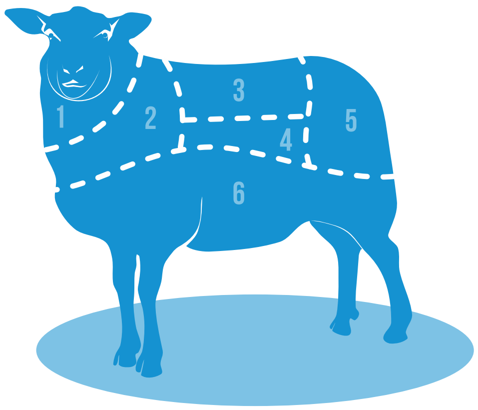
2 Shoulder wool is the best on the sheep and is often used as a standard to compare the rest of the wool on the fleece

3 Back wool is inclined to be open, weathered and musky and of medium density

4 Fleece and breast wool are similar in quality to shoulder wool, usually in good condition and relatively free from vegetable matter

5 Britch wool is coarser than the other sections of the fleece, and may contain many burrs and seeds

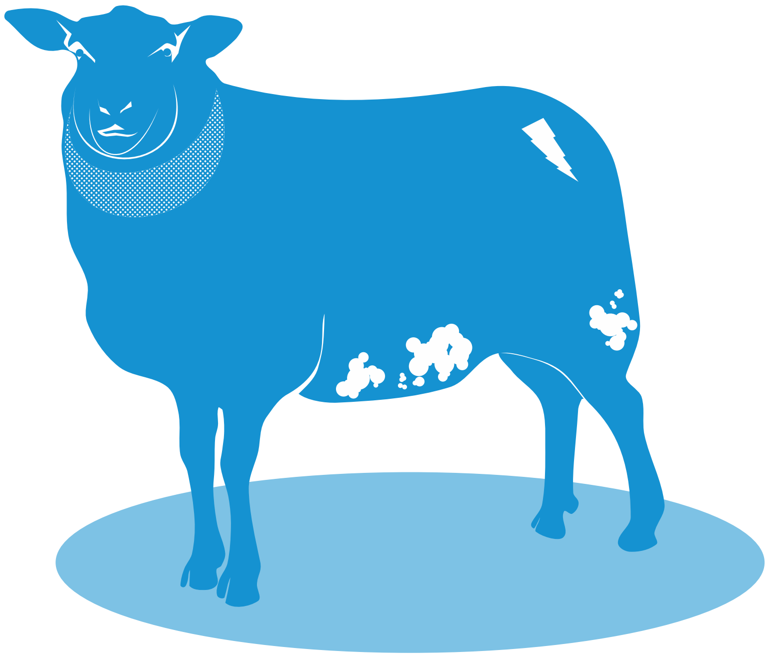
6 Arm, shank, and belly wool are usually coarse and short, and can be matted with burrs and seeds



FIBRE PRODUCTION: PROCESSING OF PROTEIN FIBRES

On a freshly sheared fleece, a large proportion of the raw wool fibre is composed of impurities and is not usable wool fibre.   There are three types of impurity present in wool which must be removed before the fibre can be spun into a yarn.

These impurities are removed in a strong chemical processes called scouring, with the resulting sludge disposal and its polluting potential being a further cause for concern.



NATURAL IMPURITIES the glandular secretions that adhere to the fleece. Suint (sweat salts) and lanolin (wool grease), together known as yolk, are such two major components. The wool grease is usually recovered and refined as lanolin and its derivatives are used extensively in personal and health care products.

ACQUIRED IMPURITIES these include soil, dust, dirt, faeces, straw, burrs, and other vegetable and mineral matter

APPLIED IMPURITIES there are due to the treatments given to the animal against insects, pests etc. and due to the markings made on them with tar or paints for identification.

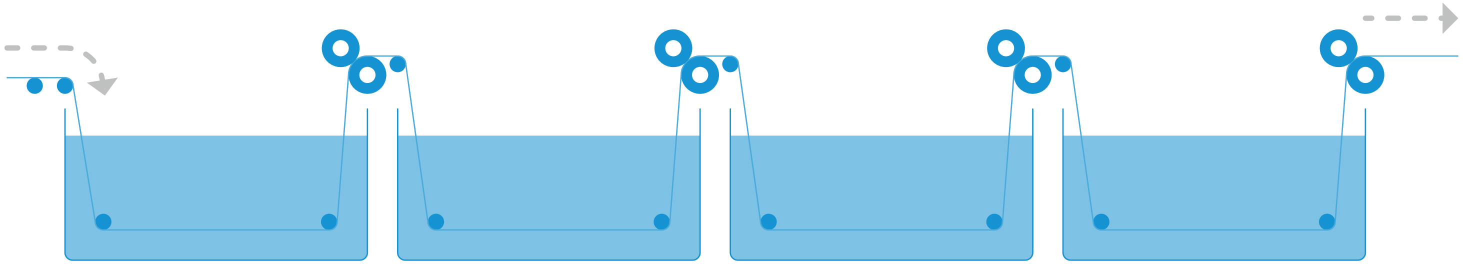
FIBRE PRODUCTION: PROCESSING OF PROTEIN FIBRES

Scouring

Wool scouring is usually carried out with detergents in liquid solution, however, the scouring effluent remains highly alkaline and so, although seldom, some mills prefer to scour with organic solvents.

Detergent scouring

The aim of the scouring process is to rid the wool of grease and dirt and involves the greasy wool being passed through a series of water bowls (typically 6 to 8) containing water or wash liquor.



1 The first bowls contain water at temperatures between 32°C to 42°C, with this heavy dirt particles and water soluble suint are washed away

2 The following bowls contain highly concentrated mixtures of detergent and sodium chloride (or sodium sulfate) at temperatures of around 65°C. This highly alkali solution breaks down natural oils and surfactants to remove water insoluble lanolin and wool grease and and suspends these impurities in the bath

3 The final baths contain fresh water which is used to thoroughly rinse the wool

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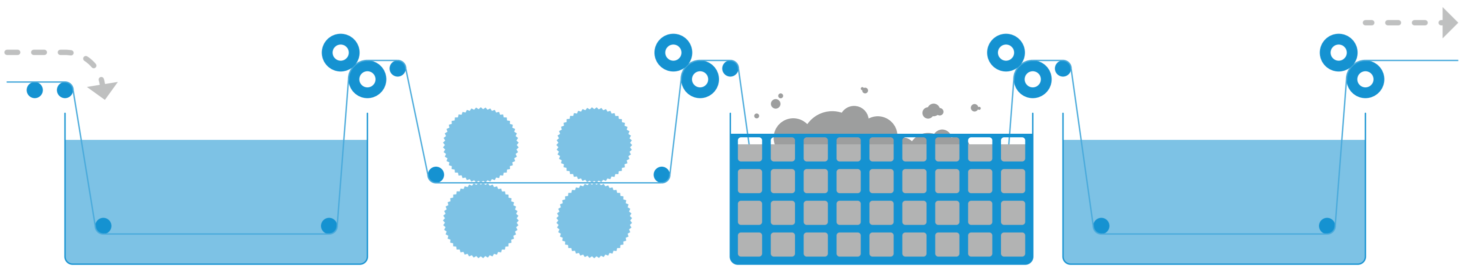
FIBRE PRODUCTION: PROCESSING OF PROTEIN FIBRES

Solvent scouring

In the solvent scouring process the desuinted wool is scoured with organic solvents such as benzene, carbon tetra chloride, ethyl alcohol, methyl alcohol or isopropyl alcohol. Although solvent scouring removes grease effectively, dirt is not removed, and so solvent scouring is generally followed by a detergent wash to remove the residual chemicals and remaining dirt.

Carbonising

If the greasy wool combines a high percentage (typically in excess of 2-3%) of vegetable matter (burrs, seeds, grass, etc), it will be subjected to a carbonising process, which uses chemicals to break the cellulosic material into carbon.

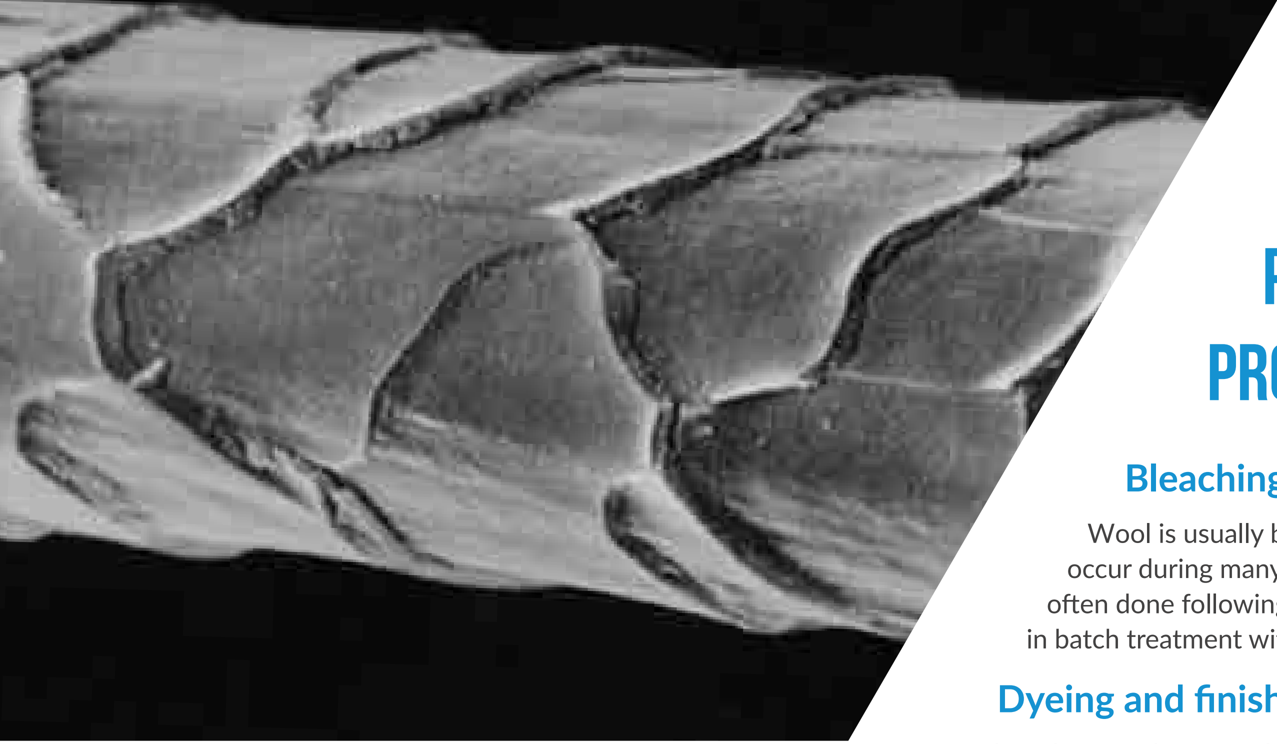


1 Concentrated sulphuric acid carbonises (breaks down) the vegetable matter

2 Heavy rollers crush the carbonised vegetable matter to dust

3 The dust is shaken out of the wool

4 Sodium carbonate neutralises the acidic wool



FIBRE PRODUCTION: PROCESSING OF PROTEIN FIBRES

Bleaching

Wool is usually bleached to improve the colour and this can occur during many stages of the manufacturing process but is often done following scouring. Wool bleaching is usually carried out in batch treatment with hydrogen peroxide.

Dyeing and finishing

Although some dyeing and bleaching of woollen-spun products takes place in fabric or garment form, the vast majority of wool used in the woollen system is dyed or bleached in scoured loose wool form - prior to the carding and spinning process. Regardless of the processing stage, the dyeing procedure is the same and so will be addressed in the dyeing section of the guide.

De-scaling

Naturally, wool fibres are covered in scales or barbs and the processing stages up to this point cause the natural fibre alignment of these scales to be disrupted which can make the wool itchy and cause the fibre to shrink when wet.

In order to prevent these effects and to prepare the wool for the following production stages, many producers either use chlorine or an acid bath to burn off the scales, or coat the fibre with a polymer that glues them down.

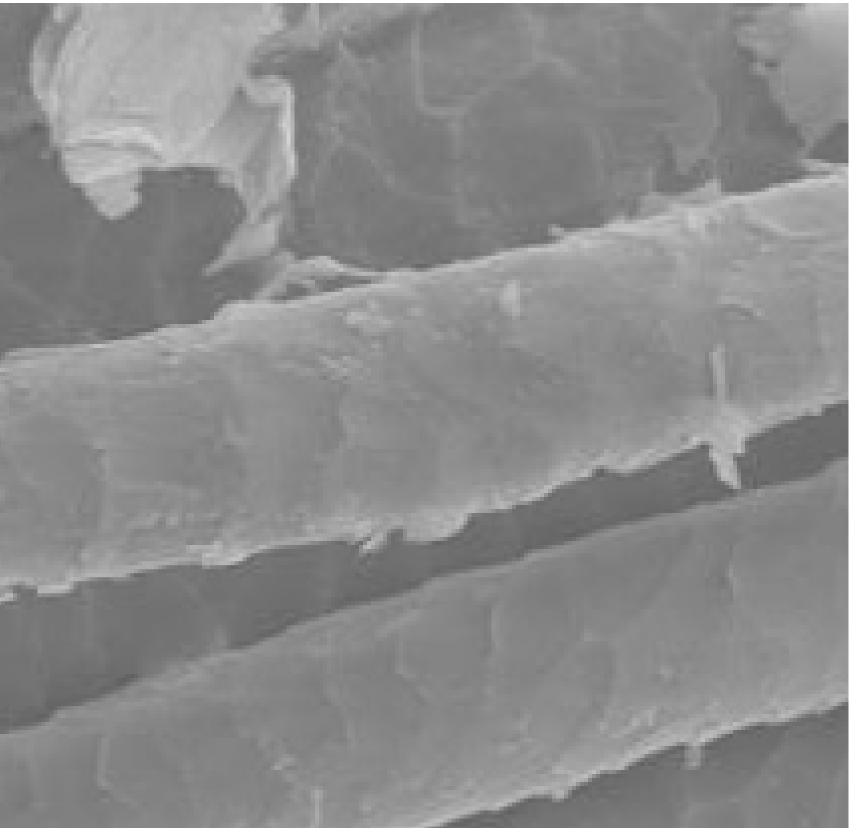


Image credit: http://www.tikp.co.uk/knowledge/technology/advanced-technologies/

FIBRE PRODUCTION: PROCESSING OF PROTEIN FIBRES

The cleaned and dried wool is then ready to be carded in preparation for spinning.

Blending

Fibres are blended or mixed mechanically with fibres from several different batches to help unify the slightly different colours of raw wool, and to standardise staple length and uniform quality.

Prior to carding, a mixture of a synthetic processing lubricant, and water is applied to the scoured and blended loose wool. This provides a number of functions

- reduces fibre to metal friction and static, both of which cause excessive fibre breakage and reduceprocessing efficiency
- reduce wastage by minimising the number of short fibres which fall out during the carding process and accumulate under the machine.

Carding

The carding process passes the wool through a series of wire rollers to straighten the fibres and remove any remaining impurities, resulting in a thin web of aligned fibres called a roving or slubbing.

Following the blending and carding processes, the fibre slubbings and rovings are ready to be spun into yarns.

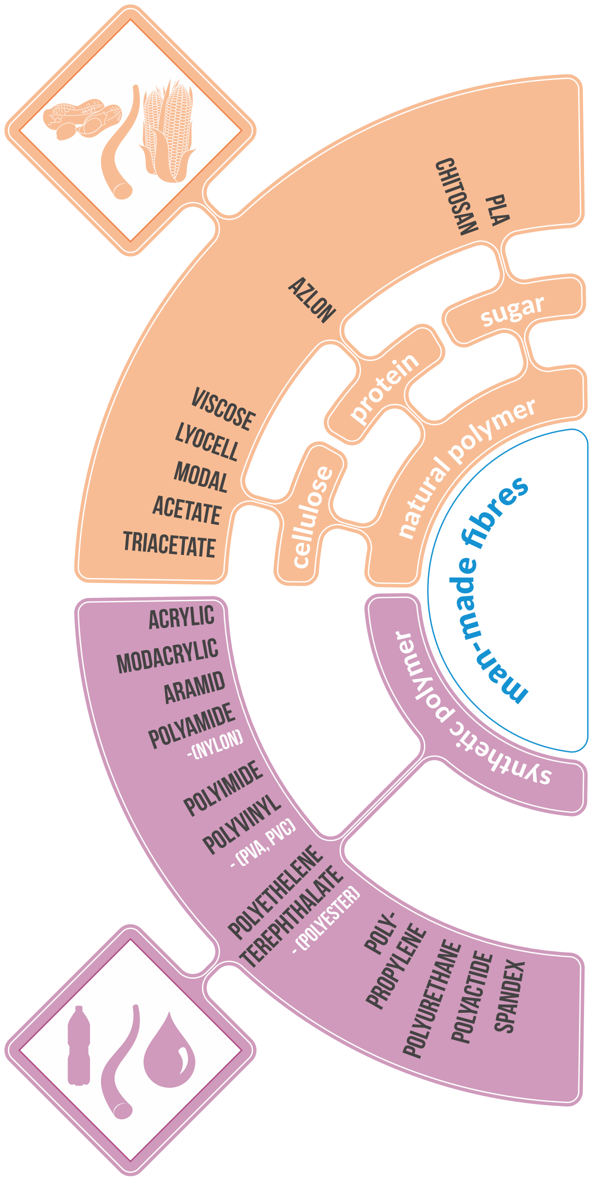
Image credit: Stephen Bay, http://bayimages.net/

FIBRE PRODUCTION: MAN-MADE FIBRES

Man-made fibres are those where the fibre is produced artificially through the extraction, manufacture, and extrusion of polymers. These polymers can be both natural, and synthetic:

- **NATURAL POLYMERS** are those that occur in nature and can be extracted, such as cellulose, proteins, and sugars
- **SYNTHETIC POLYMERS** are those that do not occur naturally and are derived from raw materials such as coal and petroleum

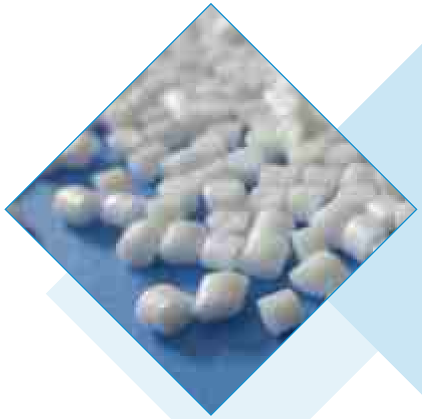
Man- made fibres are produced as continuous filaments which are then collected together into a tow. The tow is then either prepared and spun into a continuous filament yarn, or cut into short lengths to form staple fibre, which is usually done in order to blend the fibre with other fibre types i.e. cotton, wool etc.



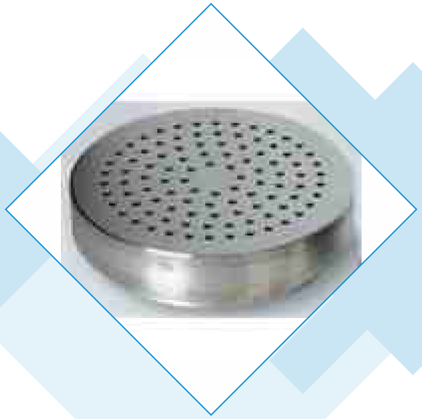
FIBRE PRODUCTION: MAN-MADE FIBRES

The extrusion of man-made fibres follows the a general principle, with variations depending predominantly on the melting behaviour of the polymer

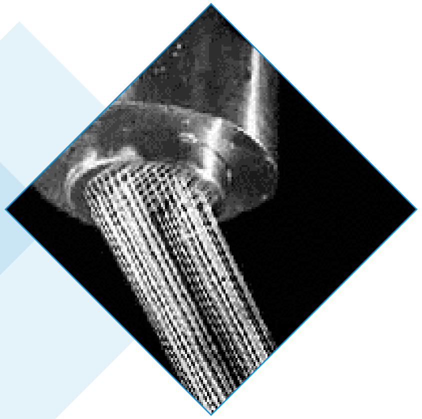
1. A highly viscous spinning dope is prepared. If the polymer is thermoplastic it is melted, if not then it must be dissolved in a solvent, or chemically treated to form a soluble or thermoplastic derivative
2. The fluid polymer is then forced through a spinneret, where the polymer is cooled and solidified by various means suitable to the speficic polymer
3. Following spinning, the filaments are drawn and stretched to increase strength and orientation. This is done while the chains are still relatively mobile and causes the chains to stretch out and orient along the fibre axis. As the chains become more parallel, inter-chain bonds form, causing cohesion resulting in a considerably stronger yarn and imparting necessary properties for use as textile fibres



POLYMER PELLETS BEFORE EXTRUSION



SPINNERET HEAD



FIBRES LEAVING SPINNERET

Image credit: Original source uknown, taken from https://www.indiamart.com/proddetail/pet-resin-bottle-grade-8147996248.html
Image credit: http://www.textilemachinery-spares.com
Image credit: Original source uknown, taken from https://oliverands.com/community/blog/2013/05/fabric-friday-petroleum-based-manufactured-fibers.html

FIBRE PRODUCTION: MAN-MADE FIBRES

There are three principle methods of spinning man-made fibres depending on the ease of the conversion process from solid to liquid

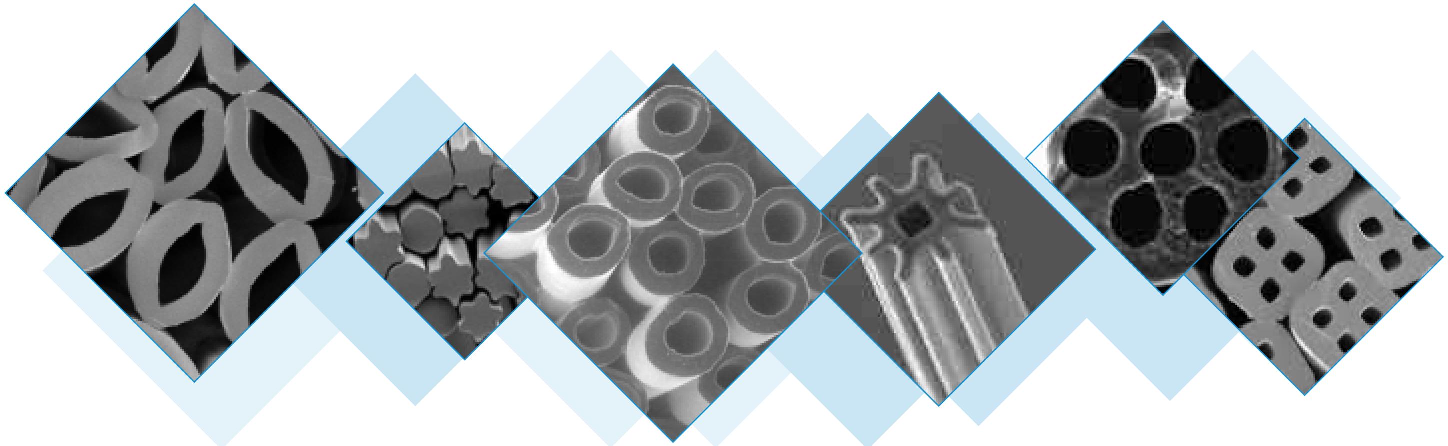
- **MELT SPINNING** is used for thermoplastic polymers
- **DRY SPINNING** involves dissolving the polymer into a solvent that can be evaporated
- **WET SPINNING** is used when the solvent cannot be evaporated and must be removed by chemical means

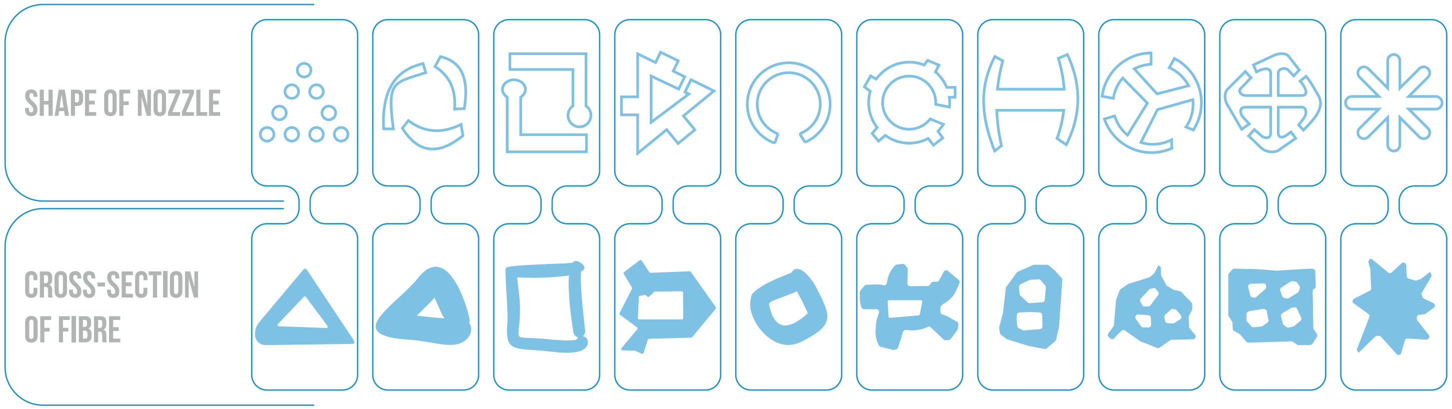
	MELT SPINNING	DRY SPINNING	WET SPINNING
PRODUCTION FIBRE TYPE	FILAMENT AND STAPLE	FILAMENT	FILAMENT AND STAPLE
PRODUCTIVITY	HIGH	HIGH	LOW
INVESTMENT COST	LOW	HIGH	LOW
SOLVENT	NONE REQUIRED	ONLY VOLATILE ORGANIC SOLVENTS	BOTH ORGANIC AND INORGANIC SOLVENTS
ENVIRONMENTAL HAZARD	NON-TOXIC	TOXIC	TOXIC
HEAT OF SPINNING	HIGH	VERY HIGH	LOW
SPINNING SPEED	750 – 1000 M/MIN	750 – 1000 M/MIN	50 – 100 M/MIN
SPINNERETS HOLES	2000	300-900	300-900
FIBRES	POLYESTER, NYLON, POLYPROPYLENE, POLYETHYLENE	ACETATE, TRIACETATE, ACRYLIC, MODACRYLIC, SPANDEX, VINYON, AND PVC	ACRYLIC, VISCOSE, LYOCELL, ARAMID, AND SPANDEX

FIBRE PRODUCTION: MAN-MADE-FIBRES

Fibres can be spun using two or three different types of polymer (bi-component or tri-component) in different configurations. This allows for example, combinations of different thermal melting points or varying dye affinities which can be exploited in different stages of the manufacturing process.

Spinnerets can have holes of various sizes and shapes to produce fibres with a several different cross-sections and so resultant properties.



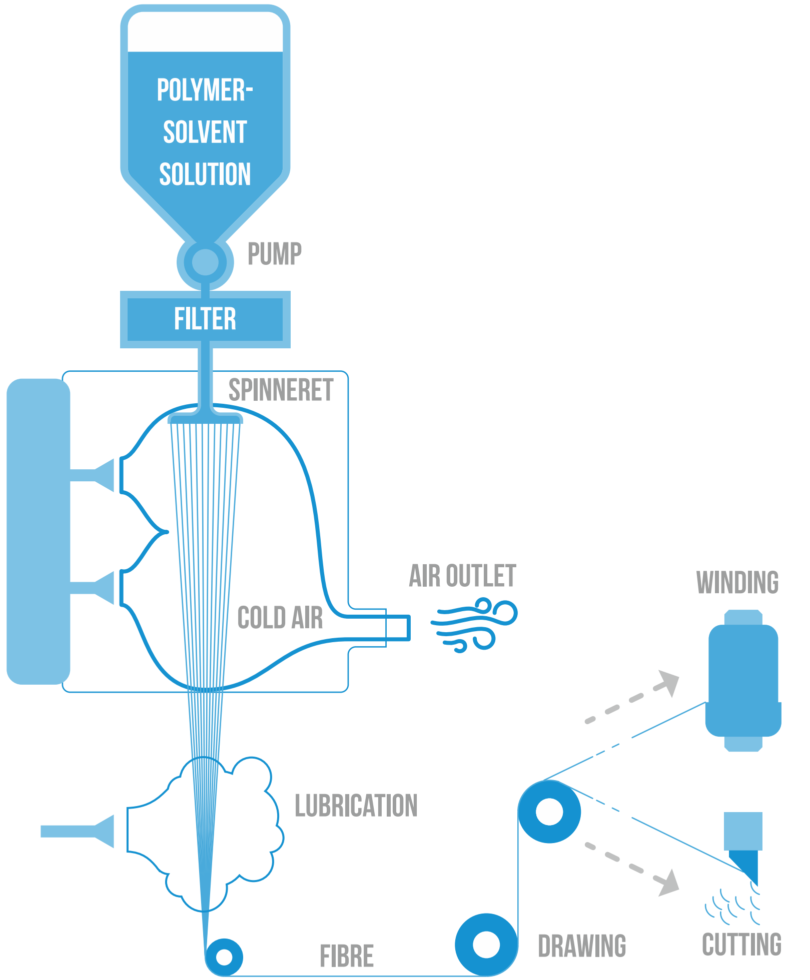


FIBRE PRODUCTION: MAN-MADE FIBRES –MELT SPINNING

Melt spinning

Melt spinning is used for thermoplastic polymers, i.e. those that become liquid above a certain temperature, and solidify again when cooled. These are usually synthetic polymers derived from from oil such as polyester, nylon, polypropylene, and polyethylene.

- Polymer granules or chips are melted at very high temperatures and extruded through a spinneret
- Solidification is achieved through cooling. This is usually in cold air, but where fibres have large cross sectional areas, can also be in water



FIBRE PRODUCTION: MAN-MADE FIBRES – DRY SPINNING

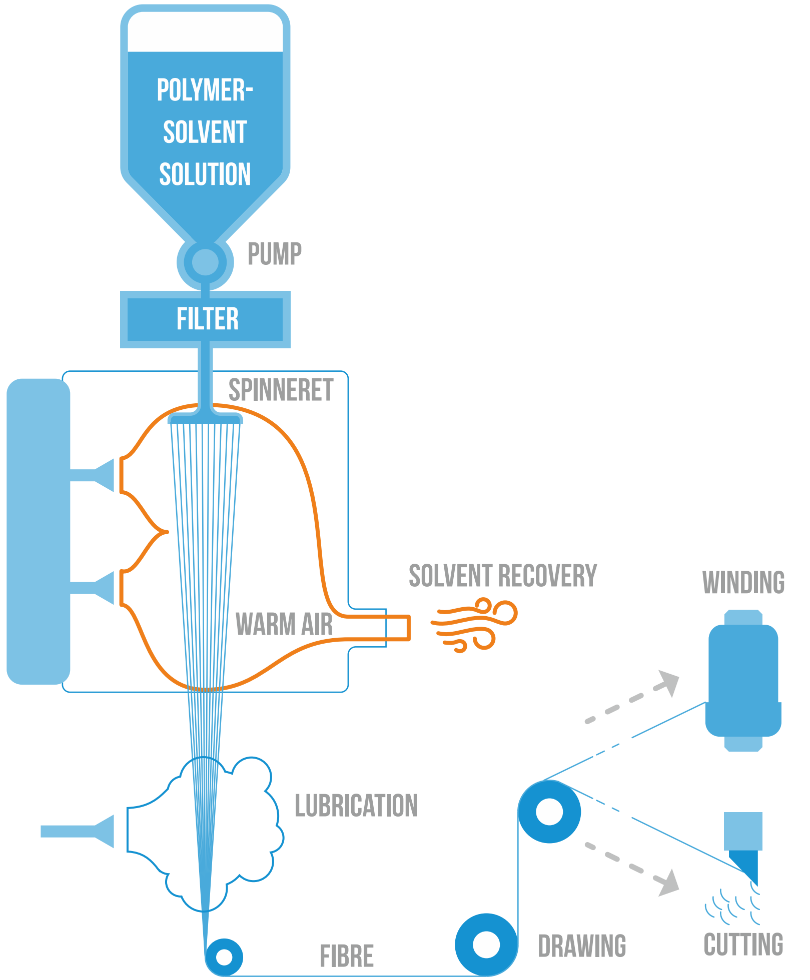
Dry spinning

Dry spinning is used for polymers that must be dissolved into a solvent because their melt temperature is equal or close to their thermal degradation temperature and they are damaged by heat. Fibres spun using this process include acetate, triacetate, acrylic, modacrylic, spandex, vinyon, and PVC.

- A spinning solution is prepared by dissolving the polymer in an appropriate solvent
- Solidification is achieved through evaporation of the solvent. This is usually achieved with hot air or inert gas

Solvent recovery

As there are no precipitating liquids involved, the gaseous solvents are generally recovered fairly easily. This enables them to be cleaned and/or re-used.



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FIBRE PRODUCTION: MAN-MADE FIBRES – WET SPINNING

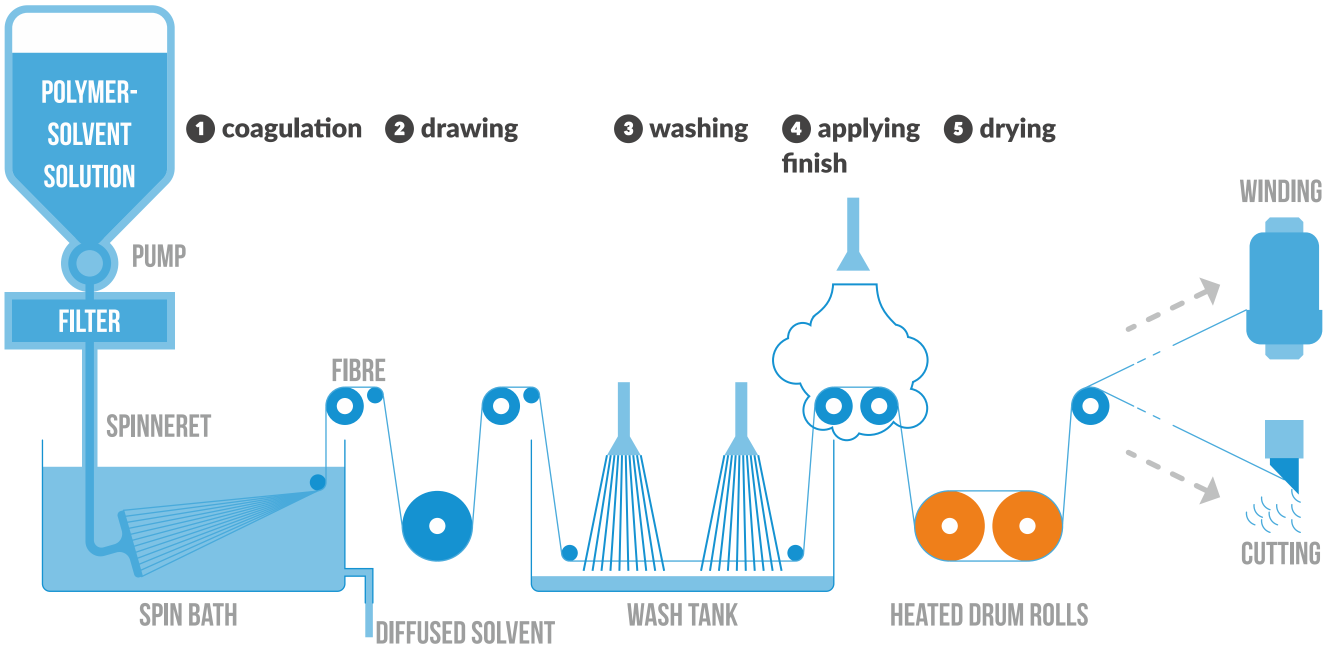
Wet spinning

Wet spinning is used for polymers that need to be dissolved into a solvent to be spun (i.e. non thermoplastic) . It is named wet spinning because the fibres are extruded directly into a spin bath containing a chemical mixture known as the coagulant. Fibres spun using this process include acrylic, viscose, aramid, and spandex.

- A spinning solution is prepared by dissolving the polymer in an appropriate solvent
- Solidification is achieved as the polymer-solvent solution is extruded into the spin bath, this causes the solvent to be drawn out, leaving behind only the polymer fibre
- After drawing and stretching the fibres must be washed to remove any remaining solvent, before being dried

Solvent recovery

The solvents can usually be recovered by treating the liquid in the spin bath. This can be a complicated procedure due to the chemical mixtures, however, the solvent can usually be recovered and cleaned or re-used. Chemicals must also be removed from the wash tanks.



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FIBRE PRODUCTION: MAN-MADE FIBRES – DRY-JET WET SPINNING

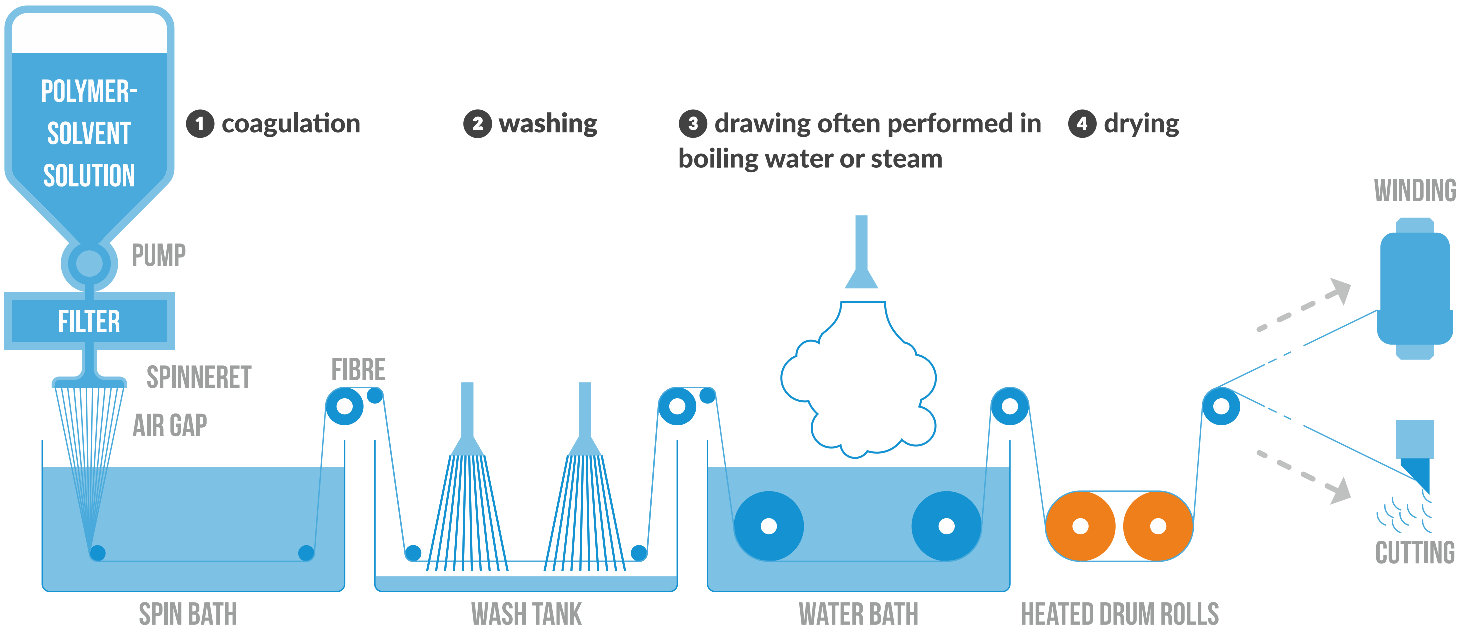
Dry-jet wet spinning

Dry jet-wet spinning is a variant of wet spinning which is used when spinning directly into the spin bath draws out the solvent too quickly and damages the fibre. Lyocell is spun using this process.

- A spinning solution is prepared by dissolving the polymer in an appropriate solvent
- The solution is extruded under heat and pressure into an air gap before it enters the spin bath. To prevent oxidisation in some polymers an inert atmosphere may be required which can be achieved with nitrogen
- Solidification is achieved in the spin bath where the solvent is drawn out, leaving behind only the polymer fibre
- The fibre is then washed and dried before it is heat treated and drawn

Solvent recovery

The solvents can usually be recovered by treating the liquid in the spin bath. This can be a complicated procedure due to the chemical mixtures, however, the solvent can usually be recovered and cleaned or re-used. Chemicals must also be removed from the wash tanks.



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FIBRE PRODUCTION: MAN-MADE FIBRES – CHEMICAL ADDITIVES

During the production of man-made fibres many chemical additives are used. These additives are either present in the polymer chips supplied to the fibre manufacturer, are incorporated to the polymer melt or spinning dope before extrusion, or are applied after spinning to the finished fibre.

These additives provide a considerable number of functions:

PROCESSING ADDITIVES	FUNCTIONAL ENHANCERS
• SPINNING/STRETCHING AIDS • HEAT STABILISERS • PH STABILISERS • VISCOSITY MODIFIERS WHICH CAN AFFECT EASE AND SPEED OF SPINNING • ANTI-STATIC/LUBRICANTS • FILLERS AND BULKERS TO 'BULK OUT' EXPENSIVE POLYMERS • SPIN FINISHES	• DELUSTRANTS WHICH REDUCE THE SHEEN OF THE FIBRES • BRIGHTENERS • PILLING REDUCERS • DYE RECEPTOR/COLOUR ENHANCERS • DYES/PIGMENTS • FLAME RETARDANTS • ANTIMICROBIALS • UV STABILISERS • PLASTICISERS • ANTIOXIDANTS

However, these additives can be problematic:

As the additives provide increased functionality, this gives a competitive market advantage and so many producers are unwilling to declare which chemical additives are used thus creating hotspots for unknown chemicals in fibre production.

These additives pose problems when trying to recycle materials, as they effectively become unknown impurities

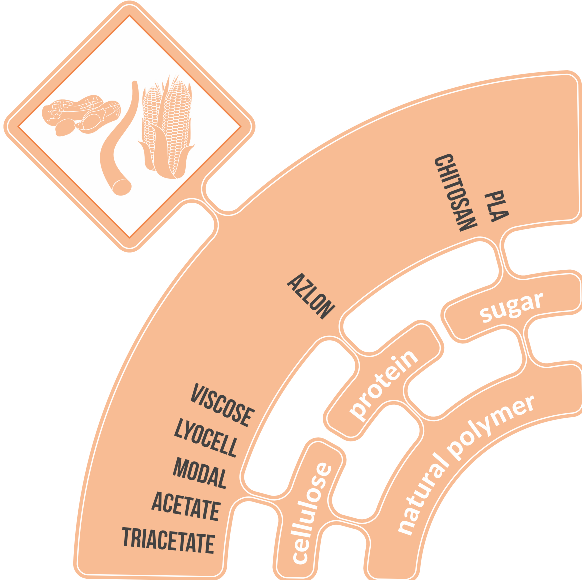
FIBRE PRODUCTION: NATURAL POLYMER

Regenerated, or semi-synthetic fibres are manufactured from the chemical extraction and regeneration of natural polymers.

For the textile sector, cellulose is the most important natural polymer source. Cellulose is present in all plants but for regeneration into fibres it is mainly extracted from wood pulp. Sometimes cotton linters (fine fibres from cotton seeds), and other trees and plants such as bamboo, eucalyptus, or sugar cane can be used. Fibres from these sources are often referred to as 'regenerated cellulose'.

The natural polymers can also come from protein sources such as peanuts, soy, milk or corn (azlon fibre), and natural sugars such as corn starch (PLA), or from the shells of crustaceans (chitosan).

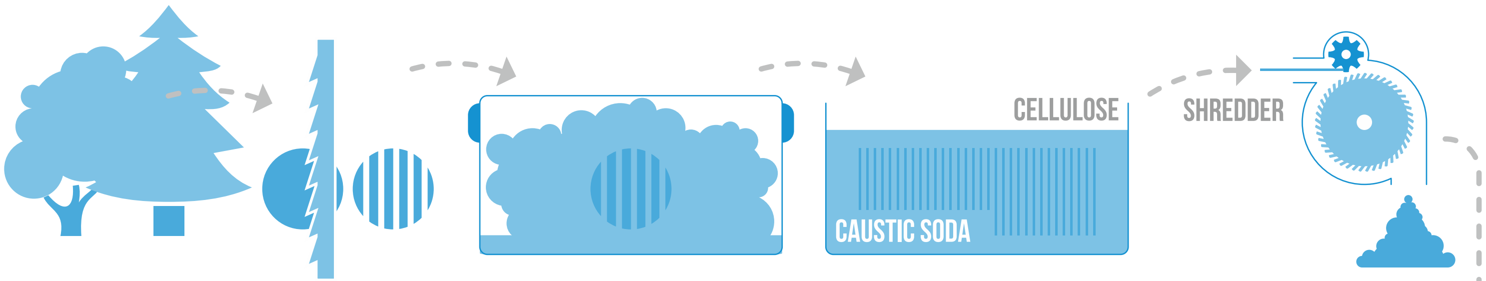
Production of regenerated or semi-synthetic fibres require extensive chemical processing to extract the natural polymers, to prepare them into a solution in preparation for fibre extrusion, and often require extensive washing to remove these chemicals afterwards.



FIBRE PRODUCTION: NATURAL POLYMERS - VISCOSE

Viscose is by far the most prevalent, versatile and successful type of regenerated cellulose. It can be blended with man-made or natural fibres and made into fabrics of varying weight and texture. The cellulose must first be extracted from wood in a chemically intensive procedure.

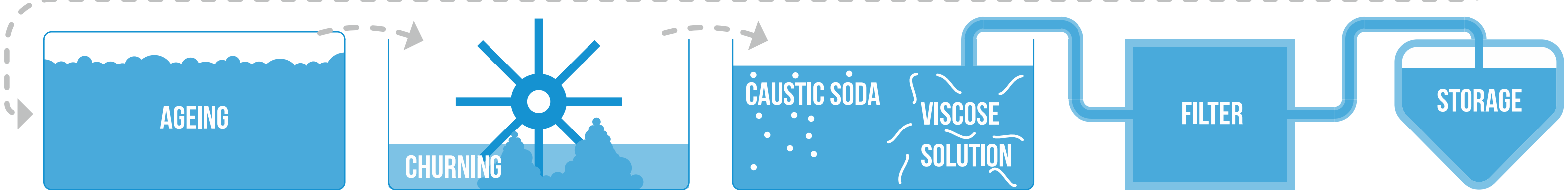
Preparation of cellulose



1 Cut and debarked wood is treated with a solution of calcium bisulphite, and steamed under pressure. This process converts the lignin into a soluble solution which can be washed off, purifying the remaining cellulose which is then treated with a bleaching agent (sodium hypochlorite) and converted into paper boards or sheets

2 These sheets of purified cellulose are steeped in sodium hydroxide (caustic soda), which produces sheets of alkali cellulose.

3 The dried sheets are then shredded into crumbs, and aged in temperature and humidity controlled metal containers.



4 After ageing, the crumbs are ripened by churning with liquid carbon disulfide, which turns the mix into yellow/orange-coloured crumbs known as sodium cellulose xanthate.

5 The cellulose xanthate is dissolved in more sodium hydroxide, resulting in a viscose solution that looks and feels much like honey. Any dyes or delusterants can be added at this stage. The syrupy solution is filtered for impurities and stored in vats to age.

FIBRE PRODUCTION: NATURAL POLYMERS - VISCOSE

Production of filaments

The viscose solution is then spun into strings of fibres using a wet spinning technique.

Viscose fibres are spun into a spin bath containing a cocktail of chemicals, all performing a specific function and controlling the rate of fibre formation (sulphuric acid, sodium sulphate, zinc sulphate). These chemicals help to coagulate and solidify the filaments into regenerated cellulose fibres.

Drawing

The filaments are then drawn and stretched while the cellulose chains are still relatively mobile.

Washing and bleaching

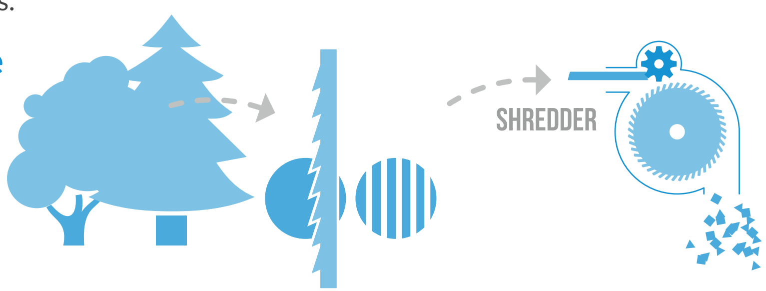
Fibres are then washed, further chemically treated to remove and neutralise the various chemicals from the spin bath, and bleached with sodium hyperchlorite solution to oxidise impurities.

FIBRE PRODUCTION: NATURAL POLYMERS - CELLULOSE

Lyocell

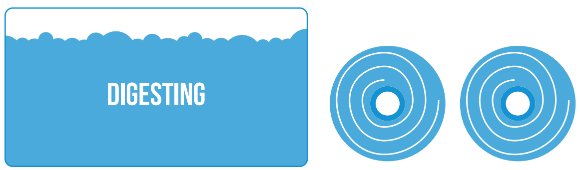
Lyocell, often known by is trade name 'tencel', is an alternative to viscose. While like viscose it is produced through the regeneration of cellulose, it is distinguishable from viscose due to its vastly different regeneration method, where fibres are produced by direct dissolution. The lyocell production process is much simpler, and less chemical intensive than the viscose process.

Preparation of cellulose

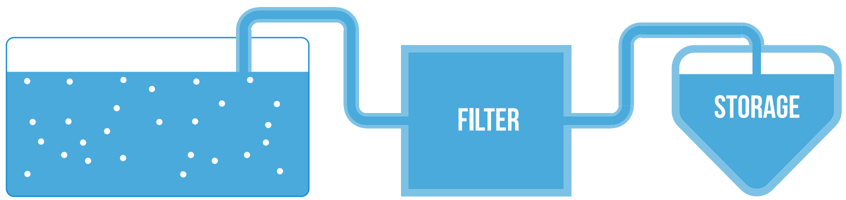


❶ **Hardwood logs are cut and debarked, and the wood is chipped**

❷ **Wood chips are softened into a pulp in a vat of chemical digesters to remove the lignin**



❸ **The pulp is washed, and bleached, dried into sheets, and rolled onto spools**



❹ **The sheets of pulp are broken into small pieces and dissolved in an amine oxide (N-Methylmorpholine N-oxide, or NMMO)**

❺ **The syrupy solution is filtered for impurities and ready to spin**

FIBRE PRODUCTION: NATURAL POLYMERS - CELLULOSE

Production of filaments

The lyocell solution is spun using a dry-jet wet spinning technique.

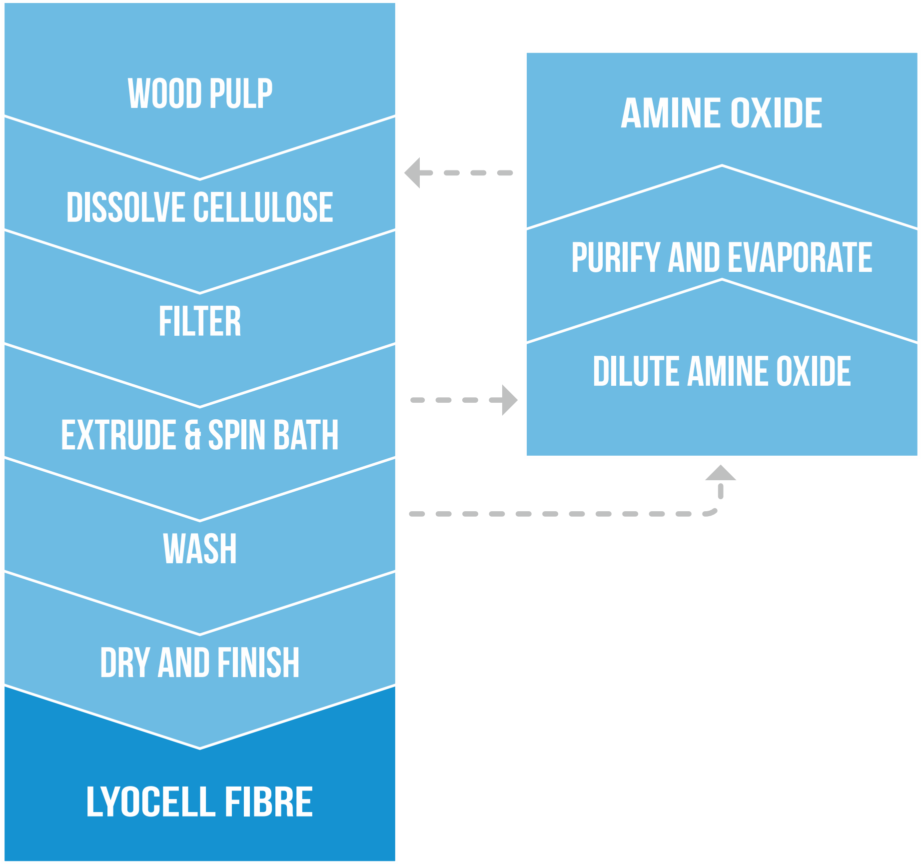
After emerging from the spinneret into the air, the fibres are immersed in a bath containing dilute amine oxide to remove the solvent (NMMO) from the cellulose.

Washing and drying

The fibres are then washed in de-mineralised water, and dried to remove any remaining water.

Solvent recovery

In a typical lyocell manufacturing process up to 98% of the amine oxide used to dissolve the cellulose and set the fibre after spinning is recoverable for reuse. The used spin bath solution is evaporated, removing the water, and the amine oxide is rerouted back to dissolve the wood pulp.



FIBRE PRODUCTION: NATURAL POLYMERS

Non-cellulosic natural polymers

Natural polymers can also be protein, sugar (derived from starches), or oil/lipid based, and come from various sources. These fibres are sometimes termed 'bio-synthetics', are much less common than regenerated cellulose fibres. However, current advances in production technologies suggest they may become more prevalent and commercially viable in the future.

Chemicals in bio-synthetics

As with regenerated cellulose, these natural polymers must first be extracted and prepared into a suitable solution before they can be regenerated into man-made fibres using standard fibre extrusion techniques, processes which can be extremely chemically intensive.

As these polymers are not usually thermoplastic (with the exception of some types of PLA), this is usually performed using variations of dry, and wet spinning techniques which again requires many solvents and spin bath additives to promote fibre formation.

		PROTEIN	STARCH/SUGAR	OILS
CROP BASED	specifically grown for polymer production	• Corn • Soy • Peanuts	• PLA from corn, sugar beet, sugar cane etc • Alginate from seaweed (depending on geography)	• Castor oil • Palm oil • Soybean oil
WASTE BASED	waste products from the food or farming industries that have the polymers extracted	• Casein and other dairy by-products • Chicken feathers • Leather and hide waste	• Chitosan from crustacean shells • Alginate from seaweed (depending on geography) • Corn stover	• Waste food/cooking oil
NON-FOOD BASED	typically algae or bacteria, grown specifically for polymer production		• Microbial/bacterial cellulose	

FIBRE PRODUCTION: SYNTHETIC POLYMERS

Synthetic fibres are made of polymers that do not occur naturally but instead are synthesised entirely in a chemical plant or laboratory, predominantly from distillates of petroleum, but also natural gas.

Synthetic polymers are produced through series of chemical reactions or ‘polymerisations’ of smaller building blocks called monomers, causing them to join together to create larger molecular units. The reactions are usually driven by heat, pressure, or the introduction of a chemical catalyst to drive the reaction.

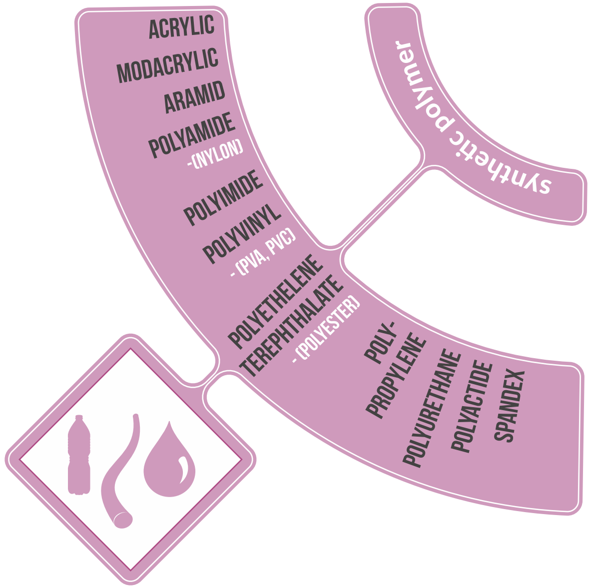
- Some polymerisation reactions join entire monomers together, whereas others join only portions of monomers and create ‘leftover’ materials, or by-products.
- Co-polymers can be formed using two or more different monomers
- Two or more polymers can be combined to produce an alloy, or blend, that displays characteristics of each component

The field of synthetic polymers is vast, and there are endless possibilities to produce a wide range of materials with different properties. Synthetic polymers are are highly versatile and can be engineered to offer numerous performance attributes.

Although there are many fibres made from synthetic polymers, four of them, dominate the market:

- Polyester
- polyamide (nylon)
- polyacrylonitrile (acrylic, modacrylic)
- polyolefin (polyethylene, polypropylene)

These four account for approximately 98 percent by volume of synthetic polymer fibre production, with polyester alone said to account for around 60 per cent.



FIBRE PRODUCTION: SYNTHETIC POLYMERS

Chemicals in synthetic polymers

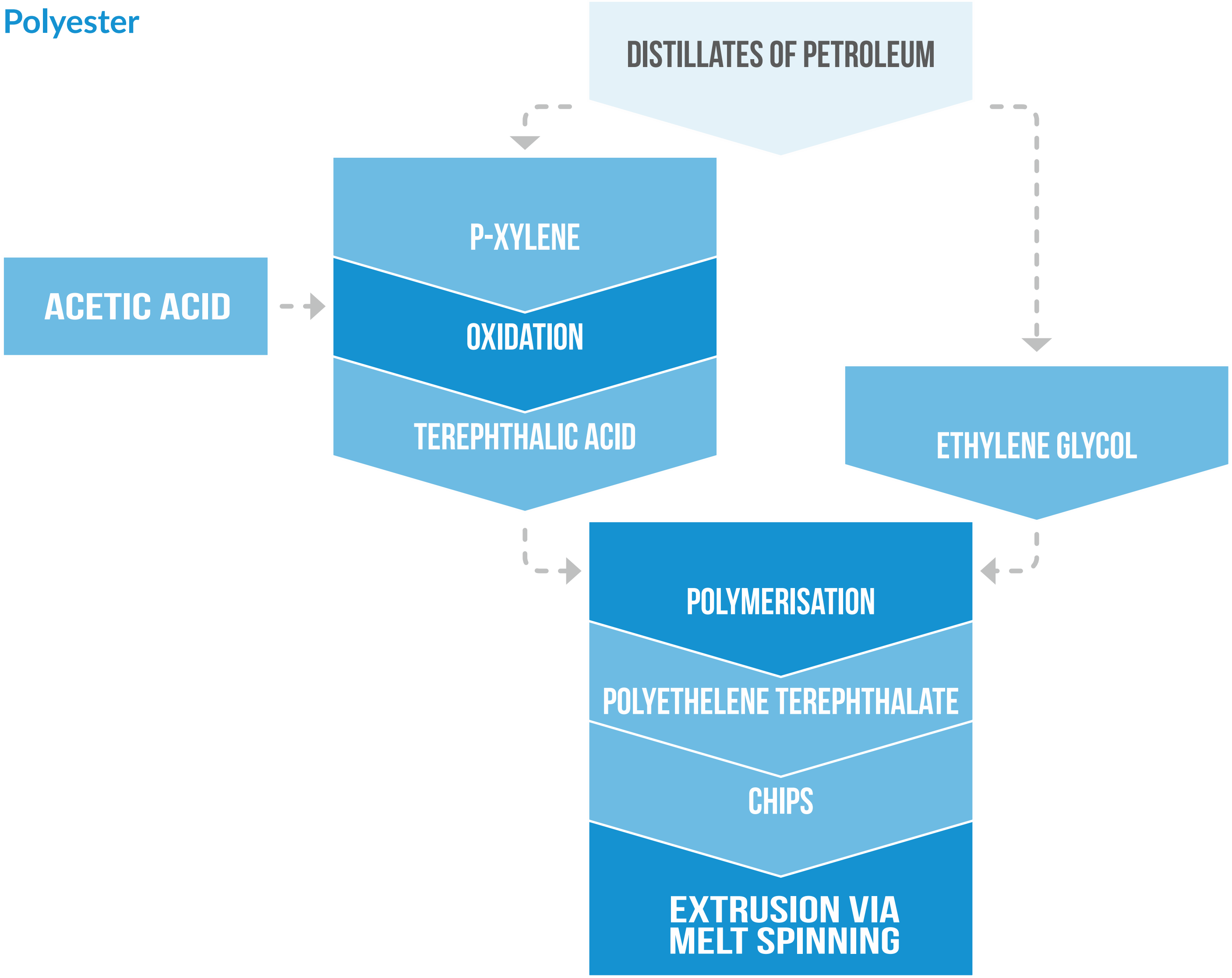
The production of synthetic polymer fibres is by its nature highly chemically intensive:

- numerous chemical ingredients are used (often derived using a series of chemicals reactions)
- further process or catalysts chemicals are used

Often, there are a number of ways to produce fibres of the same type. An example of this is nylon 6, and nylon 6.6. While both fibres have the same ratios of carbon, hydrogen, oxygen, and nitrogen atoms, they begin with different polymer building blocks or monomers, which ultimately drive the differences in polymer structure and physical properties.

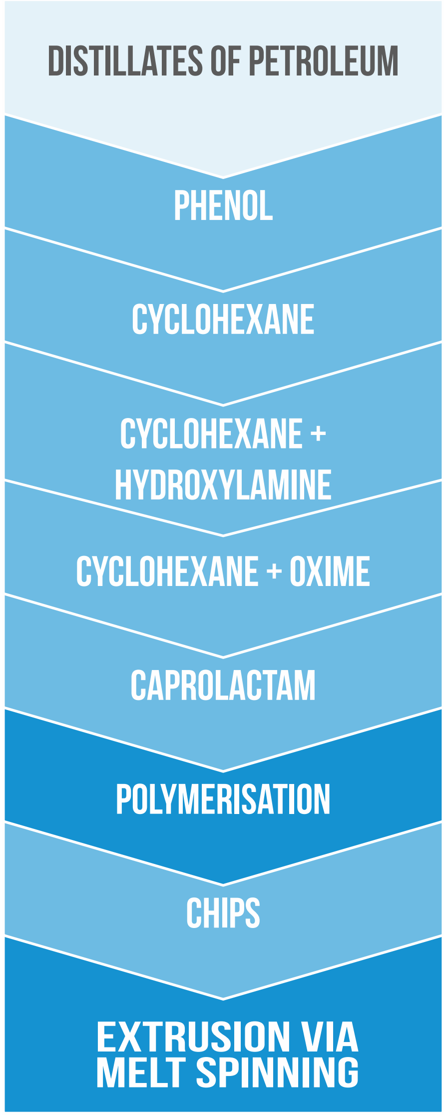
FIBRE PRODUCTION: SYNTHETIC POLYMERS

Polyester



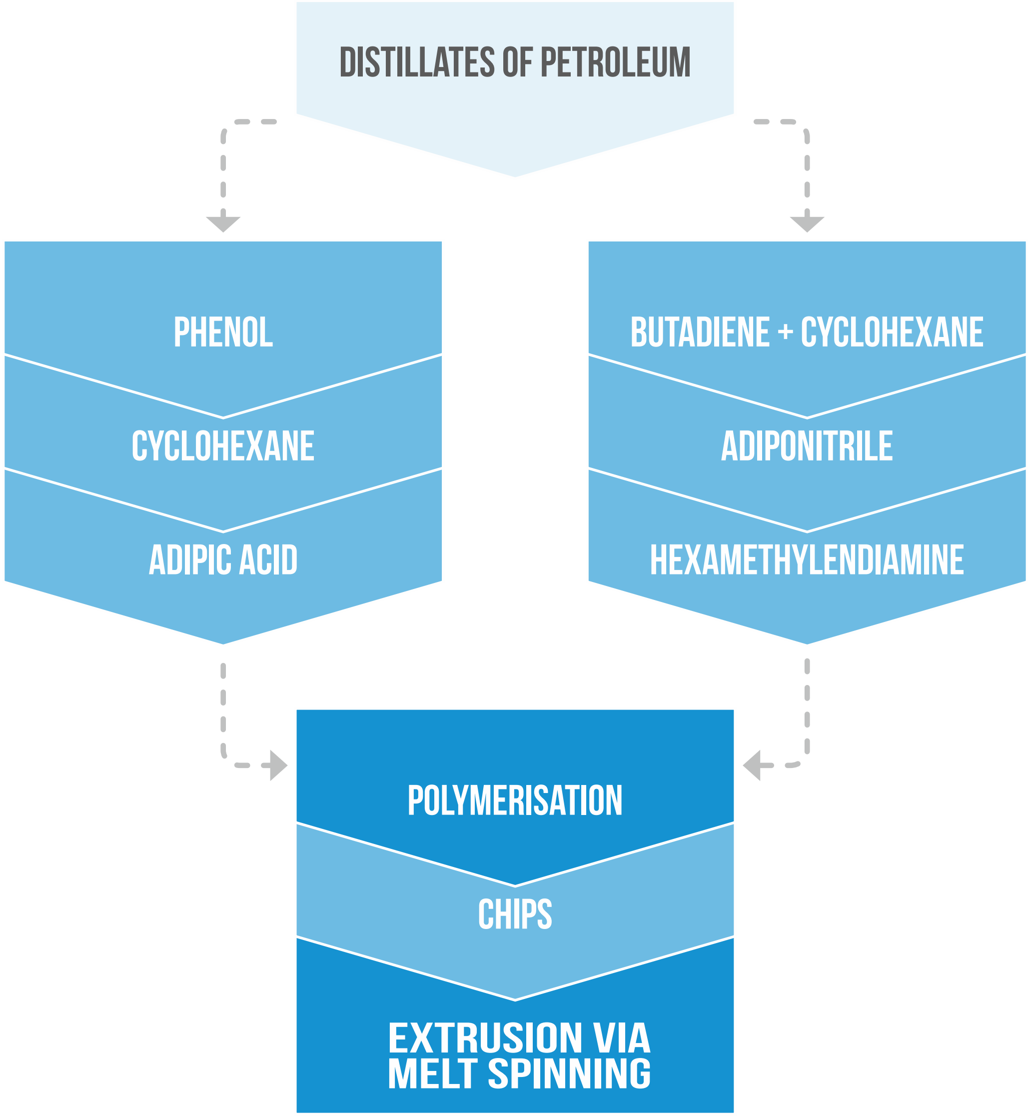
FIBRE PRODUCTION: SYNTHETIC POLYMERS

Polyamide (Nylon) 6



FIBRE PRODUCTION: SYNTHETIC POLYMERS

Polyamide (Nylon) 6.6



YARN PRODUCTION

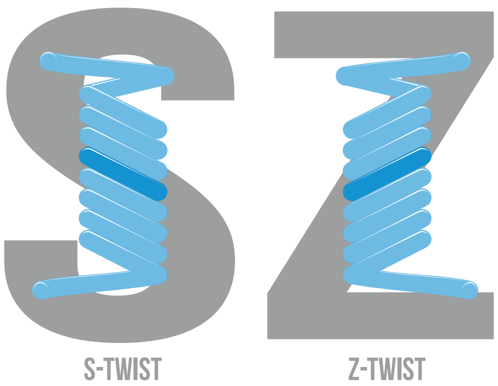
Yarns are linear structures that are produced by collecting and twisting fibres together. Following production and preparation of fibres, they are ready to be transformed into yarns, a necessary step for knitting or weaving fabrics.

Spun or staple yarns are spun from short or staple length fibres. These short fibre lengths come from either natural fibres (with the exception of silk), or man-made fibres which have been intentionally cut to short staple lengths.

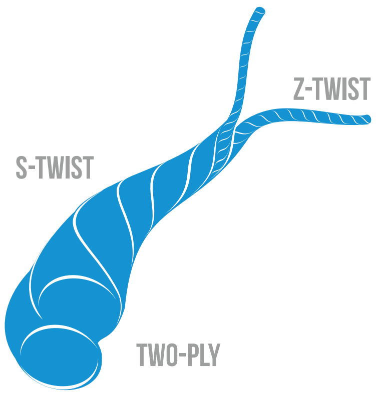
Filament yarns are collections of long continuous filament fibres which are usually man-made (with the exception of silk). Continuous filaments may only require additional twisting to make them into yarns, but sometimes they are put through an additional process called texturing.

Yarns can be described as

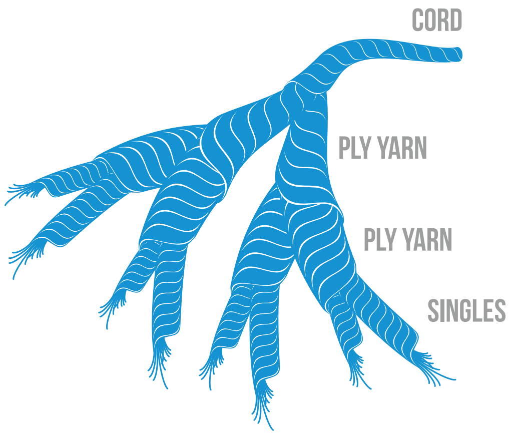
- **single or one-**ply - are single strands composed of fibres held together by
    - at least a small amount of twist
    - or of filaments grouped together either with or without twist;
    - or of single man-made filaments extruded in sufficient thickness for use alone as yarn (monofilaments).
- **ply, plied, or folded** - are composed of two or more single yarns twisted together. Two-ply yarn, for example, is composed of two single strands; three-ply yarn is composed of three single strands. In making ply yarns from spun strands, the individual strands are usually each twisted in one direction and are then combined and twisted in the opposite direction.
- **Cord yarns** - are produced by twisting ply yarns together, with the final twist usually applied in the opposite direction of the ply twist



SINGLE YARN



PLY YARN



CORD

YARN PRODUCTION

Production of spun yarns

The slivers and rovings that are produced during the fibre preparation stages are drawn out (elongated) and twisted over a series of mechanical operations that imparts twist into the yarn. This operation is repeated until the yarn is of a desired thickness. There are a number of different spinning machines and methods that are used for different fibre types and yarn specifications. Once the single or one-ply yarns have been spun, they can be used in this state, or go on to be twisted into ply yarns.

Production of filament yarns

Following extrusion, filament fibres are already in a continuous yarn state, and so do not need to be spun. Sometimes they are simply left as 'singles', or gathered into bunches, with or without inserting twist. The singles can also be twisted together to create ply-yarns. Filament yarns are often textured to reduce such characteristics as transparency, slipperiness, and to improve the appearance and functional properties of the yarns such as warmth, absorbency. Textured yarn fabrics are also more permeable to moisture and air, increasing the comfort to the wearer.

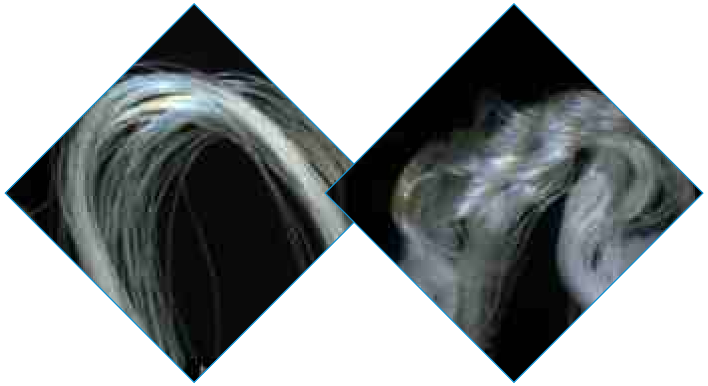
Texturing filament yarns

Texturing is the formation of crimp, loops, coils, or crinkles in filaments. It can be performed:

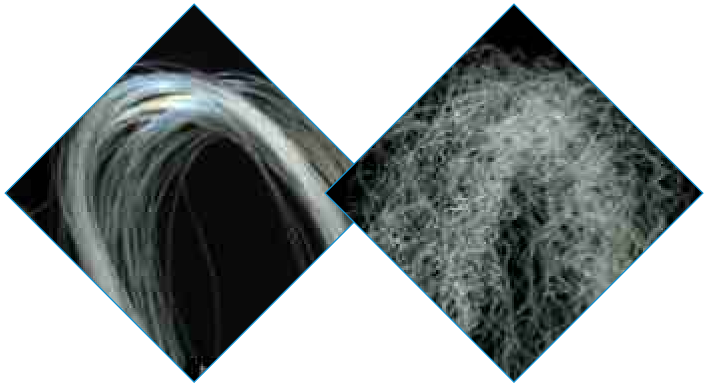
- Mechanically by passing the heated yarn through rollers
- Mechanically by twisting the yarn and cooling it in a highly twisted state
- Chemically by controlling the coagulation of a filament in order to create an asymmetric cross-section

Chemicals in yarn production

Yarn production is mainly a mechanical process, however, sometimes spinning oils are used to increase the strength of the fibre, increase fibre cohesion and reduce friction and static during the spinning.



NYLON YARN TEXTURED BY CURLING

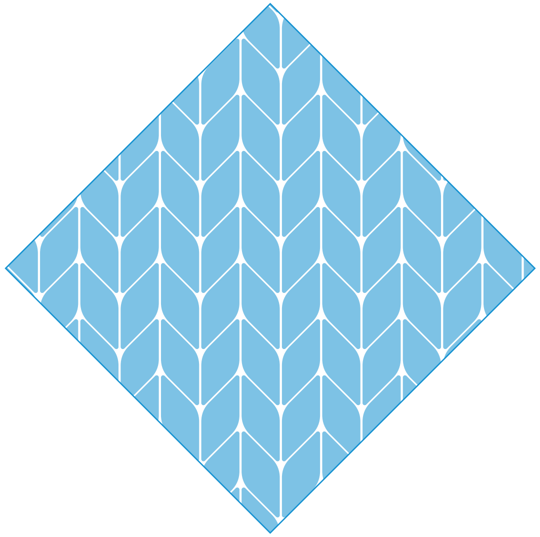


NYLON YARN TEXTURED BY CRIMPING

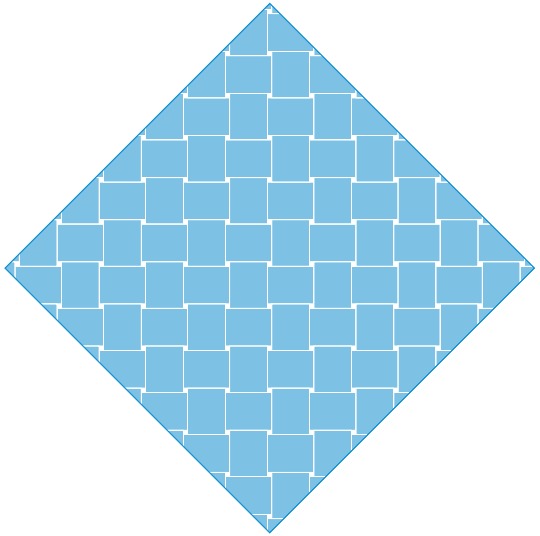
Image credit: iTextiles, http://www.itextiles.com/v30/itext/thumbnails/ai_2_1200.htm

FABRIC PRODUCTION

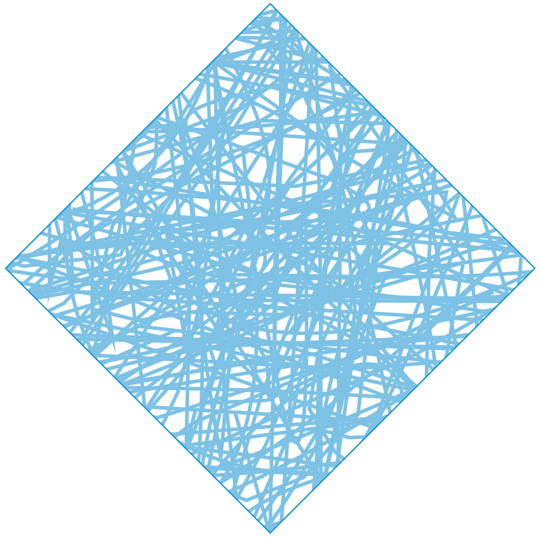
A textile fabric is a flexible material made from the interlacing of spun yarns. For apparel, this is achieved predominantly through knitting or weaving the yarns together. A further construction technique, nonwoven, produces fabrics directly from fibres (either natural staple length, or pre-cut filament fibres or in some cases directly from the polymer melt) by randomly laying them down and then bonding them together.



KNITTED FABRIC



WOVEN FABRIC



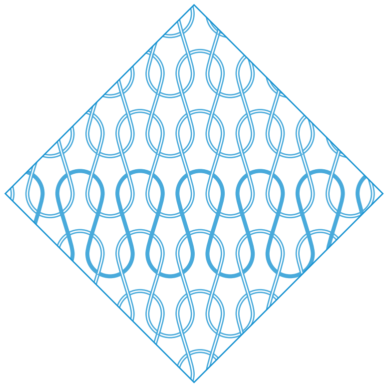
NONWOVEN FABRIC

FABRIC PRODUCTION: KNITTED FABRICS

Knitted fabrics are produced from yarn by forming interlocking loops with the help of hooked needles. Fabrics can be weft knit, which is by far the most common type of knit for apparel, or warp knit. Knitted fabrics have a face (knit), and a back (purl) side.

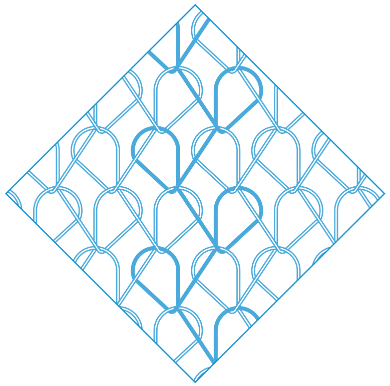
Double knit (interlock) fabrics are constructed when two layers of fabric are knit together as they are formed. The finished fabric has two knit sides, and the purl back sides are interlocked together.

Knitted fabrics are inherently stretchy due to their structure and are used for underwear and base layers, t-shirts, fleeces and insulation layers, and so on.



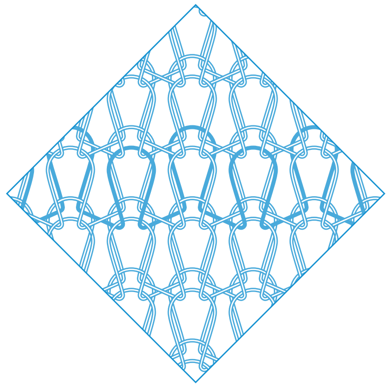
WEFT KNIT

CONTINUOUS YARNS FORM COURSES ACROSS THE FABRIC



WARP KNIT

A SERIES OF YARNS FORM WALES IN THE LENGTHWISE DIRECTION OF THE FABRIC



DOUBLE KNIT

TWO LAYERS ARE KNIT TOGETHER BY INTERLOCKING PURL STITCHES

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FABRIC PRODUCTION: KNITTED FABRICS

Industrial knitting

Industrially, fabrics are knit on flat or circular knitting machines

- Flat machines knit a flat piece of fabric which must be then transformed into garments via a 'cut and sew' process, where individual clothing pattern pieces are cut out and sewn together
- Circular machines knit the fabric into a seamless tube which can be knit in a variety of sizes and seamed together to create garments (fully fashioned knitting). Modern computerisation of knitting machines now allows the production and construction of several tubular knitted forms to create a complete garment in a single production step with the advantage of being completely seamless (complete garment knitting).

NEEDLE CONFIGURATION

EXAMPLE OF FLAT BED KNITTING MACHINE

NEEDLE CONFIGURATION

EXAMPLE OF CIRCULAR KNITTING MACHINE

Image credit: https://dir.indiamart.com/ludhiana/flat-bed-knitting-machine.html
Image credit: http://www.learnmachineknitting.com/
Image credit: http://textilelearner.blogspot.de/2012/01/mechanical-interlock-circular-knitting_29.html
Image credit: https://pt.wikipedia.org/wiki/Malharia#/media/File:Rundstrickmaschine_Nadel_scharf.jpg

FABRIC PRODUCTION: CHEMICALS USED IN KNITTING

Chemicals are often used to prepare the yarn for knitting.

Yarns are often oiled or waxed to lubricate the yarn and consequently increase the speed and ease with which knitting can be accomplished.

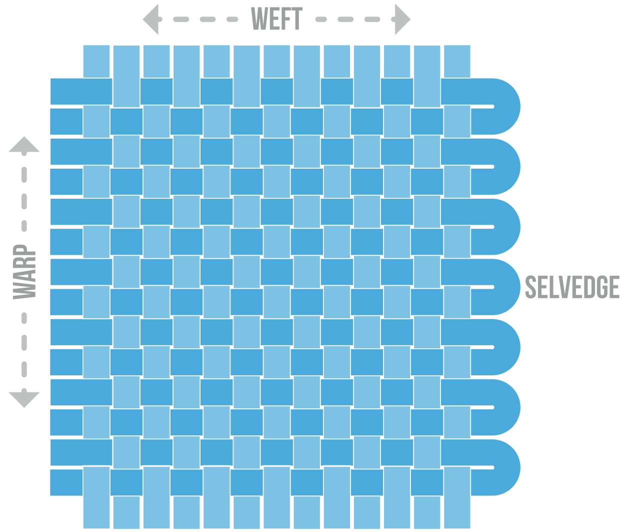
Lubricating finishes applied to knitting yarns generally are based on mineral oils, vegetable oils, synthetic ester-type oils, or waxes, and may also contain antistatic agents, antioxidants, bacteriostats, and corrosion inhibitors.

FABRIC PRODUCTION: WOVEN FABRICS

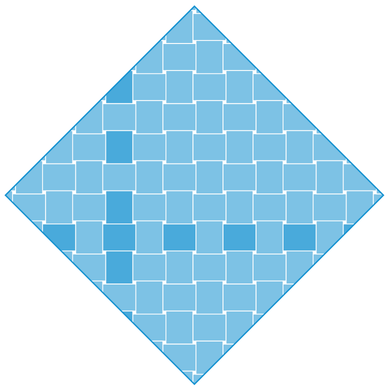
Woven fabrics are produced when two sets of yarns are interlaced at right angles to form a cloth. The vertical threads are called the warp, and the horizontal threads are called the weft.

Woven fabrics are inherently tough and durable, and the woven surface is ideal for coating and laminating, as such, woven fabrics are often used for outwear.

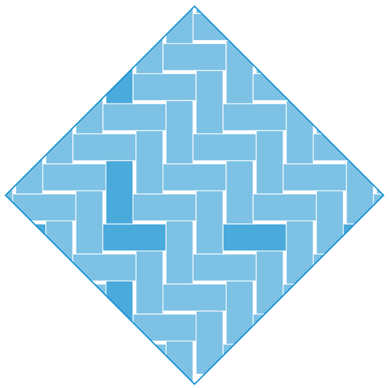
The are a number of ways to configure the weft and warp yarns which affects the properties and applications of the final fabric.



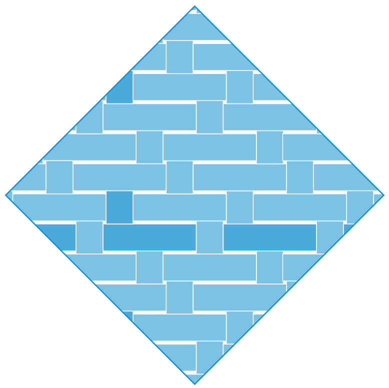
ARRANGEMENT OF WOVEN FABRIC



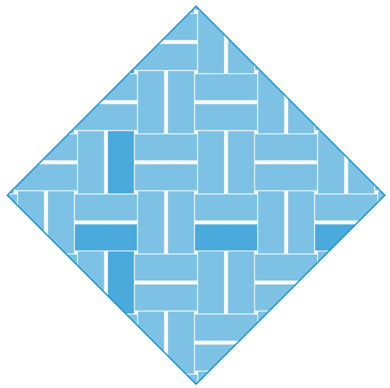
PLAIN WEAVE



TWILL WEAVE



SATIN WEAVE



BASKET WEAVE

FABRIC PRODUCTION: CHEMICALS USED IN WEAVING

Before weaving, size is often applied to the yarn to act as a protective coating or glaze during the weaving process. These sizing chemicals perform a number of functions:

- Facilitate weaving by giving the threads strength and smoothness and protect them from the flexion, friction, abrasion and strains that they are subject to during weaving
- Maintain good quality fabric by reducing hairiness, weakness and increasing smoothness of the yarn resulting in a better weave

The active ingredient in many textile sizing agents are water soluble polymers, usually modified natural starches such as carboxymethyl cellulose (CMC), however, other synthetic compounds such as polyvinyl alcohol (PVA), and acrylates can be used, although these are usually for sizing man-made fibres. Additionally waxes can be applied to reduce the abrasion of the warp yarns on the beams.

These additives must be removed again before a fabric can be bleached and dyed which is done in the desizing process.

FABRIC PRODUCTION: NONWOVEN FABRICS

Nonwoven fabrics are sheet or web structures bonded together by entangling the fibres or filaments mechanically, thermally, or chemically. Nonwoven fabrics are lighter and weaker than knitted or woven fabrics but are very cheap and quick to produce.

Nonwovens are extremely versatile and can be engineered to perform a vast number of functions through various combinations of fibre and productions methods.

Typical uses in outdoor apparel would include synthetic insulation (as an alternative to down), interlinings, padding, and in shoe and bag components.

TYPICAL APPLICTIONS OF NONWOVEN MATERIALS

PRIMALOFT

Image credit: Daren Wendell, https://darenwendell.wordpress.com/2014/01/24/i-sawed-my-running-shoes-in-half/
Image credit: Primaloft.com

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FABRIC PRODUCTION: NONWOVEN FABRICS

The nonwoven process is in principle very simple. Fibres are arranged in a sheet or web, and then bonded together

METHODS OF WEB FORMATION

CARDED

Fibres are combed into a web using a series of rotating drums covered in fine wires or teeth

AIR LAID

Fibres are fed into an air stream onto a moving belt to form a randomly orientated web

WET LAID

Fibres are suspended in water and the slurry is deposited onto a moving screen which is drained/dried

SPUNLAID

Molten polymer is extruded through spinnerets. The filaments are deposited on to a conveyor to form a web

MELTBLOWN

Molten polymer is extruded into a high velocity airstream. This scatters the melt, solidifies it and breaks it up into a fibrous web

BONDING METHODS

CHEMICAL

a liquid based bonding agent is applied to the web. This can be applied in many ways: impregnating through pressurised rollers, coating, or spraying. Print bonding is also possible where specific patterns are required or it is necessary to have the majority of fibres free of binder for functionality.

MECHANICAL

the strengthening of the web is achieved by inter-fibre friction as a result of the physical entanglement of the fibres. This is achieved using needles to entangle the fibres (needlepunching), or using fine, high pressure jets of water to interlace the fibres (hydroentangling).

THERMAL

the thermoplastic properties of synthetic fibres are used to bond webs under controlled heating. Usually a low melt fibre or bicomponent fibre is introduced at the web formation stage, but also the web fibre itself can be used.
Heat is applied using high pressure rollers (calendaring), or in a through-air oven.

FABRIC PRODUCTION: CHEMICALS USED IN NONWOVENS

During web formation

- During the carding process, fibres are often sprayed with oils and lubricants to reduce the static of the fibres as they pass through the machinery
- In some high function methods of spunlaid/meltblown web formation, a solvent is added to the polymer mix. This aids the formation of certain polymer type fibres and flashes off as the fibres are produced

During web bonding

- Mechanical web bonding is a chemical free process.
- Thermal bonding relies on thermoplastic fibres but the production of these and the associated chemicals are dealt with in the fibre production section.
- Chemical bonding uses a wide variety of chemicals to act as glues to bond the fibres and must be specially engineered to suit the specific fibre properties and end use requirements. Four groups of materials are commonly used: vinyl polymers and copolymers, acrylic ester polymers and copolymers, rubber and synthetic rubber, and natural binders (principally starch)

PRE-TREATMENT: PROCESS OVERVIEW

Pre-treatment is the process of removing impurities and preparing the textile substrates for dyeing, printing, and finishing.

The impurities can be either

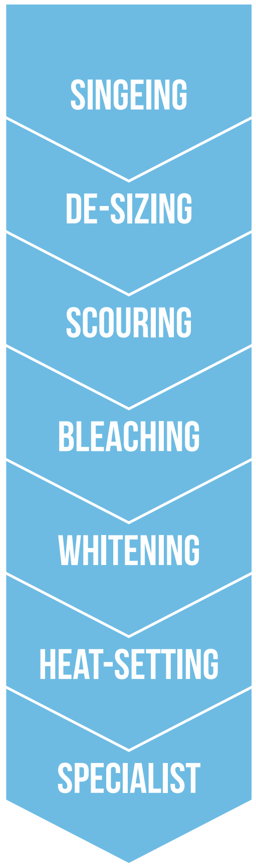
- naturally occurring oils, waxes, pectins, soils, and grease that are found on natural fibres
- deliberately applied processing aids such as spin finishes, knitting oils, or weaving size

These impurities can act as a waterproof barrier on the surface of the fibre which prevents or inhibits dye penetration. Furthermore, if they leech into the dyebath they can adversely affect dyebath dynamics such as solubility of dyes, pH, and uniformity of dyeing.

In general, natural fibres require a more intensive pre-treatment process due to the presence of the natural impurities and their natural creamy colour, man-made and synthetic fibres have no natural impurities present and they are generally white – meaning no additional bleaching is required except for very pale bright colours.

The major objectives of a pre-treatment process are

- Remove dust, dirt, and chemical residue from the surface of the textile substrate (and ensure it is not present in subsequent dyebaths)
- Achieve a desired degree of whiteness for the final shade
- Some fibres are naturally white and all shades are achievable on the base fibre
- Some fibres are naturally creamy and have to be bleached to achieve pale, bright shades
- Ensure the substrate has optimum absorbency for the dyes and chemicals used in subsequent processing



PRE-TREATMENT: SINGEING

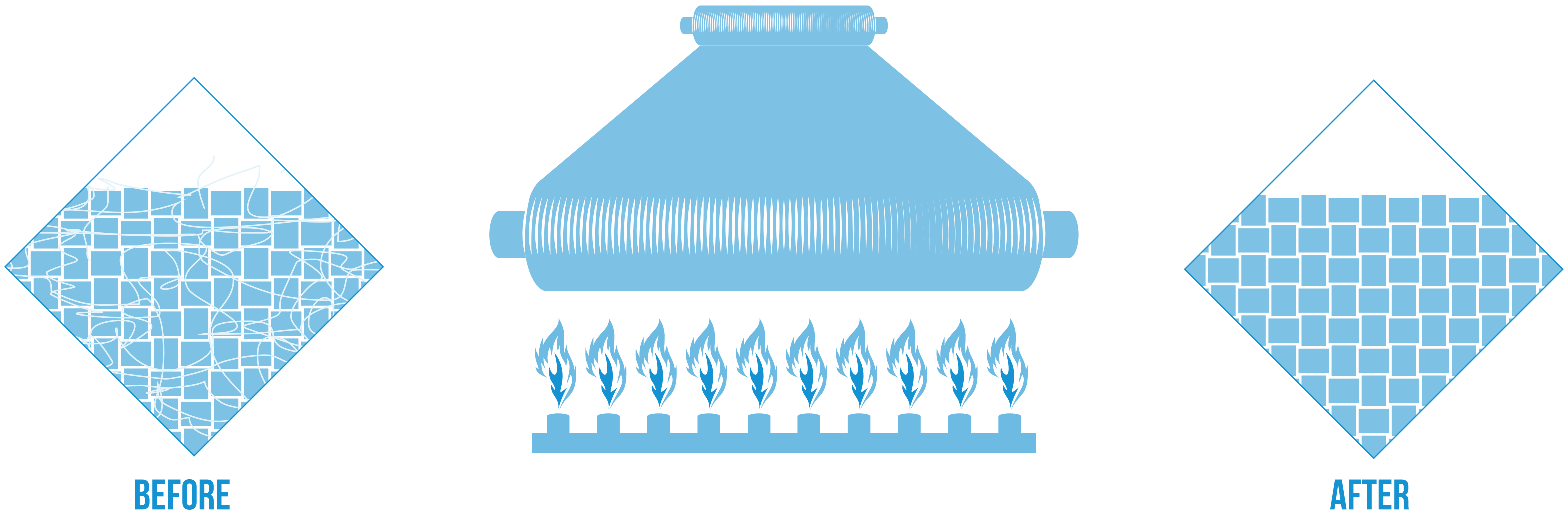
The first stage for preparation of many woven fabrics made from staple yarns is singeing (there is no need to singe fabrics made from filament yarns as there is no surface hair present). This process simply burns raised hairs off the surface of the fabric to make the surface smoother.

The fact that there is often weaving size present means that some hairs will be 'glued' down and inaccessible to the flames so it is best practice to singe after a fabric has been de-sized/scoured – although this requires an extra intermediate drying process.

Care has to be taken when singeing fabrics containing synthetic fibres as they can melt and form beads on the surface that affect hand-feel and dyeability.

Yarns intended for knitted fabrics or knitted fabrics themselves can be singed - but this is unusual.

No chemicals are used in the singeing process, but it can save chemicals, energy, and water in downstream processing as it is reduces the need for biopolishing, which is often used to clean up hairy cotton fabrics.

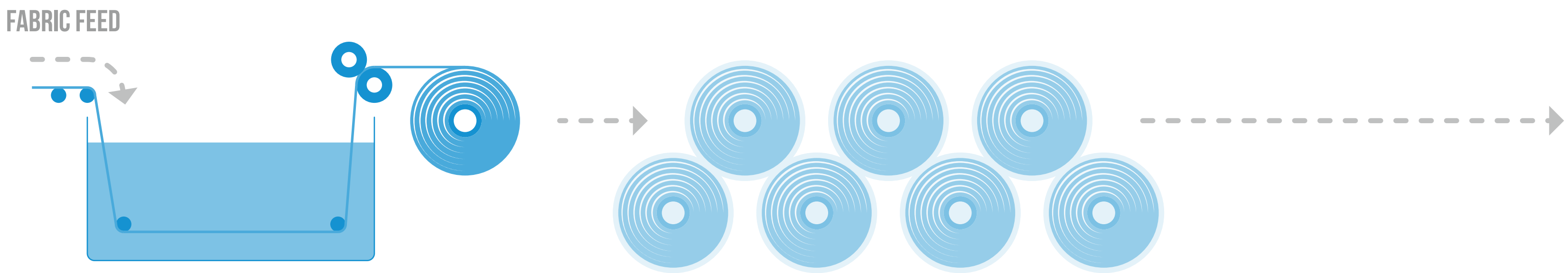


PRE-TREATMENT: DE-SIZING

De-sizing specifically refers to the removal of size from a woven fabric. If the size is not water soluble (e.g. starch based) then an initial de-sizing process is required before scouring.

Starch from corn, rice or potato is commonly used as size for woven cellulosic yarns (cotton, linen, viscose, lyocell) and this needs to be removed via a treatment with amylase enzymes in order to break down the starch. This is usually done as a stand alone 'cold pad batch' procedure.

If the size is water soluble then de-sizing and scouring are a single process.



1 Enzyme, pH control, and detergent solution

2 Fabric rolls are wrapped in plastic. 1-24 hours, 20-30°C

3 After the starch has been digested by the amylase enzyme the fabric goes on to be scoured, bleached or whitened.

PRE-TREATMENT: SCOURING

Scouring refers to the final removal of all remaining impurities, both natural substances and residual processing chemicals, from the fabric before dyeing.

Scouring is essentially an optimised washing procedure but as many of the chemicals are not readily soluble in water alone, a detergent base is used.

Scouring natural fibres

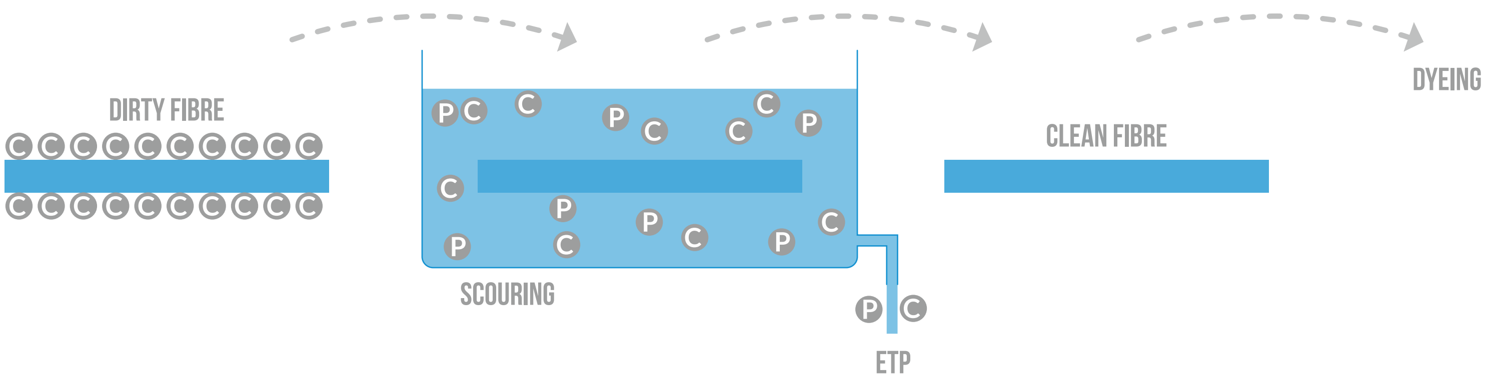
For cotton or linen it is normally necessary to use highly alkaline (pH 12 achieved using caustic soda) boiling detergent baths at with high levels of dispersants to remove natural oils, waxes and pectins. and prevent their re-deposition back onto the fibre.

There are some new, highly effective, lower temperature, enzyme-based scouring systems for cotton that operate at around pH 6 and 70oC and use pectinase enzymes rather than hot alkali to do the majority of the scouring – they do still use detergents and dispersing agents but, due to the gentler pH, are reported to cause less fibre damage than traditional scouring systems.

Scouring synthetic fibres

For man-made fibres that have no natural waxes, pectins etc present a hot/warm scour at around 70oC with a small amount of detergent all that is normally required to remove traces of spinning or knitting oil. Where there is a requirement to remove water soluble size that was not removed in a prior de-sizing process, then greater amounts of detergent - and dispersing agents, to prevent re-deposition back onto the fibres - may be required.

C= **Contaminant (natural impurities plus e.g. spinning oils, knitting oils, weaving size)**
P = **Process chemicals**
ETP = **Effluent Treatment Plant**



PRE-TREATMENT: BLEACHING

Bleaching is the removal of colour from a textile fibre to produce a white base, it is only really required to achieve the palest, brightest colours. However, where the source (and therefore the colour) of base fibres and yarns is inconsistent, some dyers bleach in order to achieve a consistent base white. As such, almost all cotton, viscose and linen is bleached.

It is very rare that synthetic polymer fibres (nylon, polyester) require bleaching as whiteness/brightness can be managed during extrusion through the use of delustrants etc. Bleaching or the use of reducing agents can be employed but the improvement in white of the base fibre is minimal.

Almost all bleaching processes use hydrogen peroxide as the bleaching agent – this converts to oxygen and water during processing and has no environmental impact.

When adding hydrogen peroxide it is necessary to add a peroxide stabiliser (to prevent explosion, decomposition), and sequestrants to capture metal ions that can cause rapid decomposition of peroxide and/or formation of holes in fabric.

There are some new enzyme based bleaching processes for cotton and other cellulosic fibres (still hydrogen peroxide based but added to the enzyme-based scouring systems) – these tend to give moderate levels of white and are not always suitable for the palest, brightest shades.

BEFORE

AFTER

Image credit: https://www.musicjinni.com/iNZO9jzmZwH/Preparation-Properties-Uses-of-bleaching-powder.html

PRE-TREATMENT: WHITENING

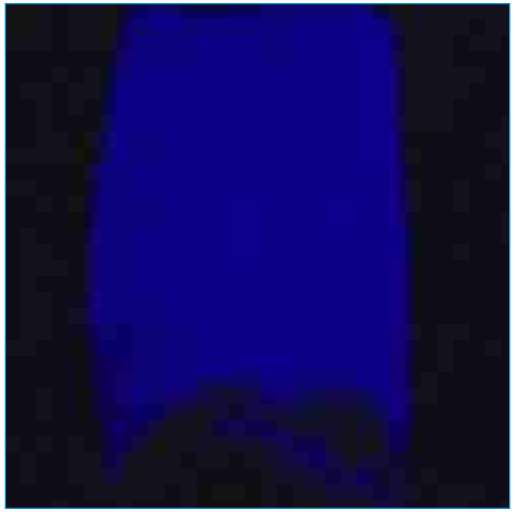
If an actual white colour is required at the point of sale then a 'white dye' called an optical brightening agent (OBA) is applied. Optical brightening agents and compounds that absorb UV light and emit blue light – the emitted blue light enhances the whiteness of a slightly creamy coloured bleached base substrate.

Depending on the process (batch or continuous) OBA's can be applied in the same bath as scouring/bleaching, or in a subsequent bath following bleaching.

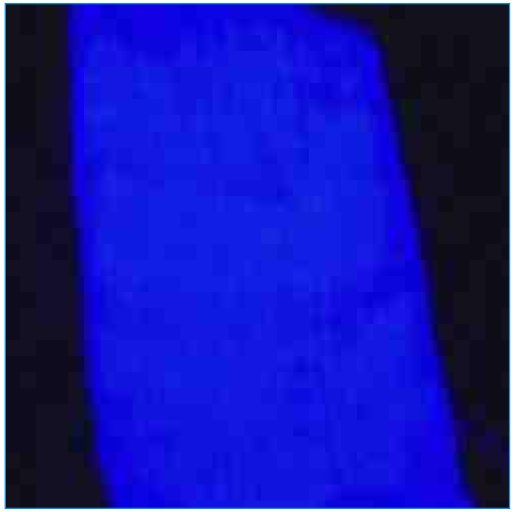
The application of OBA is normally relatively simple with a small amount of acid/alkali for pH control required to achieve good levels of fixation.

Synthetic fibres may be produced containing white pigments (typically titanium dioxide) but this tends to act as a dulling agent rather than delivering the levels of white consumers now expect from white textiles.

It is very rare that OBA whitened fabrics are dyed, but it is very common for prints to be applied on fabrics that have OBA applied.



UNTREATED FABRIC WHEN VIEWED UNDER UV LIGHT



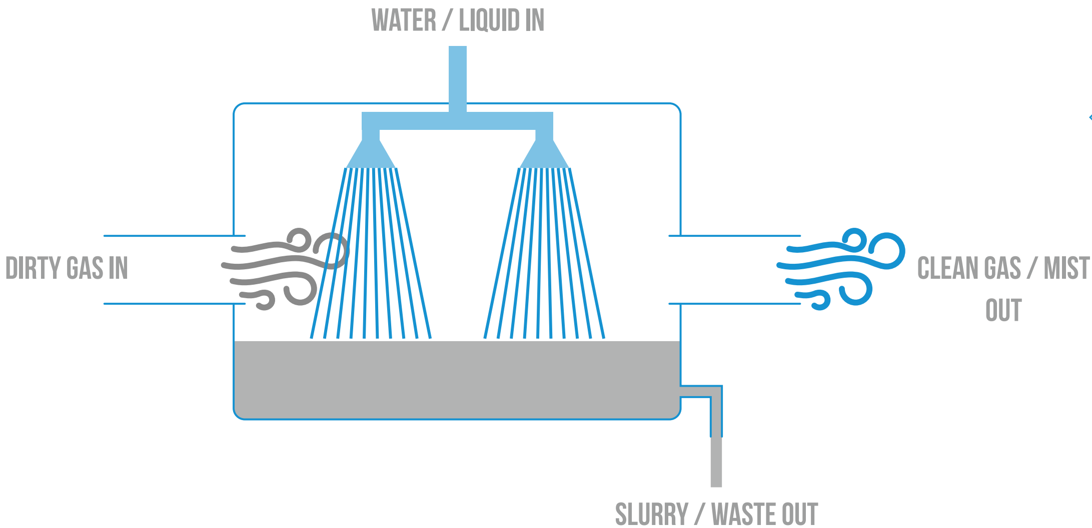
FABRIC TREATED WITH OBA WHEN VIEWED UNDER UV LIGHT

PRE-TREATMENT: HEAT-SETTING

Synthetic fabrics and elastane (or natural/synthetic blends) can be heat set using high temperatures (180 to 220oC) to give fabric a 'memory'. This memory allows the fabric to revert back to the exact configuration after dyeing and finishing or customer laundry, meaning that shrinkage and creasing can be controlled.

Nylon is a special case because it has dye sites that are crucial to high fastness dyeing that can be damaged by heat setting – so it is best practice to apply a fibre protecting agent to nylon after scouring and before heat setting.

Heat setting can 'cook'/crosslink any impurities that are present on the fibres and make them more difficult to remove so it is best practice to de-size/scour before heat setting – although this does not always happen. Pre-setting of fabrics straight from the loom or knitting machine can cause smoke and fumes that, ideally need to captured in filters or air scrubbers rather than released to the environment.



FUNCTIONALITY OF A STANDARD AIR SCRUBBER, INTENDED TO REMOVE CONTAMINANTS

Image credit: https://shedhatextile.blogspot.de/

PRE-TREATMENT: SPECIALIST TREATMENTS

Mercerisation

Mercerisation is a process where very strong caustic soda is applied to woven cotton fabrics to change the cross sectional shape of cotton fibres and thus increase dye uptake and lustre.

Polyester Weight Reduction

Over time, the requirement for finer fibres and fabrics has increased. These fine synthetic filaments and yarns are relatively expensive to produce and to weave/knit. As such, some polyester fabrics are made with fairly standard decitex filaments/yarns and are then treated with hot, highly alkaline baths to reduce the weight by dissolving lower molecular weight polymers from within the fibres. These polymers can enter waste streams along with other fibre additives and even quantities of antimony trioxide catalyst.

Wool Shrink Resist

To reduce felting and shrinkage of wool during consumer laundering, fibre scales can be altered. This can be achieved through stripping the scales using very aggressive chlorine gas or chlorinated chemicals before dyeing, and/or the application of polymeric resins after dyeing to create a smooth coating over the scales.

Cotton Biopolishing

Cotton biopolishing uses cellulase enzymes to remove surface hairs from cotton. The surface hairs are removed but the underlying fabrics are also significantly weakened, a lot of potentially harmful cotton dust is generated and effluent loading is increased (fibres and chemicals).

Lyocell Peachskin

Some types of lyocell fibre fibrillate if they are abraded when they are wet, which when controlled can generate an attractive peachskin finish on the fabric. The process uses a hot, fairly alkaline scouring or de-sizing process to generate the fibrillation followed by a biopolishing process using cellulase enzymes – the final peachskin finish is developed in subsequent processing, such as dyeing, via the formation of very short fibrils on the fabric surface.

PRE-TREATMENT: PROCESS OVERVIEW

The table below gives an overview of some common fibre/fabric types and typical pre-treatment processes.

It is not intended to be exhaustive but rather aims to show that there is a significant variety of pre-treatment processes with very different levels of chemical usage and that different pre-treatment methods may be employed depending on the subsequent dyeing method.

					BATCH SCOUR / BLEACH			CONTINUOUS SCOUR / BLEACH							
		SINGE	ENZYME DE-SIZE	FIBRE SCOUR	BATCH SCOUR – MILD/WARM	BATCH SCOUR – HOT	BATCH SCOUR AND BLEACH - HOT	CONTINUOUS SCOUR – MILD/WARM	CONTINUOUS SCOUR - HOT	CONTINUOUS SCOUR AND BLEACH - HOT	DRY HEAT-SET	PAD-> HEAT-SET	MERCERISE / CAUSTICISE	OPTIONAL SPECIAL PRE-TREATMENT PROCESS	USUAL DYEING METHOD
	SILK			✓	✓										BATCH
	WOOL			✓	✓									SHRINK RESIST	BATCH
	WOVEN LINEN	✓	✓	✓						✓					CPB/CONTINOUS
	ACRYLIC				✓										BATCH
KNITTED	100% POLYESTER, POLYESTER/ELASTANE				✓						✓				BATCH
KNITTED	100% NYLON, NYLON/ELASTANE				✓							✓			BATCH
KNITTED	COTTON					DARK SHADES	LIGHT SHADES							BIOPOLISH	BATCH
KNITTED	COTTON/ELASTANE					DARK SHADES	LIGHT SHADES				✓				BATCH
KNITTED	VISCOSE				DARK SHADES		LIGHT SHADES								BATCH
KNITTED	VISCOSE/ELASTANE				DARK SHADES		LIGHT SHADES				✓				BATCH
KNITTED	LYOCELL				DARK SHADES		LIGHT SHADES							PEACHSKIN	BATCH
KNITTED	LYOCELL/ELASTANE				DARK SHADES		LIGHT SHADES				✓			PEACHSKIN	BATCH
WOVEN	100% POLYESTER, POLYESTER/ELASTANE				✓			✓			✓			WEIGHT REDUCTION	BATCH
WOVEN	100% NYLON, NYLON/ELASTANE				✓			✓				✓			BATCH
WOVEN	COTTON	✓	✓						DARK SHADES	LIGHT SHADES			✓		CPB/CONTINOUS
WOVEN	COTTON/ELASTANE	✓	✓						DARK SHADES	LIGHT SHADES	✓		✓		CPB/CONTINOUS
WOVEN	VISCOSE	✓	STARCH SIZE					DARK SHADES		LIGHT SHADES					CPB/CONTINOUS
WOVEN	VISCOSE/ELASTANE	✓	STARCH SIZE					DARK SHADES		LIGHT SHADES	✓				CPB/CONTINOUS
WOVEN	LYOCELL	✓	STARCH SIZE					DARK SHADES		LIGHT SHADES			✓		CPB/CONTINOUS
WOVEN	LYOCELL/ELASTANE	✓	STARCH SIZE					DARK SHADES		LIGHT SHADES	✓		✓		CPB/CONTINOUS

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PRE-TREATMENT: RESTRICTED SUBSTANCES

CONCERNS RELATED TO PRE-TREATMENT

Pre-treatment processes can be chemical, water, and energy-intensive and the effluent loading from some processes is very high containing the chemicals deliberately used in the pre-treatment process and the chemicals/natural impurities that are were removed.

Care has to be taken when using permitted-but-harmful substances like strong acids and strong alkalis and it is important to ensure that effluents - that can contain very high levels of oxygen depleting substances – are remediated to ensure damage to the environment is minimized.

As far as restricted substances are concerned, that may be restricted by legislation or by brand RSL's, then there are a few chemicals to consider that may be present in the pre-treatment process.

- The major concern is APEO's – alkyl phenol ethoxylates are used as detergents and in lower amounts as wetting agents and emulsifying agents. They are known to be harmful to aquatic species and their use has been commonplace in some areas of the world. They are illegal in formulations in the EU and recently introduced EU legislation on finished products means there are intensive efforts to phase them out of deliberate and unintended use throughout supply chains
- There are various types of preservatives that can be used to protect substrates and formulations from microbial attack. Some are permitted but others are illegal/restricted.
- Pesticides – farmers may use chemicals to protect crops and animals from attack by pests. Some pesticides are restricted by legislation and should not be used – they can enter a wet processing facility on natural fibres or fabrics.
- As scrutiny increases on the content of wastewater then the presence of additives in synthetic fibres, that may be washed out to some extent during wet processing, may require further examination

DYEING: INTRODUCTION

At some stage during the textile production process, it is normal to introduce a colour via a dyeing process. Dyeing involves the use of dyes, water, and additives like salt or various other chemicals to fix the dye to the textile substrate.

The dyeing process is most commonly carried out on fabric, but can be carried out at various stages in the production process:

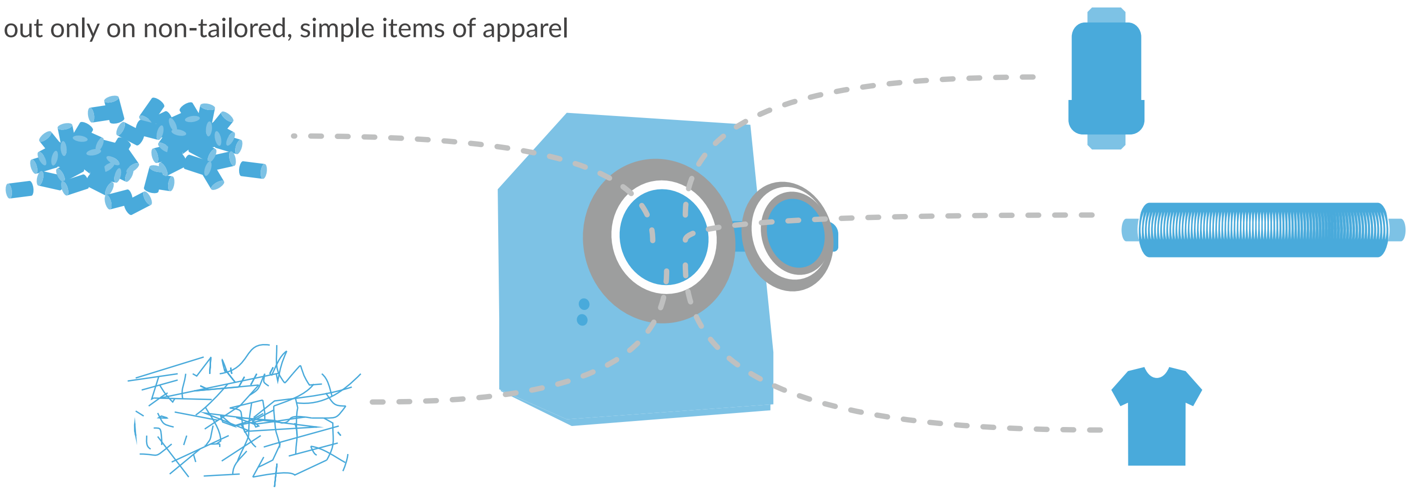
Dope colour is introduced to the polymeric melts or before filament extrusion. From a chemical and environmental perspective dope dyeing is the favourable as it requires no separate dyeing process.

Fibre also known as stock or top dyeing, fibres are dyed before they are spun into a yarn

Yarn yarns are dyed as loose hanks (skeins), on wound packages or spools, or as entire warp beams

Fabric dyeing also known as piece dying, completed knitted or woven fabrics are dyed after a pre-treatment preparation process, by far the most prevalent form

Garment dyeing usually carried out only on non-tailored, simple items of apparel



DYEING: DYE CLASSIFICATION

There are two main classes of dye, natural dyes made from animals and plants, and synthetic dyes made from petroleum sometimes in combination with mineral derived compounds. Dyes are classified according to their solubility and chemical properties and certain dyes are more appropriate for different types of fibre.

ACID	Water-soluble anionic dyes that are applied to fibres using neutral to acid dye baths. Attachment to the fibre is attributed, at least partly, to salt formation between anionic groups in the dyes and cationic groups in the fibre.
BASIC	Water-soluble cationic dyes. Usually acetic acid is added to the dye bath to help the uptake of the dye onto the fibre.
DIRECT OR SUBSTANTIVE	Water-soluble compounds that have an affinity for the fibre and are taken up directly. It is normally carried out in a neutral or slightly alkaline dye bath, at or near boiling point, with the addition of either sodium chloride, sodium sulfate, or sodium carbonate.
MORDANT	Colorants that can be bound to a material for which it otherwise has little or no affinity by the addition of a mordant (such as a salt). Mordants combines with the dye and the fibre to facilitate dying and improve the fastness against water, light, and perspiration.
MORDANT	Insoluble in water and incapable of dyeing fibres directly. However, reduction in alkaline liquor produces the water-soluble alkali metal salt of the dye, which, in this leuco form, has an affinity for the textile fibre. Subsequent oxidation reforms the original insoluble dye.
REACTIVE	Organic substances, primarily used for tinting textiles, that attach themselves to their substrates by a chemical reaction that forms a covalent bond between the molecule of dye and that of the fibre. The dyestuff thus becomes a part of the fibre and is much less likely to be removed by washing.
DISPERSE	Suspensions of insoluble, organic pigments. The dyes are finely ground in the presence of a dispersing agent and sold as a paste, or spray-dried and sold as a powder. The very fine particle size gives a large surface area that aids dissolution to allow uptake by the fibre. The dyeing rate can be significantly influenced by the choice of dispersing agent used during the grinding.
AZOIC	Insoluble dyes which are produced directly onto or within the fibre. Dyeing is achieved by treating a fibre with both a diazoic acid and a coupling component. With suitable adjustment of dyebath conditions the two components react to produce the required insoluble azo dye. This technique of dyeing is unique, in that the final colour is controlled by the choice of the diazoic acid and the coupling component.
SULFUR	Synthetic organic dyes applied from an alkaline solution of sodium sulfide (in which they dissolve) to cellulose, where they become substantive to the fibre. On exposure to air, the dyes in the fibre are oxidized back to their original insoluble form.

DYEING: FUNDAMENTALS

The fundamental task that must be accomplished in dyeing is the transfer of dye from the dyebath onto the fibres or material being dyed, and then fixation of this dye onto the fibres.

Transfer of dye onto fibre surface

- Dye liquors are prepared through the dissolution of dyes into a solvent (often water, although other chemicals may be used/added depending on the type of dye and fibre properties)
- Textile substrates (fibre, yarn, fabric, garment) are immersed in the dye liquor in a manner and process suitable to the specific substrate and dye type.

For economic and environmental reasons, a high degree of exhaustion (take up of the dye by the substrate) is desirable. Dyes are expensive, and dye that is left in the bath is wasted. Furthermore, dye left in the dyebath is a pollutant that must be controlled and disposed of along with the wastewater from the plant. Often auxiliary chemicals are added to the dyebath to improve exhaustion.

Fixation

Different chemicals are required to fix different types of dye to different types of fibre and these do not particularly vary with dyeing method. The sequence of addition of process chemicals (such as lubricants, anti-crease chemicals), dyes and fixation chemicals (such as salt or alkali) depends on the specific dye/fibre combination and dyer's preference.

Not all dyeing processes are the same. Different types of machinery can be used and different dye/fibre combinations require different conditions (e.g. chemicals, temperature, pH and so on) to achieve a successful dyeing.

For some dye/fibre combinations it is necessary to mix the dyes and chemicals together using intelligent dosing systems as close to the time of application as possible in order to prevent unwanted reactions that that can result in reduced dye fixation.

DYEING: GENERAL PROCESS

Dyeing conditions

The conditions have to be set so that the dyes are attracted to the fibre and then fixed – sometimes this is essentially a single process (for example dyeing polyester with disperse dyes) but sometimes it is very much a two stage process (such as the attraction of reactive dyes to cotton in the presence of salt and the fixation using the addition of alkali).

A dyer can control the uptake and fixation of dyes by either:

- adding all the dye at the start and then slowly changing the dyebath conditions e.g. changing the pH or the temperature

  and/or

- setting the dyebath conditions to be perfect for dyeing and then dosing the dye over a prolonged period of time to ensure uniformity.

Occasionally, as is the case with acrylic dyeing, the dyer may even add a retarder to hold a highly substantive dye away from the fibre.

Dyebath preparation

- the dyebath is brought to the correct start temperature for the dyeing process
- the dyebath is brought to the correct pH for the start of the dyeing process – this depends on the pH of previous baths but usually involves the addition of an acid such as acetic acidw
- if any dyes are susceptible to damage by reducing agents an anti-reductant may be added to the dyebath
- if the substrate has been bleached prior to dyeing it is normal to apply a chemicals to remove any traces of peroxide bleach as this can affect the dye. Historically this was done using mild reducing agents which necessitated a separate process bath but is now normally done using catalase enzymes which have no negative effect on dyeing
- if there is any risk of foaming, either from dyebath additives or residues from previous processes then an anti foam may be added
- depending on the type of fibre and processing conditions a wetting agent may be added
- if a fabric is being dyed in rope form (for example on a jet dyeing machine) then a fabric lubricant/anti-crease may also be employed

DYEING: GENERAL PROCESS

Dye addition

- Once a dye-bath has been set as described above then it is normal to introduce the dye using carefully controlled dosing (maybe over a period of 20 to 30 minutes) to ensure uniformity of dyeing.

- One exception is reactive dyeing of cellulosic fibres where it is normal to add salt (sodium chloride or Glauber's salt) to the dyebath prior to adding dye and then adding dye over a slightly longer period of time.

Dye penetration and fixation

- Once the dye has been added it has to penetrate into the fibre (rather than just sitting on the surface) and it has to be fixed.
- How a dye is fixed depends on the specific fibre/dye combination but it can be by raising the temperature, adjusting the pH or both.
- Once the temperature, pH and other dyebath conditions are correct for dyeing the process is left to run for typically 30 to 60 minutes after which time the dye will have fixed

Removal of dyes

If things go wrong in the dyeing process, the dyer may be forced to remove the dye already applied by a process called stripping or discharging. This normally means destroying the dye with powerful reducing agents such as sodium hydrosulfite or oxidizing agents such as hydrogen peroxide or sodium hypochlorite. However, the process risks damaging the substrate and so where possible, it is often less risky to dye the material a darker shade, with black often being the easiest or last option.

DYEING: GENERAL PROCESS

Wash off

At the end of the dyeing process the dye is in three places – in the fibre, on the fibre and in the dyebath. A wash off process is required to remove the unfixed dye from the surface of the fibre and from the dyebath to ensure good wash fastness of the final product.

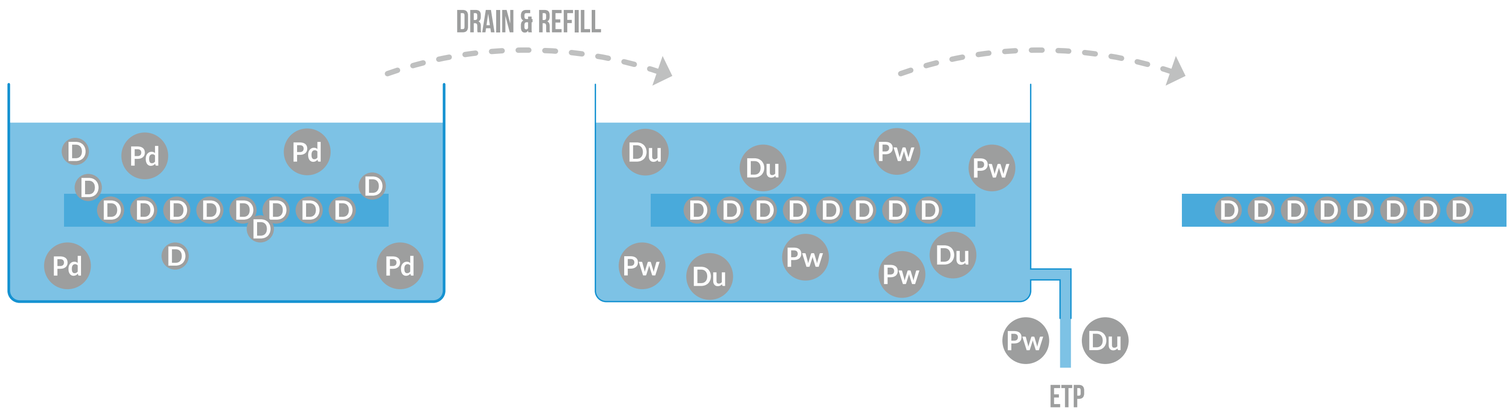
For some fibre/dye combinations this can be achieved using just water – or perhaps a very small amount of detergent but other require a more extensive and/or chemically intensive wash off process.

For example, over 99% of the dye applied to polyester is taken up by the fibre and very little remains in the dyebath. However the small amount of disperse dye on the fibre surface can cause very poor wash fastness and is very difficult to remove so a process called reduction clearing is employed – this requires the use of highly alkaline caustic soda and a reducing agent (hydros - sodium dithionite) at 85oC to achieve good wash fastness in medium or dark shades.

The fastness of acid dyes on some nylon fibres (there are different variants of fibre with different levels of dyeability) is poor unless any loose dye is removed using a mild alkaline scouring process followed by cationic fixatives and special fastness improvers called syntans.

Some fibres can be successfully dyed using different types of dye - and a dyer has a choice – and individual dye types can be used to successfully dye different fibres.

D = **Dye**
Du = **Unfixed dye**
Pd = **Process chemical for dyeing**
Pw = **Process chemical for wash off**
ETP = **Effluent Treatment Plant**



DYEING: FIBRE TYPE SPECIFICATIONS

The following table summarises common dyeing systems by fibre type

Where pH control is required then a pH of below 4 may be achieved using sulphuric acid, a pH of 4 to 7 achieved using acetic or formic acid, a pH of 7 to 10 achieved using sodium carbonate (soda ash) and a pH of greater than 10 achieved using caustic soda

FIBRE	DYE TYPE	APPLICATION CONDITIONS	FIXATION	SPECIAL WASH OFF	AFTER-FIX
POLYESTER	DISPERSE DYE	PH 4-5 DISPERSING AGENT - ANTI-REDUCTANT 130°C		REDUCTION CLEAR [CAUSTIC SODA AND HYDROS] 85°C	NONE
NYLON	ACID DYE	PH 4-5 98°C		MILD ALKALI WASH	CATIONIC AFTER-FIX, SYNTAN
	REACTIVE DYE	PH 4 75°C	TREATMENT WITH CALCIUM CHLORIDE AT 110°C		TREATMENT WITH PROPRIETARY FIXING AGENT AT 80°C
WOOL	ACID DYE	PH 3-4 98°C		WATER / MILD DETERGENT ONLY	NONE
	WOOL REACTIVE DYE	PH 4 0.5	TREATMENT AT PH 9		
ACRYLIC	BASIC DYE	PH 4-5 DYE RETARDER SOMETIMES USED		WATER / MILD DETERGENT ONLY	
COTTON VISCOSE LYOCELL LINEN	REACTIVE DYE	SALT (HIGH LEVELS) PH 7	PH 10-12	HOT SOAPING	CATIONIC FIXATIVE ON DARK SHADES
	DIRECT DYE	SALT (LOW LEVELS) PH 7		WATER / MILD DETERGENT ONLY	CATIONIC FIXATIVE
	SULPHUR DYE	PH 10-12 REDUCING AGENT	OXIDISING AGENT	HOT SOAPING	
	VAT DYE	PH 10-12 REDUCING AGENT	OXIDISING AGENT	HOT SOAPING	
ALL FIBRES	PIGMENT	FABRIC OR GARMENT IS PRETREATED WITH A BINDER, DYES ARE APPLIED TO BINDER AND (AFTER OPTIONAL LEVELS OF WASHING) AN FINAL BINDER IS APPLIED			

DYEING: METHODS

Batch dying

Batch dyeing is suitable for fibres, yarns, fabrics, and garments.

In batch dyeing, the dyes, and chemicals required to fix them to a fibre, are dissolved in water of a specific temperature and either:

- The substrate is moved through the dye liquor e.g. winch dyeing
- The dye liquor is pumped through a stationary substrate e.g. stock, beam dying

STOCK/TOP DYEING

Stock/top dyeing fibres or 'stock' are dyed before it is spun into yarn. It is done by putting loose, un-spun fibers into large vats containing the dye liquor, which is heated to an appropriate temperature.

HANK (SKEIN) DYEING

Hank (skein) dyeing large, loosely wound hanks (skeins) of yarns are immersed into dye vats that are especially designed for this purpose. Soft, lofty yarns such as hand knitting yarns are usually hank dyed. Hank dyeing is the most costly yarn-dye method.

PACKAGE DYEING

Package Dyeing yarn is wound on a small perforated spool or tube called a package. many spools fit into the dyeing machine in which the flow of the dye bath alternates from the center to outside, and then form outside to the center of the package.

Warp beam dyeing - a much larger version of package dyeing. An entire warp beam is wound onto a perforated cylinder, which is then placed in the dyeing machine where the flow of the dye bath alternates as in package dyeing.

Image credit: https://www.briggsandlittle.com/tour/
Image credit: Original source uknown, taken from http://textilelearner.blogspot.de/2011/12/methods-of-dyeing-different-dyeing.html
Image credit: Original source uknown, taken from http://textilelearner.blogspot.de/2011/12/methods-of-dyeing-different-dyeing.html

DYEING: METHODS

Jet/winch dyeing the fabric being dyed is circulated in a rope form through a closed system static dyeing machine on a jet flow of the dye bath.

Beam dyeing fabric is wound on to a perforated cylinder and the dye liquor is pumped through the fabric layers. The fabric remains stationary.

Garment dyeing complete garments are dyed in small batches using industrial garment dyeing machines.

JET/WINCH DYEING

BEAM DYEING

GARMENT DYEING

Image credit: https://www.textileweb.com/doc/cloth-beam-dyeing-machines-0001
Image credit: https://www.wotol.com/tonello-u-3250-garment-dyeing-machine/second-hand-machinery/prod_id/222982

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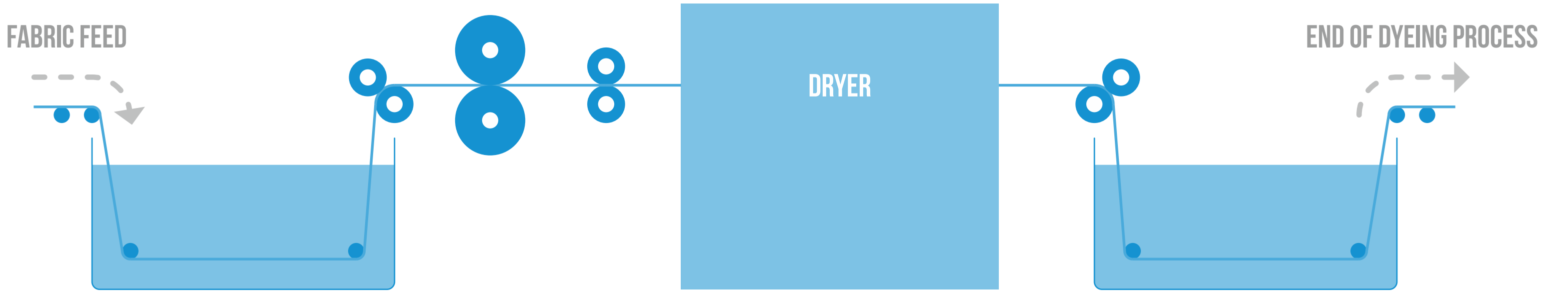
DYEING: METHODS

Continuous dying

Continuous or jig dying is only suitable for fabrics. In continuous dyeing the dye/chemical mix is applied through immersion of the fabric in the dye liquor contained in a trough. The fabric then passes through mangles evenly distributing the liquor and squeezing out any superfluous fluid.

The dye is fixed by application of steam / dry heat after which any unfixed dye is removed by a sequence of wash baths.



1 Fabrics immersed in dye liquor

2 Hot air flue on cylinder dryer

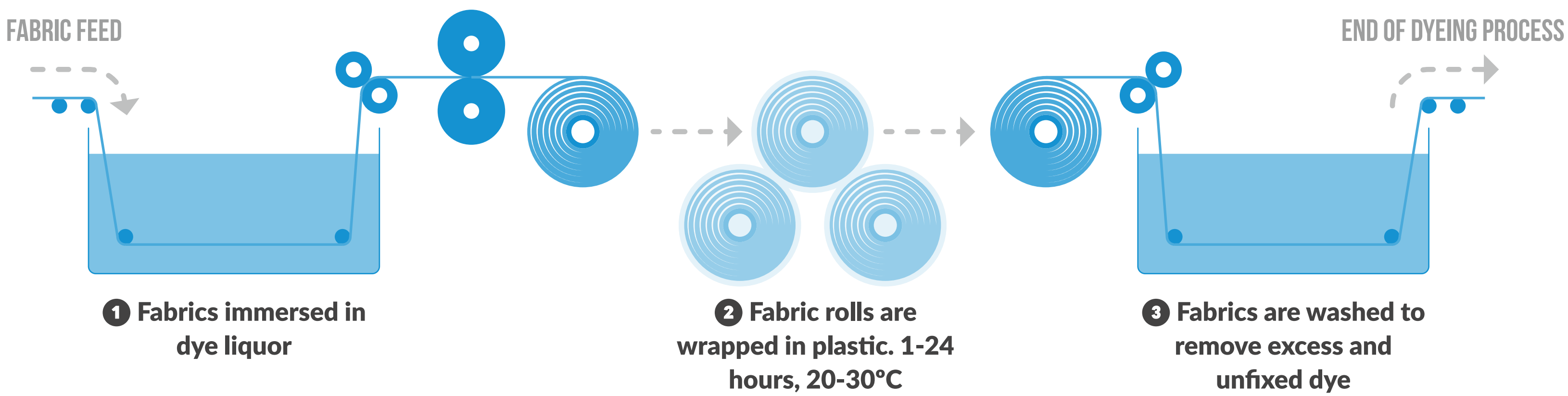
3 Fabrics are washed to remove excess and unfixed dye

DYEING: METHODS

Semi-continuous dying

Semi-continuous dying is also only suitable for fabrics. In semi-continuous dyeing (Cold Pad Batch dyeing for cellulosic fabrics) the dye/chemical mix is applied through immersion of the fabric in the dye liquor contained in a trough. The fabric then passes through mangles evenly distributing the liquor and squeezing out any superfluous fluid. The fabric is then wound on a roll without drying.

The dye is fixed by covered the roll in plastic sheets to stop the fabric drying and the batch is slowly rotated for 12 – 24 hours at room temperature (there is no need to apply heat).



DYEING: RESTRICTED SUBSTANCES CONCERNS RELATED TO DYEING

Dyeing is concerned with using chemicals to apply dyes to the fibre – for most processes there are relatively few major worker safety issues (apart form the use of strong acids or alkalis) and the major effluent concern is the presence of colour from unfixed dyes.

As far as restricted substances are concerned, those that may be restricted by legislation or by brand RSL's, there are a few chemicals to consider that may be present in the dyeing process.

- Some dyes, from less reputable suppliers can be harmful to workers and downstream customers – the main concerns are some azo dyes that can form carcinogenic amines and some dyes for polyester that can cause skin sensitization
- Some process chemicals can contain APEO's which are harmful to aquatic species
- There are various types of preservatives that can be used to protect dye and process formulations from microbial attack. Some are permitted but others are illegal/restricted
- Reactive dyeing on batch dyeing machines usually requires large amounts of salt which passes through standard effluent treatment plants unremediated

PRINTING: INTRODUCTION

Textile printing is the process of applying colour in definite patterns or designs. Printing can only be performed on fabrics and from a chemical perspective it is related to dyeing as it involves the permanent fixation of dyes or pigments. However, in dyeing the whole fabric is uniformly covered with one colour, whereas in printing one or more colours are applied to it in certain parts only, and in sharply defined patterns.

Colour can be imparted to textile substrates using either dyes or pigments which must be prepared into thickened pastes to allow specific application, and to prevent the colour from spreading via capillary action. Specific fibre materials and dye and pigment types interact with each other in well defined ways, and it is these interactions that determines the best composition of a printing paste. The preparation of this paste is one of the most important steps in printing.

PRINTING: DYE PRINTING

Dye based printing pastes

Dyes impart colour via the same mechanisms as dyeing, through dissolution of a dye into a solvent which penetrates the fabrics and/or fibres. From a chemical perspective printing with dyes should be broadly considered as 'localised dyeing', where the dye and fixation chemicals are dissolved in a viscous paste that are applied in the desired pattern prior to drying and subsequent fixation using either steam or dry heat.

Compared to pigment printing, 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:

Thickening agents various natural and synthetic chemical types are used including alginate, extracted from seaweed and carboxymethyl cellulose (CMC). It is important to select a thickener that is inert with respect to the dyes in the paste some dyes irreversibly bind to some thickeners)

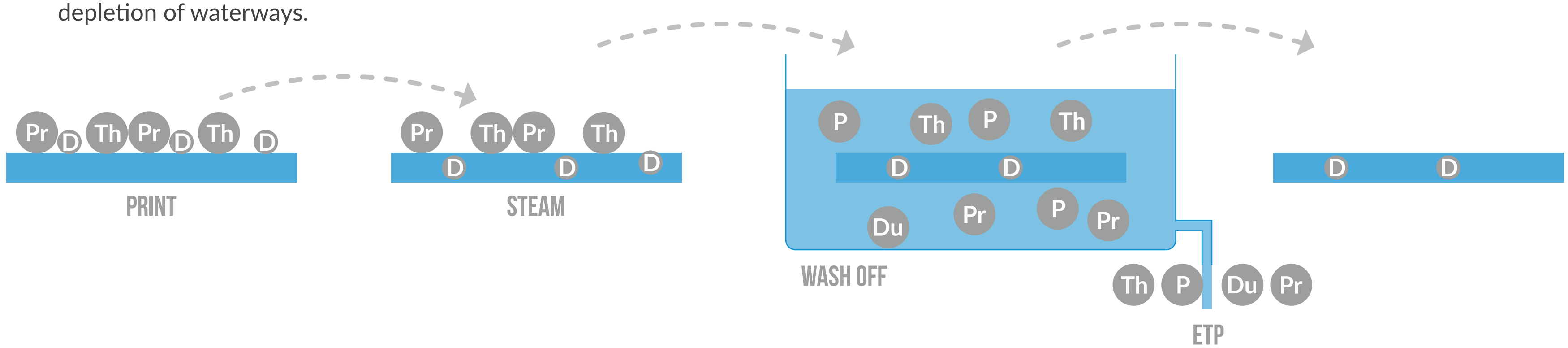
Auxiliaries

- Oxidizing agents (e.g. m-nitrobenzenesulphonate, sodium chlorate, hydrogen peroxide)
- Reducing agents (e.g. sodium dithionite, formaldehyde sulphoxylates, thiourea dioxide, tin(II) chloride)
- Discharging agents for discharge printing (e.g. anthraquinone) Substances with a hydrotropic effect, like urea
- Dye solubilisers, which are polar organic solvents like glycerine, ethylen glycol, butyl glycol, thiodiglycol, etc.
- Resists for reactive resist printing (e.g. sulphonated alkanes)
- Defoamers, (e.g. silicon compounds, organic and inorganic esters, aliphatic esters, etc.)

PRINTING: DYE PRINTING

- In a normal dyeing process the dyes and fixation chemicals can be brought together very close to, or indeed within the dyeing process but with printing everything has to put together in the paste before the printing process – great care has to be taken to avoid unwanted reactions (such as the dyes going 'off') and therefore dye based pastes have a limited shelf life of a few hours.
- A steaming process is used to provide energy and moisture for the dyes to migrate from the paste to the fabric surface.
- There is a very fine balance between getting sufficient moisture on the fabric surface to allow dyes to fix and having too much moisture such that the dyes bleed from the design area, creating blurriness.
- Historically printers (and continuous dyers) typically used quite dry steam but included humectants (chemicals that attract moisture) in the print paste. Urea was often used and this is a major environmental concern as it acts as a fertiliser that can cause damaging effects such algal blooms with serious oxygen depletion of waterways.
- Modern steamers have atomiser sprays on their entry slots so that humectants can be removed from print pastes and sufficient moisture can be applied to fix the dyes without causing flushing/blurring of the print.
- After fixation by steaming any unfixed dye is removed by a sequence of wash baths – often in a highly efficient, low water consumption continuous wash range, but sometimes in older less efficient equipment.
- Before removing unfixed dye the wash off process has to remove the dried print paste which, after a hot fixation process, can be a hard, difficult to remove polymeric layer.

Pr = **Print auxiliary**
Th = **Thickener**
D= **Dye**
P = **Process Chemical**
Du = **Unfixed dye**
ETP = **Effluent Treatment Plant**



PRINTING: PIGMENT PRINTING

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 modern auxiliaries, it is now possible to obtain high-quality printing using this technique.

Pigment printing involves the permanent adhesion of insoluble particles of colour (pigments) to the surface of a fabric using polymeric binders. The polymeric binders are designed to bind to, and stay on the surface throughout the useful lifetime of a textile product. For standard all over fabric printing the binders are normally based on acrylic or polyurethane but other chemical types such as PVC or silicone are sometimes used if a 3D effect or glossy finish is required.

Pigment printing pastes generally contain a thickening agent, a binder and, if necessary, other auxiliaries such as fixing agents, plasticisers, de-foamers, etc.

Pigment printing takes three general forms:

Fabric printing where a design is applied to the whole area of a fabric using standard print screens and machinery.

Panel printing where prints are applied to either garment/product panels or finished products

Logo printing very similar to panel printing but normally using small, often single colour, print techniques with raised/3D prints.

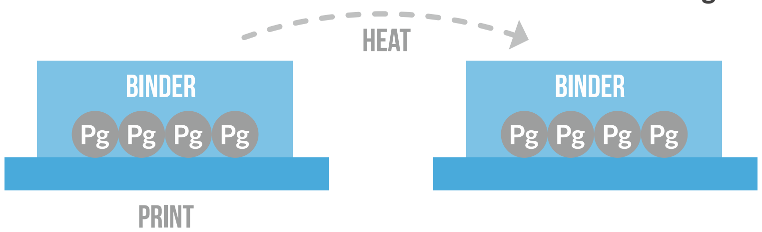
Pigment prints are normally applied, dried and then cured using dry heat. Steaming is only ever applied for all over pigment discharge printing of fabric (where a bleaching agent is incorporated into a pigment printing paste).

It is not usual to wash off pigment prints so all chemicals that are in the paste remain on the fabric until the first time a customer washes their item. The pigment print chemicals do often enter waste streams though, because residues have to be washed from screens - and this wash water should go to an effluent treatment plant.

Pigment discharge printing is common in both fabric and panel printing. Because the prints are rarely washed off a full destruction of the ground shade is not achieved (even where ground shades are fully destroyed they often leave a coloured residue) and whites are achieved by the inclusion of white pigment in the paste.

Some older type pigment binders based on formaldehyde based/formaldehyde containing chemicals are still used and these prints have to be washed off to meet the formaldehyde limits set out in RSL and some legislation.

Pg = Pigment



PRINTING: PRINTING PASTE CONTENTS

The following table shows the typical printing paste components

		COLOURANT	PASTE	FIXATION	WASH OFF	SPECIALIST FIXATION
DYE BASED	POLYESTER	DISPERSE	THICKENER PH 4-5 DISPERSE DYE ANTI-REDUCTANT HUMECTANT WETTING AGENT	HIGH TEMPERATURE STEAM 180°C	REDUCTION CLEAR	
	NYLON	ACID	THICKENER PH 4-5 ACID DYE HUMECTANT WETTING AGENT	ATMOSPHERIC STEAM 98 - 102°C	MILD ALKALI WASH	CATIONIC AFTER-FIX, SYNTAN
	WOOL	ACID	THICKENER PH 4-5 ACID DYE HUMECTANT WETTING AGENT	ATMOSPHERIC STEAM 98 - 102°C	WATER / MILD DETERGENT ONLY	
	SILK	ACID	THICKENER PH 4-5 ACID DYE HUMECTANT WETTING AGENT	ATMOSPHERIC STEAM 98 - 102°C	WATER / MILD DETERGENT ONLY	
	COTTON VISCOSE LYOCELL LINEN	REACTIVE	THICKENER PH 10-12 REACTIVE DYE HUMECTANT WETTING AGENT	ATMOSPHERIC STEAM 98 - 102°C	HOT SOAPING	
		VAT	THICKENER PH 10-12 VAT DYE REDUCING AGENT HUMECTANT	ATMOSPHERIC STEAM 98 - 102°C	OXIDISING AGENT HOT SOAPING	
PIGMENT BASED	ALL FIBRES	PIGMENT	POLYMERIC BINDER PIGMENT	DRY CURE AT 150 - 180°C	NOT COMMON	

PRINTING: SCREEN PRINTING

Screen printing is a printing technique whereby a mesh is used to transfer ink onto a substrate, except in areas made impermeable to the ink by a blocking stencil. It is by far the most popular technology in use today, and a decorative pattern or design is usually applied to fabric by, flat screen, or rotary screen methods. Both dyes and pigments can be printed in this manner.

Flat screen

Manual flat-bed screen printing is a slow process, done by hand. It is used by designer-makers for complicated fabric designs or for small runs.

Industrial flat-bed screen printing

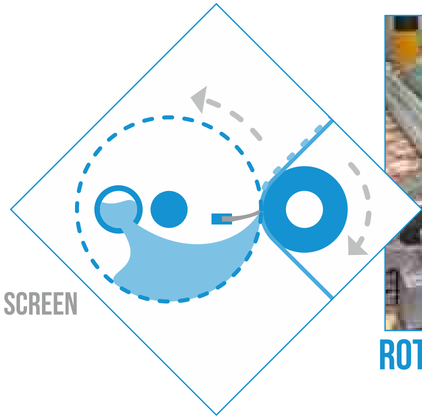
Industrial flat-bed printing automates this process, with the fabric moved through a machine on a conveyor belt and the print repeating rapidly.

Rotary screen printing

Rotary screen printing uses cylindrical screens and roller squeegees with one roller being used for each colour. This is a very fast process used in the continuous printing of furnishing and clothing fabrics.

FLAT SCREEN

INDUSTRIAL FLAT-BED SCREEN PRINTING



ROTARY SCREEN

ROTARY SCREEN PRINTING

Image credit: http://worthyshirts.com/best-blank-t-shirts-for-screen-printing/
Image credit: http://www.indiantradebird.com/j-d-engineers-flat-bed-screen-printing-machines?spid=Mzg4OCwy

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PRINTING: OTHER PRINT TECHNIQUES

Inkjet / Digital printing

Inkjet printing can be used to apply dyes or pigment to fabrics without the need to create printing screens. In principle the dyes/chemical combinations are exactly the same as for screen printing.

However the fabric has to be impregnated with fixation chemicals because the print cartridges can only contain the dye – this is to avoid unwanted reactions in the cartridge that could lead to reduced dye yields or inkjet blockages.

Pigment inks can be applied to fabrics without the need for fabric impregnation but the amount of binder in a (necessarily) low viscosity ink can be very low and can result in very limited print durability and rub fastness durability.

After printing the ink jet printed fabrics are dried, fixed/cured and washed off in exactly the same manner as screen prints.

Transfer prints

Transfer prints are quite common in the outdoor sector. Pieces of paper are printed with selected disperse dyes (dyes for polyester) and the design is then transferred to fabric (usually polyester but sometimes nylon) by the use of dry heat.

The chemicals used in paper printing are very similar to those used for polyester fabric printing

INKJET / DIGITAL PRINTING

TRANSFER PRINTS

Image credit: https://oecotextiles.wordpress.com/2012/02/03/digital-printing/

PRINTING: OTHER PRINT TECHNIQUES

Discharge printing

Discharge printing involves the application of a print paste that contains a bleaching agent to a dyed fabric. The specific bleaching agent is added to a print paste and the paste applied using normal print screens, machinery and 'fixation' conditions are the same as for standard dye prints.

A discharge paste can be used to destroy all dye in the dyed fabric to create a white colour (the most common discharging agent is the strong reducing agent zinc formaldehyde sulphoxylate) or a milder discharging agent (sodium formaldehyde sulphoxylate) can be added to a paste that includes 'bleach resistant' dyes if you want to introduce a coloured print design on a dyed fabric base.

Specialist Techniques

There are a number of specialist techniques that would ordinarily be used in fashion items but the may find use in the outdoor industry

Glitter Small pieces of aluminium or metallised plastic in a typical pigment binder

Flock Small lengths of dyed viscose or synthetic fibre attached to fabric using a binder

Puff A special chemical formula that is designed to react and create bubbles of gas when subjected to heat. The bubbles turn the printed film into a foam

Foil Foils can be actual thin sheets of metal or, more commonly nowadays, metallised plastic films

PRINTING: RESTRICTED SUBSTANCES CONCERNS RELATED TO PRINTING

As far as restricted substances are concerned – those that may be restricted by legislation or by brand restricted Substances Lists – then there are a few chemicals to consider.

- The same concerns that apply to dyeing (with the exception of salt in reactive dyeing) can be applied to printing with dyes.
- Some printing processes use urea to help with dye solubility and this can have a negative effect on the environment if released untreated.
- Pigment prints are higher risk than dye prints:
  - The binders can contain formaldehyde
  - Plastisol prints can be based on PVC and contain restricted phthalates or short chain chlorinated paraffins (SCCPs)
  - Pigments can contain lead and cadmium
  - Black pigments and some print ink additives can contain restricted Poly Aromatic Hydrocarbons (PAH)
  - Some pigment binders can contain solvents
  - Some binders can contain organotins as preservatives or catalysts

FINISHING

A fabric finish is a mechanical process or chemical coating, applied to a fabric in order to improve its aesthetic or performance characteristics.

Mechanical finishes

Mechanical finishes change the surface characteristics of a fabric via physical means. Although these treatments are not purely chemical based, there is often an application of a chemical such as a lubricant before the mechanical finishing process.

Mechanical finishes include:

Calendaring passing between heated pressurised rollers to produce a variety or surface textures or effects

Pre-shrinking fabric is passed through hot steam to control shrinkage

Decating fabric is treated with hot water and steam to set the material

Sueding fabric is passed between abrasive rollers

Shearing fibres and loose threads are removed from the surface of the fabric

Chemical finishes

Chemicals finishes impart desirable aesthetics and/or technical performance characteristics and are designed to stay on the fabric and be durable.

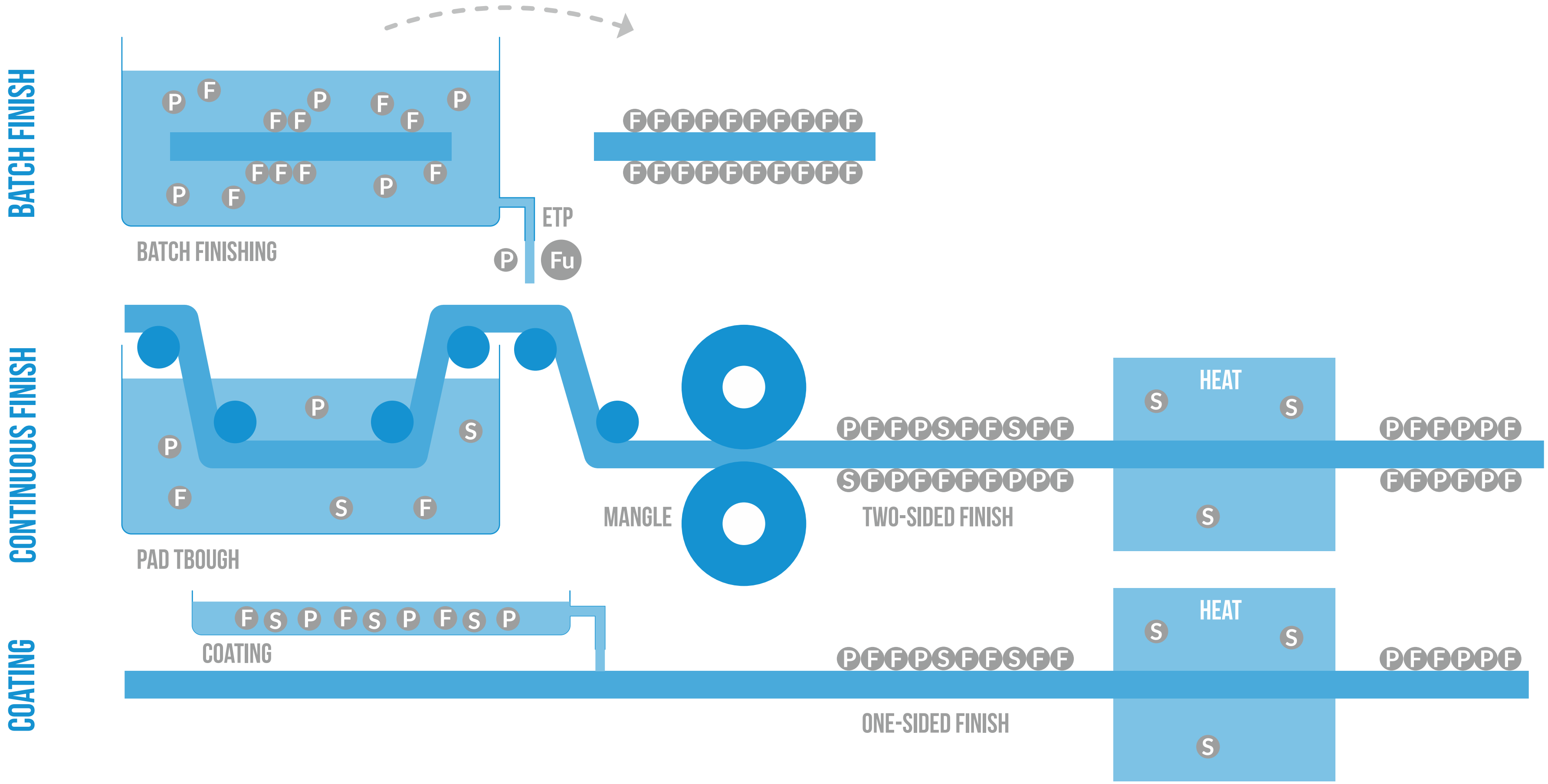
The types of finish can range from very simple needle lubricants – which have very little discernible effect on aesthetics but just allow a fabric to be sewn without the needles snagging and damaging the fabrics – to complex multi-component coating formulations where the application, drying and curing conditions are critical in achieving a controlled chemical reaction that determines final aesthetics and performance.

FINISHING: CHEMICAL APPLICATION TECHNIQUES

Usually chemical finishes are applied to fabric using a pad mangle after which the fabric is dried or cured, depending on the nature of finish.

Some chemical finishes are applied to fabrics in the last wash-off bath on a dyeing machine however this is rare as it can contaminate the inside of the machine with a film of chemical, necessitating a water, chemical and energy-intensive machine cleaning cycle.

F = Finish chemical
P =Process chemical
Fu = Unfixed finish
S = Solvent
ETP = Effluent Treatment Plant



FINISHING: COMMON CHEMICAL FINISHES

TYPE OF FINISH	EXAMPLE (NOT EXHAUSTIVE)	TYPICAL BATH FORMULATION	PROCESS	NOTES
SOFTENER	SIMPLE CATIONICS POLYETHYLENE SILICONES	SOFTENER PH 4-5	MAINLY DRY ONLY SOME DRY->CURE	
HANDLE MODIFIER TO CHANGE BULK, DRAPE, 'WETNESS'/ 'DRYNESS'	POLYURETHANES ACRYLICS PVA	POLYMER DISPERSION PH 4-5	DRY->CURE	
EASY CARE EASIER TO IRON, REDUCED WRINKLING ETC (SYNTHETIC FIBRES INHERENTLY	CROSS-LINK RESINS	RESIN PH CONTROL SOFTENER CATALYST	DRY->CURE	
NON-IRON	CROSS-LINK RESINS	RESIN PH CONTROL SOFTENER CATALYST	LIQUID AMMONIA MOIST-CURE RESIN	WASH OFF REQUIRED
FLAME RETARDENT	PHOSPHATE FR HALOGENATED FR	FR CHEMICAL CROSS-LINK RESIN FORMULATION	DRY->CURE	WASH OFF REQUIRED
DURABLE WATER REPELLENT (DWR)	FLUOROCHEMICALS	DWR CHEMICAL BINDER PH CONTROL	DRY->CURE	
WATER REPELLENTS (WR)	PU SILICONES		DRY->CURE	
ANTIMICROBIAL	QUATERNISED SILICONES SILVERBASED		DRY (NO RESIN) DRY->CURE WITH RESIN	

FINISHING: COMMON CHEMICAL FINISHES

TYPE OF FINISH	EXAMPLE (NOT EXHAUSTIVE)	TYPICAL BATH FORMULATION	PROCESS	NOTES
ANTI-ODOUR	CYCLODEXTRIN	CYCLODEXTRIN CROSS LINK RESIN	DRY->CURE	WASH OFF MAY BE REQUIRED
COATING	PVC PU ACRYLIC	ACTIVE INGREDIENT/S SOLVENT CROSS-LINKER	DRY->CURE	AIR EMISSIONS MAY NEED REMEDIATION
ANTI-STATIC		CAN BE CO-APPLIED IN DYEBATH	DRY ONLY	
CHLORINE PROTECTION	FADEX	ACTIVE INGREDIENT PH CONTROL	DRY ONLY	
ANTI-YELLOWING	PROPRIETARY FORMULATIONS		DRY ONLY	
WELLBEING: ALOE VERA VITAMINS	VARIOUS: NORMALLY APPLIED WITH RESINS/BINDERS	MICROENCAPSULATED INGREDIENT, BINDER, PH CONTROL	DRY CURE	ANYTHING THAT IS INTENDED TO BE RELEASED NEEDS SPECIAL ATTENTION IN REACH LEGISLATION
SUN PROTECTION	UV ABSORBERS		DRY ONLY	
BRUSHING LUBRICANT	VARIOUS OILS / WAXES		DRY ONLY	

FINISHING: CHEMICAL FORMULATIONS

Chemical formulations as purchased from the chemical industry contain active ingredients, the chemicals that are intended to do a particular task in the process or that are intended to remain on the textile at point of sale.

The formulations will also include various chemicals additives such as preservatives, wetting agents, emulsifying agents, stabilisers, and inert diluents (to standardise products).

Most chemical finishes are simply applied, dried or cured before the fabrics are delivered to a garment or product factory, and so, these formulation additives will remain on the textile. Sometimes it is necessary to wash fabrics to remove very harmful substances (such as formaldehyde in some resins) and/or neutralise extremes of pH (such as the very low pH's used for the moist cross-linking process used in non-iron finishing of cotton).

Restricted substances concerns related to finishing

The types of chemicals used in finishing are diverse – many different types of active chemicals are used and many of those are held onto the surface of fabrics using various chemical binders, which may carry their own restricted substances risks.

As far as restricted substances are concerned – those that may be restricted by legislation or by brand restricted Substances Lists – then the following should be taken into consideration

- The risks associated with coated textiles are the same as the risks associated with pigment printing
- The binders used in finishing formulations can contain formaldehyde or solvents
- Some formulations can contain restricted preservatives or APEO's
- Some antimicrobials are restricted
- Some flame retardant finishes are restricted
- Some chemicals associated with DWR's are restricted

EFFLUENT: INTRODUCTION TO WASTE WATER TREATMENT

The wastewater from textile plants is classified as one of the most polluting of many industrial sectors, considering the volume generated as well as the effluent composition. In addition, the increased demand for textile products, the use of synthetic dyes, and the increase in speciality finishing, have together contributed to textile wastewater becoming one of the substantial sources of severe pollution problems in current times.

In many countries it is mandatory for textile factories to use to treat wastewater before it leaves the factory premises. Pressure for effective effluent treatment is also mounting and many international buyers are now showing more concern over whether or not textiles are produced with due ecological consideration. This shift in the textile trade's paradigm means that in the future it is likely that the operation of an effluent treatment plant (ETP) will be integral to sustain business in the competitive world market.

The purpose of an ETP is to render effluent safe and legal to discharge to the environment and to meet the criteria set by authorities and in some cases specified by buyers.

Most wet processing facilities have their own ETP's and discharge treated effluent to a natural water course, some use shared facilities, and others use a municipal ETP. In the latter case the responsibility for proper treatment is passed on to another, albeit usually at a very high cost for the wet processes.

EFFLUENT: CONSIDERATIONS

There are a number of considerations related to the content of textile effluent.

	COMMENTS
COD (CHEMICAL OXYGEN DEMAND)	Chemicals can react with oxygen and be oxidized. Any oxidisable chemicals that were released into waterways would react with dissolved oxygen in the water and that oxygen would be depleted. If oxygen levels drop too much the waterway cannot support life. COD is a measure of the oxygen depletion potential of the effluent.
BOD	Chemicals can be biodegraded by the action of bacteria to form simpler (and normally less harmful) chemicals. The bacteria need dissolved oxygen to 'breathe' and if biodegradable chemicals are released into waterways they act as 'food' for bacteria. The bacteria will biodegrade the chemicals but the ingestion of 'food' will mean they multiply and when more bacteria 'breathe' the oxygen levels can drop. BOD is a measure of the oxygen depletion potential of effluent – the amount of dissolved oxygen 'breathed' out of the water by chemical digesting bacteria.
COLOUR	The whole purpose of a dye is to be very strongly coloured at low concentrations. The presence of colour in effluent is largely an aesthetic problem rather a particular scientific problem – although very intense colour can stop light getting through to plants and animals that need it.
TEMPERATURE	Any water course has a natural ambient temperature that is appropriate for the species within it. If discharged effluent is considerable hotter (it is rarely colder) than the receiving water it can upset the natural balance.
TDS (TOTAL DISSOLVED SOLIDS)	This is a measure of the dissolved salts in the effluent. Salts are not removed by typical effluent treatment and levels can cause damage when introduced into fresh water courses. If salt is introduced into the process water (for example by adding salt to reactive dyebaths) then the only way to reduce levels is via dilution unless reverse osmosis is employed.
TSS (TOTAL SUSPENDED SOLIDS)	This is a measure of solids that have not been removed during effluent processing. The presence of fibres, dust, trash, bacteria can cause light transmission problems, pose a risk to simple organisms that may ingest small particles and ultimately cause silting problems in river beds.

EFFLUENT: CONSIDERATIONS

	COMMENTS
TOXINS HEAVY METALS	Aquatic species can be poisoned by toxic substances.
AMMONIA/ NITROGEN PHOSPHOROUS	Nitrogen and phosphorous compounds can act as fertilisers that can cause uncontrollable growth of plant life and algae – this can cause oxygen depletion.
AOX	Adsorbable Organic Halides can be formed by the action of halogens or halogenated chemicals on organic matter (e.g. chlorine bleaching of cotton) or they can be the breakdown products of larger halogenated chemicals such as some dyes. AOX can themselves be toxic and non-biodegradable or they can react to form even more toxic or persistent chemicals. AOX can react to form mutagens.
BACTERIA COUNT	The bacteria used in effluent treatment is different to the bacteria that may be present in a natural water course – it is not good to introduce alien species into an aquatic environment.
PHENOL	Phenol is toxic and liver and kidney damage (to humans and aquatic species). It can cause skin irritation/burns at high concentrations.
SULPHIDES	Sulphide ions are highly corrosive. Hydrogen sulphide is a particular problem in terms of odour and toxicity. Sulphur chemistry is complex but wet processing facilities where sulphur based chemicals are used (e.g sulphur dyeing, reduction clearing) need to ensure generation of H_2S is minimized.

EFFLUENT: CONSIDERATIONS

	COMMENTS
OIL AND GREASE	Oil and grease can form films over species in a water course and disrupt normal biological processes.
FOAM	Foam – rather like colour is unsightly rather than necessarily harmful. It doesn't take much chemical to form a lot of foam. However the presence of foam does indicate that the surface tension of the water has been affected.
ODOUR	Biodegradation can degrade certain chemicals into simple – but smelly chemicals, such as sulphur dioxide and hydrogen sulphide. This can be unpleasant but also damaging to aquatic species.
....RSL CHEMICALS	There is an increasing expectation that wet processing facilities not only ensure that the products they produce are free from chemicals that appear on restricted substances list but ensure that those chemicals are not present in effluent – this is not enshrined in law but is a voluntary restriction being demanded by some brands.
ANTIMICROBIALS	Great care has to be exercised when disposing of anti-microbial finish baths. Antimicrobials can undoubtedly deliver benefits to customers in terms of reduced odours on textile products but this is achieved by killing or suppressing the growth of microbes (bacteria and fungi). A critical part of effluent treatment is biological treatment where bacteria biodegrade chemicals so it is essential the chemicals that are designed to kill bacteria are not introduced in quantities that would essentially stop the effluent treatment plant from working.

EFFLUENT: CONTENT

With the exception of the chemicals that are intended to stay on the textile (dyes and the chemicals in performance finish formulations) most of the chemicals end up in the effluent. They may be present in the same form that they were inputted into the process, they may have been partially degraded (e.g. starch to sugars) or they may have reacted during the process.

A critical part of effluent treatment is biological treatment where bacteria biodegrade chemicals so it is essential the chemicals that are designed to kill bacteria are not introduced in quantities that would essentially stop the effluent treatment plant from working.

The effluent can contain the following chemical inputs:

GROUP	EXAMPLES OF INPUTS INTO WASTE WATER	COMMENTS
NATURAL IMPURITIES FROM FIBRES REMOVED DURING SCOURING	• OILS • WAXES • PECTINS • COLOURS, • TRASH/DUST	• REMOVED OILS, WAXES AND PECTINS HAVE HIGH BOD/COD
	• LANOLIN	• WOOL ONLY – NORMALLY SCOURED IN SEPARATE UPSTREAM FACILITY AND LANOLIN RECOVERED, BUT VERY HIGH EFFLUENT LOADING IF NOT
	• SERACIN	• SILK ONLY – NORMALLY DEGUMMED IN SEPARATE UPSTREAM FACILITY
CHEMICALS FROM WITHIN SYNTHETIC AND MAN-MADE FIBRES	• OLIGOMERS • PIGMENTS • POLYMER ADDITIVES • CATALYSTS	
PROCESSING AIDS USED IN FABRIC PRODUCTION	• SPINNING OILS, WAXES, LUBRICANTS • KNITTING OIL • WEAVING SIZE (STARCH, CMC, PVA)	• WEAVING SIZE CAN HAVE VERY HIGH BOD/COD
CHEMICALS USED IN SIZING/DESIZING	• STARCH • WAXES • CMC, PVA	• HIGH IN BOD, COD, SUSPENDED SOLIDS, DISSOLVED SOLIDS
SOLID WASTE	• FIBRE DUST • YARNS • PRECIPITATED, INSOLUBLE CHEMICALS • PUMICE DUST • CLEANING RAGS • LITTER	

EFFLUENT: CONTENT

GROUP	EXAMPLES OF INPUTS INTO WASTE WATER	COMMENTS
CHEMICALS USED IN SCOURING AND BLEACHING	• DETERGENTS • DISPERSING AGENTS • ALKALI • AMYLASE ENZYMES • BLEACH STABILISERS • SEQUESTRANTS • SOAP • ANTI-FOAM • SURFACTANTS	• HIGH PH, COD, DISSOLVED SOLIDS • HIGHLY ALKALINE SUSPENDED SOLIDS • FOR COTTON / LINEN SCOURING THE CHEMICAL LOAD IS VERY HIGH. • RESPONSIBLE CHEMICAL MANUFACTURERS SHOULD ENSURE PRODUCTS CAN BE RENDERED SAFE AND LEGAL BY STANDARD ETP
DYES INTENDED TO STAY ON THE TEXTILE	• UNFIXED DYES	• SOME DYES FIX AT 99% (E.G. DISPERSE DYES ON POLYESTER) LEAVING VERY SMALL AMOUNTS IN EFFLUENT WHEREAS OTHERS FIX AT ONLY 70% (SOME REACTIVE DYES ON COTTON) LEAVING HIGHLY COLOURED EFFLUENT
DYEING AUXILIARIES	• CATALASE ENZYMES • ALKALI • BUFFERS • SALT • ACID • ANTI-REDUCTANTS • ANTI-CREASE AGENTS • FABRIC LUBRICANTS • ANTI-FOAM • REDUCING AGENTS • OXIDISING AGENTS • FIXATIVES • MORDANTS • FIXATIVES • MORDANTS	• STRONGLY COLORED, HIGH COD, DISSOLVED SOLID • MOST INDIVIDUAL DYEING AUXILIARIES ARE USED IN SMALL QUANTITIES BUT THE TOTAL CONTRIBUTION TO EFFLUENT LOADING CAN BE SIGNIFICANT • RESPONSIBLE CHEMICAL MANUFACTURERS SHOULD ENSURE PRODUCTS CAN BE RENDERED SAFE AND LEGAL BY STANDARD ETP • ACIDS, ALKALIS AND BUFFERS CAN BE USED AT HIGHER QUANTITIES • SALT IS USED IN VERY LARGE QUANTITIES IN SOME REACTIVE DYEING PROCESSES AND IT IS NOT REMEDIATED BY A STANDARD ETP
DYE PRINT CHEMICALS	• UNUSED PRINT PASTE – STARCHES, GUMS, OILS • PRINT PASTE WASHED FROM SCREENS • PRINT PASTE WASHED FROM FABRICS • MORDANTS • ACID • SOAP	• PRINT THICKENERS HAVE VERY HIGH BOD/COD

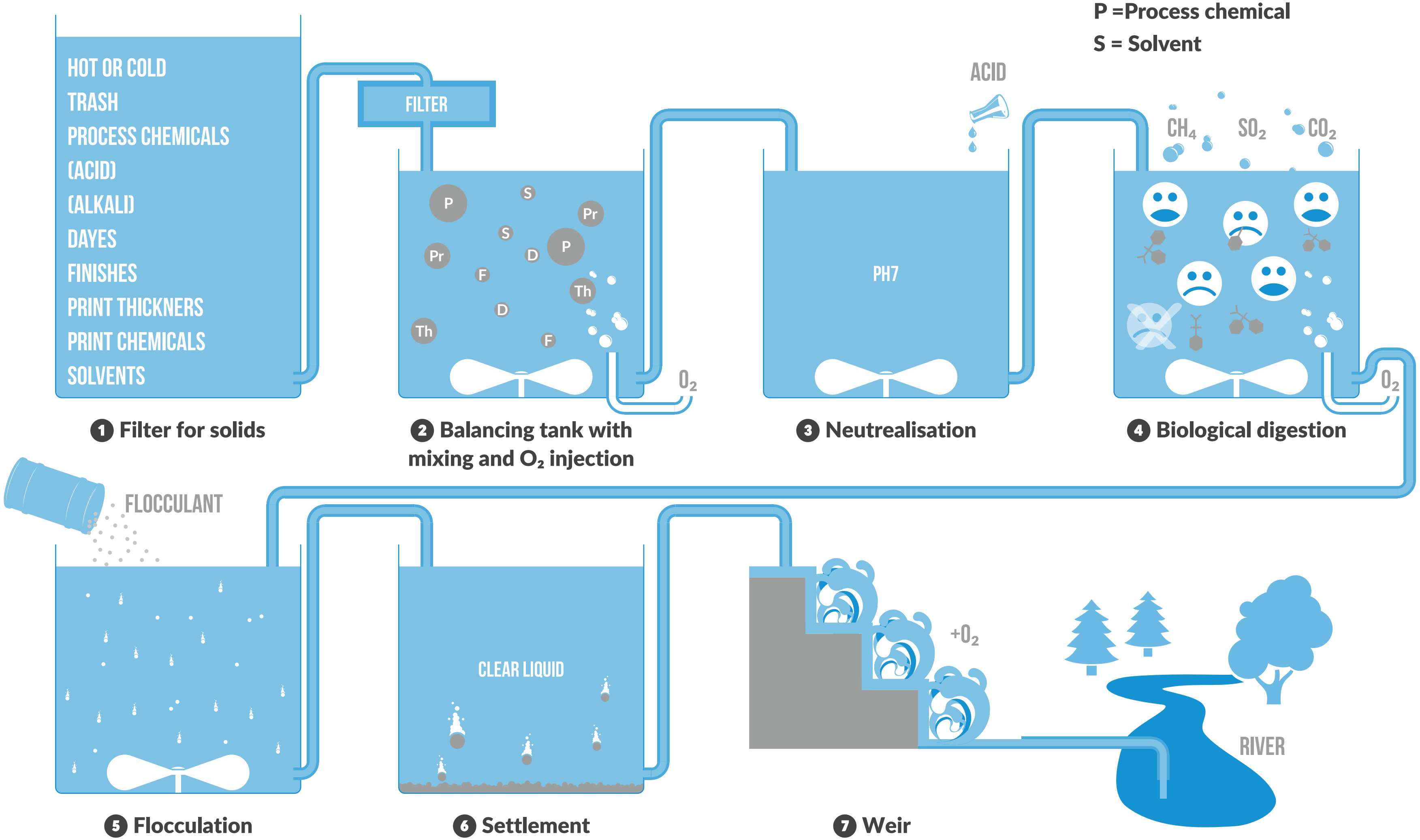
EFFLUENT: CONTENT

GROUP	EXAMPLES OF INPUTS INTO WASTE WATER	COMMENTS
PIGMENT PRINT CHEMICALS GENERALLY INTENDED TO STAY ON THE TEXTILE	• PIGMENT INK WASHED FROM SCREENS • CLEANING CHEMICALS USED TO CLEAN SCREENS (SOMETIMES VERY HARSH SOLVENTS)	
PERFORMANCE FINISHES INTENDED TO STAY ON THE TEXTILE	• ANY PERFORMANCE FINISH THAT IS NOT FULLY EXHAUSTED FROM A BATH. • RESIDUAL, UNUSED QUANTITIES OF PAD BATHS, COATING TROUGHS ETC • INORGANIC SALTS	• QUANTITIES SHOULD BE LOW BUT WHERE PRODUCTION RUNS ARE SMALL, THE UNUSED PAD BATHS CAN ACCOUNT FOR A RELATIVELY LARGE AMOUNT • GREAT CARE HAS TO BE TAKEN WITH ANTIMICROBIALS
FINISHING AUXILIARIES	• ACIDS • ALKALIS • CATALYSTS • WETTING AGENTS • DISPERSANTS • STABILISERS • THICKENERS • SOLVENTS • MORDANTS	• QUANTITIES SHOULD BE LOW BUT WHERE PRODUCTION RUNS ARE SMALL, THE UNUSED PAD BATHS CAN ACCOUNT FOR A RELATIVELY LARGE AMOUNT
CLEANING CHEMICALS CHEMICALS DELIBERATELY USED TO CLEAN FLOORS, PRINT SCREENS, MACHINES ETC	• DETERGENTS • SOLVENTS	• AMOUNT SHOULD BE LOW – SHOULD BE PURCHASED FROM REPUTABLE TEXTILE CHEMICAL COMPANIES
CHEMICAL RESIDUES	• CHEMICAL DRUMS ARE OFTEN WASHED ON-SITE PRIOR TO RE-USE OR RECYCLING.	• THE RESIDUES MUST GO TO THE ETP AND NOT SURFACE WATER DRAINS. • GREAT CARE HAS TO BE TAKEN WITH ANTI-MICROBIALS
FORMULATION AIDS CHEMICALS PRESENT IN FORMULATIONS THAT ARE NOT ACTUALLY THE ACTIVE INGREDIENT. THESE CAN BE PRESENT IN OILS, WAXES, SIZES, DYES, FINISHES SCOURING/DYEING/PRINTING /FINISHING AUXILIARIES	• E.G. EMULSIFYING AGENTS • PH BUFFERS PRESERVATIVES • STABILISERS • DILUENTS • SOLVENTS • WETTING AGENTS • ANTI-OXIDANTS • ANTI-REDUCTANTS • ANTI-FOAM	• QUANTITIES SHOULD BE LOW • RESPONSIBLE CHEMICAL MANUFACTURERS SHOULD ENSURE PRODUCTS CAN BE RENDERED SAFE AND LEGAL BY STANDARD ETP

EFFLUENT: THE ETP PROCESS

There is no single defined design or sequence of processes for an effluent treatment plant but there are some key processes that must take place to render the effluent safe and legal – and some optional ones to improve it further.

Pr = Print auxiliary
Th = Thickener
D = Dye
F = Finish chemical
P = Process chemical
S = Solvent



EFFLUENT: THE ETP PROCESS

COARSE FILTER AND OIL TRAP	• Removal of large solid objects such as rags, yarns, litter • Skimming of surface oil
BALANCING	• A large number of different baths from wet processing are mixed together to homogenise waste streams of very different composition. • Air blowers mix the tank and start to reduce COD of effluent
NEUTRALISATION	• Balanced effluent is adjusted to correct pH for subsequent biological treatment
BIOLOGICAL TREATMENT	• Chemicals are biodegraded by action of bacteria – reducing the BOD of effluent • Biodegradation can fully biodegrade some chemicals to very simple chemicals like water, carbon dioxide and methane • Air blowers mix the tank and reduce COD of effluent • Chemicals in effluent ‘feed’ the bacteria and population of bacteria grows • Bacteria cannot degrade ‘persistent’ (non-biodegradable) chemicals and some chemicals are only partially degraded • Some chemicals bio-accumulate in bacteria
FLOCCULATION	• Chemicals are added to precipitate dissolved colour • Some other non-coloured, dissolved chemicals are also precipitated – reducing chemical content of effluent
SETTLEMENT	• Solids are separated from clear liquid, normally via gravitational settlement • Solids contain live bacteria and can be re-used in biological treatment
AERATION AND DISCHARGE	• Treated effluent is aerated (to top up dissolved oxygen levels) and discharged • This is NOT pure water but contains • dissolved salts • residues of chemical inputs that have not been fully remediated • breakdown/reaction products from chemicals inputs • Small amounts of suspended solids (which have not settled)
SLUDGE MANAGEMENT	• Sludge is de-watered and disposed • If it is free from chemical contamination it can be used as fertilizer • If it is contaminated (added ETP chemicals and harmful chemicals that have bioaccumulated in bacteria) then it must be disposed of according to local regulations for harmful waste

EFFLUENT: THE ETP PROCESS – ADDITIONAL MODULES

Denitrification

If urea is used in wet processing (it is sometimes used as a humectant in printing) then special steps have to be take to remove nitrogen from the wastewater. This can be done chemicals or microbiologically but the aim is to convert nitrogen containing compounds to atmospheric nitrogen.

ZLD

In some areas of the world, such as parts of India, there has been a 'Zero Liquid Discharge' mandate – meaning that no liquid can leave the site of a wet processing facility. The main purpose is to stop the discharge of dissolved salts, which are not removed by standard ETP's, entering water courses and causing damage. This forces the factory to recycle water and this is normally achieved by augmenting a standard ETP with a reverse osmosis module (RO). Treated effluent containing salt is forced through a semi-permeable membrane and pure water is obtained which can be re-used in processing.

Approximately 75% of the water is re-cycled using RO and the other 25% of liquid is in a highly concentrated slurry called RO permeate. The water has to be evaporated from this and condensed for re-use – this achieved using energy-intensive vacuum evaporators that convert the slurry to solid waste (mainly salt) and pure water.

Some of the salt can be re-used in some non-critical dyeing processes (e.g. dyeing black colours) but it is normally contaminated with other chemical residues so cannot be fully re-cycled. In water stressed areas the use of RO for water recycling is beneficial but there are impacts associated with greenhouse gases from energy use. There is also no satisfactory solution for all the solid water recovered from the vacuum evaporators.

Ultra-filtration and Nano-filtration

These technologies are similar in concept to reverse osmosis in that they use fine membranes that can theoretically filter out chemicals from solutions to yield clean, re-usable water but they are not in widespread use in textiles.

EFFLUENT: THE ETP PROCESS – NOTES ON…

Continuous processing, ETP capacity and flow rates

- Just because effluent goes through an ETP doesn't mean it is treated!
- The nature of a continuous ETP is that each module has a high capacity that is continuously mixed and a small volume (representing a very small % of total volume) is pumped in and pumped out on a constant basis. The flow rate is adjusted to give an appropriate minimum average dwell time to ensure the process is carried out properly.
- Inevitably a small amount of the inputs to a process tank will leave it much sooner than the average dwell time so full treatment is never attainable – however the processes are set up so that overall treatment is satisfactory.
- If the ETP is under-capacity compared to the volume of effluent emerging from the wet processing facility then it is common to increase flow rates in the ETP.
- This doesn't have a catastrophic effect on balancing but it makes spikes in certain parameters more likely, it doesn't have a major impact on neutralisation IF neutralisation is managed by constant monitoring and dosing of chemicals.
- Increased flow rate has a major effect on biological treatment:
    - The need for increased flow rate is often due to increased water usage for washing/rinsing and this makes effluent dilute as such, bacteria do not have enough food concentration and can't divide)
    - Increased flow rate means contact time (with potentially unhealthy bacteria) is low and so biodegradation is poor
    - Increased flow rate with dilute effluent can mean that bacteria are lost to the next ETP step more quickly than they can re-produce and so bacterial populations not only become unhealthy but drop
    - Increased flow rates in settlement tanks can lead to shorter settling times that results in liquids that contain solids begin released to the environment – this can be solid chemicals, dust debris and bacteria.

EFFLUENT: THE ETP PROCESS – NOTES ON...

Dilution

- There is a saying that dilution is not the solution to pollution.
- In many areas of the world water is expensive so every litre used has an impact on profitability – this is compounded by costs associated with effluent discharge (even properly treated effluent discharge).
- The costs of effluent discharge are governed by both concentration of effluent content, volume and total chemicals discharged – in this scenario you can dilute to meet concentration based parameters but there is a huge cost involved. The formula is devised so that the cheapest option for the wet processor is to minimise water consumption and chemical consumption and have low volumes of quite concentrated raw effluent that have to be properly treated before discharge
- Unfortunately in some areas of the world the low price of water (or even free water) and lax nature of enforcement of simplistic standards mean that for some wet processors dilution is a solution.
- It is financially beneficial for a wet processor to use so much water in processing that effluent passes local standards by simple balancing, neutralisation and dilution. The ETP's are sometimes only there to impress western brands – and barely function.

EFFLUENT: THE ETP PROCESS – DETAILED

1 Coarse filtering and oil trap

Before entering the ETP most effluent streams are filtered to remove large solid items that may have got into machines or drains.

Following removal of solids, it is good practice to skim oil off the surface and collect it as early in the ETP process as possible.

Many different types of oil can be used in textile processing and they are mostly removed during scouring. They are normally stabilised in a formulation by the use of emulsifying agents but once removed and placed in an effluent stream they can exist as mini-oil slicks on the liquid surface.

This oil can coat the surface of the ETP tanks and can even coat bacteria in a biological digester – seriously affecting their ability to biodegrade chemicals.

Image credit: https://commons.wikimedia.org/wiki/File:Screening_of_the_wastewater_to_remove_all_larger_objects._(6845986063).jpg

EFFLUENT: THE ETP PROCESS – DETAILED

2 Balancing

To understand the importance of balancing it is necessary to consider that the following processes in the ETP is a biological digester containing highly sensitive, live bacteria. The effluent that is sent through to the biological treatment must not kill, or significantly adversely affect those bacteria.

All effluent goes to a balancing tank – this is a large tank where effluent streams from many different machines and processes are mixed together to create an average raw, untreated effluent. The capacity of the balancing tank can vary but can hold up to a couple of days' volume of all discharges from the factory – the greater the capacity of the balancing tank relative to the effluent discharge volume of the wet processing facility then the greater the consistency over a period of time.

- The temperature input to the balancing tank can vary enormously – from boiling scour/dye baths* to cold water rinses. If the overall temperature of the balance effluent is too high, it may be necessary to spray the effluent into the air to cool it on an on-going basis.
- The chemical loading input into the balancing tank can vary enormously -from highly loaded cotton scouring baths to almost pure water from final post-dye wash baths. Other than equalising the effluent via balancing there is very little that can be done to adjust this – although balancing itself irons out major spikes.
- The content of oxidising or reducing agents can vary enormously – from highly reducing reduction clearing baths to highly oxidising bleach baths.
- Quite often the mixing of a balancing tank is achieved using a combination of propellers and air blowers. The introduction of oxygen (in air) will deal with any excess of reducing agent.
- The presence of dissolved oxygen in water is absolutely essential for aquatic life and COD – chemical oxygen demand – is a measure of how much oxygen can be removed from a natural water course if oxidisable chemicals are introduced (the dissolved oxygen in the water is used up during the oxidation of the chemicals).
- Using air blowers to mix a balancing tank not only helps to homogenise the contents but also starts to oxidise the oxidisable chemicals in the effluent – thus reducing the COD.

Image credie: https://www.process-worldwide.com/water-treatment-for-the-dye-industry-a-394801/index2.html

EFFLUENT: THE ETP PROCESS – DETAILED

3 Neutralising

- pH has a direct influence on wastewater treatability and so is therefore critically important to treatment.
- The pH input to the balancing tank can vary enormously - from highly alkaline reactive dyebaths to highly acidic baths from wool dyeing:
- Although balancing does a very good job of equalising the recent production effluent this can vary from day to say so it is necessary to adjust the pH of the output of the balancing tank on an on-going basis – this requires constant monitoring and constant dosing of acids/alkali to endure the pH is stable and neutral for the next phase.
- Even where a factory uses a shared ETP or municipal ETP is it common for them to have to balance and neutralise effluent before sending it for treatment.

Image credit: http://m.satakemalaysia.com/index.php?ws=ourproducts&cat=Agitators&subcat=Application&subsubcat=Water%20and%20Wastewater%20Treatment&cid=149330

EFFLUENT: THE ETP PROCESS – DETAILED

4 Biological treatment

- Common convention has it that it is a good thing if chemicals are biodegradable – and provided the smaller chemicals that are formed are safer than the larger molecules from which they are formed then this holds true. Where relatively harmless chemicals are biodegraded into more harmful breakdown products then it is questionable as to whether biodegradation is beneficial.
- Whenever anything is biodegraded by aerobic micro-organisms (ones that require oxygen to breathe) in an aqueous environment there is a guarantee that oxygen levels in the aqueous environment will be reduced. This is simply because the chemical that is being biodegraded is essentially food for the microbes that are doing the biodegradation and when microbes fed they multiply exponentially until there is either no food or no oxygen in the water.
- If dyehouse effluent, containing biodegradable material was to be discharged into a natural water course, the microbes in the water would multiply, breathe, use up dissolved oxygen until the water could not support life.
- Releasing safe, edible chemicals such as starch causes more environmental damage than the release of toxins and therefore the purpose of the biological treatment is to biodegrade the chemicals in the effluent before discharge.
- Of course the bacteria in the biological treatment tank are constantly using up dissolved oxygen so biological digesters are always aerated to keep the bacteria healthy, and to oxidise and chemicals formed by the biodegradation that cannot be biodegraded further, but could be oxidised if released into a water course.
- The biodegradable chemical content of the effluent that enters the biological digester is food for the bacteria – they 'eat' the food, digest it and turn it into chemicals with much lower potential for depleting oxygen from waterways.
- On eating the food the bacteria multiply (exponentially in the presence of concentrated 'nutritious' food) and it is sometimes necessary to remove bacteria occasionally to maintain a healthy population (it is better to have 10 million healthy bacteria than 20 million under-nourished bacteria!).

EFFLUENT: THE ETP PROCESS – DETAILED

- It seems counter-intuitive but concentrated effluent is much better for a biological treatment plant than dilute effluent. Imagine having your meal served to you on a plate as big as a football pitch and having to find each pea, carrot, potato, piece of rice – that is what dilute effluent is like for bacteria, and it is common to find that wet processing facilities that use a lot of water for processing have very low bacteria counts and / or stressed bacteria in the plant.
- There is a constant flow of liquids from the biological digester to the next stage of the ETP (settlement) and if the throughput is too fast then there is insufficient time for the bacteria to multiply and establish an effective chemical eating colony. In this case there is very little on-site biodegradation of chemicals – although the final, released effluent may be dilute!
- Dilution of effluent does NOT reduce the total effluent loading and total oxygen depletion potential of the released chemicals but it CAN trick regulators. Dilution of effluent never morally acceptable and is only economically feasible in areas where water is free or very low cost.
- Conversely bacteria have a finite lifespan and if throughput is too slow there will be too many dead bacteria in the system – which themselves are biodegradable, with the potential to cause oxygen depletion if released into waterways. If throughput is too slow then the health of the colony can also suffer and the bacteria can spend time eating their ancestors rather than chemicals in effluent!
- Bacteria are very good at digesting chemicals but there are some chemicals that are not biodegradable and there are some chemicals that bioaccumulate – what this means in laymans terms is that when the bacteria 'eat' chemicals in the digester the following can happen:
    - The bacteria biodegrade chemicals to form smaller molecules
    - The bacteria eat the chemicals and the chemicals are excreted unchanged
    - The bacteria eat the chemicals and the chemicals stay in the body of the bacteria unchanged (bio accumulation). The concentration of such chemicals can increase over the lifetime of the bacteria.
- When bacteria die they can therefore be contaminated with harmful chemicals – the solid residues (sludge) may not be safe.
- Although the discharge of large amounts of nitrogen and phosphorous compounds into water courses can be very harmful and should be avoided, these are essential nutrients for the bacteria and if their 'diet' is deficient then small quantities do need to added to ensure the bacteria are healthy.

EFFLUENT: THE ETP PROCESS – DETAILED

5 Flocculation

- After biological treatment the liquid is a slurry of bacteria, chemicals and chemical break-down products.
- Because most ETP's work on a continuous basis there will always be a percentage of the effluent content that has been biodegraded for a longer time than average and there is a percentage that has been treated for a shorter than average time.
- This means there is often dyestuffs present that have not been biodegraded (or indeed that are not biodegradable) so if the slurry that exits a biological reactor was filtered you would observe a coloured liquid.
- The strength of colour depends on the dye fixation level (e.g. 99%+ of disperse dyes are fixed on polyester, 70% of reactive dyes are fixed on polyester), levels of dilution (world class facilities use less water and the effluent is more concentrated) and dwell time in the biological treatment process (longer treatment enables more biodegradation of colour.
- The colour has to be removed and this is normally achieved using flocculation – a process where the colour is forced out of solution to make it solid so that it can be more easily removed.
- A chemical is added to the solution, mixed and the dissolved colour forms solid particles. The flocculant can be simple iron salts in the presence of lime or, in better, operations very low quantities of specially designed organic flocculants.

Image credit: Original source unknown, taken from http://www.golantec.be/Moderniseer%20uw%20zwembad.html

EUROPEAN OUTDOOR GROUP

EFFLUENT: THE ETP PROCESS – DETAILED

- Flocculation will also precipitate some invisible, soluble chemicals (and breakdown products) so it not only removes colour but reduces the chemical content of effluent.
- The cost of the organic flocculants is much less than the simple salts but the amount of solid waste generated is much less and, because of the cost there is much less tendency to over-dose the chemicals, which is a common problem with cheap iron salts.
- The method of removal can be filtration (uncommon), floatation – where the solid is pushed to the surface of a flocculation tank using bubbles and the solid scraped off or settlement, where the solids are allowed to settle under gravity.
- Some factories use other techniques to remove colour such as the use of bleach. The use of Chlorine bleach is effective at removing colour but not good from an environmental standpoint but the use of ozone is becoming more popular. Generation of ozone is expensive and ozone is very, very toxic so needs constant monitoring but it removes colour without generating any solid waste.
- Colour removal (by flocculation or bleach) can be carried out at different stages in the process. The most common place is after biological treatment as this allows some biodegradation of colour, thus reducing flocculant cost but is can be done before biological treatment or even as the almost final stage of the ETP process.

EFFLUENT: THE ETP PROCESS – DETAILED

6 Settlement

- After treatment in the biological digester the liquid / slurry is often treated with a flocculant to encourage precipitation of some dissolved chemicals (including colour) and coagulation of any solids in the liquid.
- After mixing with flocculant the liquid is pumped to a settlement tank.
- Here the solids fall to the bottom and the liquid clears at the top. Some solid debris will float and this has to be skimmed from the surface but the clear liquid removed from the top is basically the final effluent discharge - unless colour removal is deferred to post- settlement.

- It is common to have multiple settlement tanks or a semi-continuous intake of liquid from the biological digester/flocculation tank. This is because the settlement tank has to have no or very little agitation to allow solids to settle – a fast, constant
- The design of a settling tank is often like a cone so the solids can be removed from the bottom and either re-used (it contains live bacteria that can still be of use in a biological digester) or filtered, pressed and disposed of according to local regulations.
- This solid is referred to as ETP sludge and it is an emerging issue.
- If crude flocculation using iron salts is employed immediately before settlement then the sludge is unlikely to be re-used in the biological digester but if low levels of organic flocculants are used, or flocculation is carried out before biological treatment OR after settlement then sludge re-use is possible.
- Sludge re-use should not be necessary if the population in the biological digester is healthy, given the appropriate nutrient and the dwell time is sufficient to maintain microbe numbers.
- Before final discharge of the treated effluent it should be checked for pH (particularly if highly alkaline flocculation systems have been employed) and dissolved oxygen.

Image credit: Original source unknown, taken from http://www.filterpressmanufacturer.in/filter-press-plates.html

EFFLUENT: THE ETP PROCESS – DETAILED

7 Aeration and Discharge

Some dyehouses trickle water from the settling tanks down weirs before discharge to ensure oxygen levels are topped up by rapid (and free) interchange with the air.

AUXILIARY CHEMICALS AND THEIR USES

There are a number of chemicals that are widely used within the textile industry to enable other processes to function. These chemicals do not provide any function to the finished article but facilitate other chemicals reactions and processing procedures.

- **Acids** decrease the pH of a solution
- **Anti foaming agents** reduce foam formation
- **Anti static agents** reduce static charge on fibres and fabrics
- **Bases** increase the pH of a solution
- **Catalysts** increase the rate of chemical reactions
- **Detergents** are mixtures of surfactants with cleaning properties
- **Dispersing agents** improve separation of particles in solutions to avoid clumping
- **Lubricants** reduce friction
- **pH buffers** resist changes in pH when more chemicals are added to solutions
- **Salts** are used to increase the exhaustion rate of the dyeing process
- **Sequestering agents** remove water hardness
- **Solvents** are used to dissolve chemicals
- **Stabilisers** are used to prevent degradation of solutions
- **Surfactants** lower the surface tension of water to assist with wetting, dispersion, emulsifying, and cleaning
- **Wetting agents** reduce the surface tension of water to increase penetration of chemicals on a fabrics surfaceSome dyehouses trickle water from the settling tanks down weirs before discharge to ensure oxygen levels are topped up by rapid (and free) interchange with the air.

COMMON HAZARDOUS CHEMICALS IN TEXTILE PRODUCTION

ALKYLPHENOLS (AP) AND ALKYLPHENOL ETHOXYLATES (APEO) NPEs/OPEs are included in the group of non-ionic surfactants called alkyl phenol ethoxylates (APEOs). NPEs and OPEs can degrade to NP and OP respectively. APEOs are used in detergents, scouring agents, wetting agents, softeners, emulsifier/dispersing agents for dyes and prints, impregnating agents and as degreasing agents In leather tanning, APEO is used in de-greasing, finishing etc. In silk production for de-gumming. APEO could also be present in dyes and pigment preparations. Polyester padding and down/feather fillings are risky for APEO. These chemicals are liable to be toxic , persistent and to bioaccumulate. If NPEOs and OPEOs are released to the environment, they can be degraded back to NPs and OPs, which are toxic to aquatic life, persistent in the environment and can bioaccumulated in body tissue. They are similar to natural oestrogen hormones and can disrupt sexual development in some organisms e.g. causing feminisation of fish.

AZO DYES WHICH BY REDUCTIVE CLEAVAGE MAY RELEASE ONE OR MORE AROMATIC ARYLAMINES which by reductive cleavage may release one of more aromatic arylamines incorporate one or several azo groups (N=N) bound with aromatic compounds. Thousands of azo dyes exist, however, only those which can degrade to form the listed amines are considered to be carcinogenic and are therefore restricted in textiles, leather, apparel and toys.

BIOCIDES DIMETHYL FUMARATE is used by producers as a biocide to kill moulds that may cause furniture or shoe leather to deteriorate during storage and transportation in a humid climate. Dimethyl fumarate (DMF) is a fungicide that manufacturers use for maritime transport and the storage of consumer goods. DMF can cause acute dermatitis, eczema, and general fatigue to the persons who have been in contact with this substance.

BIOCIDES GENERAL are biologically active substances, and their toxic and biocidal nature enables them to kill or harm living things. Since biocides by nature are used to have detrimental effects on biological organisms, they are at the same time a serious threat to living organisms that were not intended to be controlled. Biocides have adverse effects on the nervous system when entering into the human body. They may irritate eyes, skin, and the respiratory system.

CHLOROBENZES AND CHLOROTOLUENES are used in batch dyeing of synthetic fibres, particularly polyester fibres, to promote the absorption and diffusion of disperse dyes into the fibre at relative low temperatures. Carriers are important for dyeing blends of wool and polyester as wool cannot be dyed at higher temperatures than boiling. There is a risk that the carriers will remain on the textile material or partially evaporate during subsequent processes. Most of these carriers are toxic to humans and aquatic organisms, and some are even carcinogenic.

Information taken from 'MODINT, Zeist, The Netherlands and GermanFashion, Köln, Germany, Restricted Substances List, Toolkit for apparel companies, April 2017'

COMMON HAZARDOUS CHEMICALS IN TEXTILE PRODUCTION

CHLORINATED PARAFFINS are polychlorinated alkanes and they are divided into three categories depending on the length of the carbon chain, short (C10-C13), medium (C14-C17), and long (C20-C30). Short chain chlorinated paraffins are used as flame retardants for plastics. They are also used as a plasticizer in rubber, paints, and adhesives. Short Chain Chlorinated Paraffins are classified as dangerous to the environment because they are very toxic to aquatic organisms, and may cause long-term adverse effects in the aquatic environment.

CHLOROPHENOLS are polychlorinated compounds used as a preservative to wood, leather, and textiles. PCP and TeCP have been used as an antifungal in wood products, textiles, and leather. PCP and TeCP are irritatants to the skin, eyes and mouth and can cause harmful effects to the liver, kidneys, blood and lungs and are probable human carcinogens.

DISPERSE DYES WHICH ARE CLASSIFIED TO BE ALLERGENIC are generally water-insoluble colourants that are mainly used for dying polyester, nylon and cellulose acetate. Some disperse dyes have an allergenous (sensitizing) potential to the human skin and can be considered as a possible threat to health, especially if the dyes exhibit poor colour fastness to perspiration fastness.

DYES WHICH ARE CLASSIFIED TO BE CARCINOGENIC From the listed dyestuffs it is proven that they are carcinogenic.

FLAME RETARDENTS are chemical compounds that can be incorporated into textiles or applied by sprays to prevent burning. Brominated flame retardants are used in a wide range of products like automobiles, electronics and textiles because of their stability and heat resistance. Some flame retardents are as toxic as PCB's and DDT and are suspected to be carcinogenic. They persist once they enter the environment and food chain, and are likely to pass up the food chain.

FLUORINATED GREENHOUSE GASES Fluorocarbons are mainly used as substitutes for CFCs (Chlorofluorocarbons) and HCFCs (Hydro fluorocarbons), both of which are ozone depleting substances that the 1987 Montreal Protocol has progressively phased out of production. Fluorocarbons are mostly used as refrigerants in refrigerators and air-conditioners and as propellants in industrial aerosols. Other applications include foam-blowing, solvent cleaning and textile coating. Textiles coated with fluorocarbons provide good resistance to weathering, UV light aging, chemical and soil resistance. Treated textiles also give good water-proof and anti-pilling effect. Coated textiles.

FORMALDEHYDE is a volatile organic compound whose chemical properties make it suitable to be used for cross-linking amongst others in anti-creasing, anti-shrinking, and water repellence finishing, etc. to fabrics. It can be mixed with phenol and urea to form polymeric resins. In textiles and apparel, formaldehyde may be found in stiffened and permanent pressed fabric. Formaldehyde is a toxic chemical which can induce irritation to mucous membrane and is suspected to cause cancer.

Information taken from 'MODINT, Zeist, The Netherlands and GermanFashion, Köln, Germany, Restricted Substances List, Toolkit for apparel companies, April 2017'

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COMMON HAZARDOUS CHEMICALS IN TEXTILE PRODUCTION

HEAVY METALS (GENERAL) are found in dyestuffs and used as dye-fixing agents. They also occur in natural fibres like cotton. Many heavy metals are bio accumulative when absorbed by the human body through perspiration and give cause for concern in health terms such as chronic toxicity, allergenic reactions and cancers.

HEAVY METALS CHROMIUM VI In textiles and apparels, Chromium VI is usually associated with chrome tanned leather. Chromium VI can cause skin irritation and is considered to be carcinogenic.

HEAVY METALS ANTIMONY is used in flame-proofing, paints, ceramics, enamels, a wide variety of alloys, electronics, and rubber. The flame-retardant applications can include children's clothing, toys, aircraft and automobile seat covers.

HEAVY METALS ARSENIC is a notoriously poisonous metalloid. The toxicity of arsenic to insects, bacteria and fungi makes it an ideal component for the preservation of wood.

HEAVY METALS CADMIUM is a naturally occurring metal. In textiles and apparels, cadmium is usually used as pigments, coatings, stabilizers in plastics, dyes, paints, inks and metal accessories. Cadmium is also a well known stabilizer for the manufacturing of polymers like PVC. Cadmium and its derivatives are suspected to be carcinogenic.

HEAVY METALS LEAD is a soft, metal, also considered to be one of the heavy metals. Lead is a poisonous metal that can damage nervous connections (especially in young children) and cause blood and brain disorders. In textiles and apparel, lead can be found in plastics, paints, inks, pigments, and metal components.

HEAVY METALS MERCURY also called quicksilver is a heavy metal. Mercury is liquid at or near room temperature and pressure. Mercury exposure at high levels can harm the brain, heart, kidneys, lungs and immune system.

HEAVY METALS NICKEL is metal often combined with other metals to create alloys with increased hardness and resistance to corrosion. In textiles and apparel, nickel is mainly found in accessories for textiles and clothing, paints, inks, trims, plastics, and metal components. Nickel can cause extreme allergies.

ISOCYANATES are widely used in the manufacture of flexible and rigid foams, fibres, coatings, elastomers, polyurethane products.

N-NITROSAMINES are used in the manufacture of some cosmetics, pesticides, elastomers and rubbers. Many Nitrosamines are carcinogenic.

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COMMON HAZARDOUS CHEMICALS IN TEXTILE PRODUCTION

ORGANOTIN COMPOUNDS are a class of chemicals combining tin and organics such as butyl and phenyl groups. Organotin are predominantly found in the environment as antifoulants in marine paints, but they can also be used as biocides (antibacterials), and/or heat stabilizers in plastics. In textiles and apparel, organotins may be used in plastics, inks, paints, and heat transfer material. It is also used to prevent unpleasant odours.

PERFLUORINATED CHEMICALS are organofluorine compounds and are often used as surfactants. Like other fluorocarbons it repels water. PFOS is the main ingredient in many stain repellent finishes. Also used as: binder in non-woven fabrics to enhance dyeing; wetting agents to improve coverage and penetration of substances; achieve finish-on-yarn uniformity; water resistance; oil resistant coatings on textiles, leather, and other materials. These chemicals are persistent, bioaccumulative and poisonous to mammals.

PESTICIDES pesticides are substances or mixtures of substances used to kill a pest. A pesticide may be a chemical substance, biological agent (such as a virus or bacteria), antimicrobial, disinfectant or device used against any pest. Although there are benefits to the use of pesticides, there are also drawbacks, such as potential toxicity to humans and animals. In textiles and apparel, these pesticides may be found in natural fibres, primarily cotton.

PHTHALATES are a class of organic compounds added to plastics to increase flexibility. In textiles and apparel, phthalates can be associated with flexible plastic components, trims, screen and plastisol prints. Phthalates are reprotoxic and can cause birth defects and changes in hormone levels.

POLYCHLORINATED BIPHENYLS (PCB"s) and POLYCHLORINATED TERPHENYLS (PCT"s) are persistent organic pollutants and have entered the environment through both use and disposal. Polychlorinated biphenyls commonly known as PCBs are man made chemicals. These chlorinated oils have a low degree of reactivity. They are not flammable, have high electrical resistance, good insulating properties and are very stable even when exposed to heat and pressure. Uses for PCBs quickly expanded to include hydraulic fluids, casting wax, plasticizers, pigments, adhesives, fire-retardants; vapour suppressants to extend the kill-life of insecticides; coatings to render fabric flame-proof, rot-proof and water-repellent, lacquers, varnishes and paints.

POLYCYCLIC AROMATIC HYDROCARBONS (PAH'S) are one of the most widespread organic pollutants. In addition to their presence in fossil fuels they are also formed by incomplete combustion of carbon-containing fuels such as wood, coal, diesel, fat, tobacco, or incense PAH contaminations have been found in rubber but also in various plastics.

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POLYVINYLCHLORIDE (PVC) is a widely used thermoplastic polymer. It can be made softer and more flexible by the addition of plasticizers, the most widely-used being phthalates. In this form, it is used in clothing and upholstery It is commonly used in coats, jackets, aprons and bags. The global phase-out of PVC is advocated because it is claimed that dioxin is produced as a by product of vinyl chloride manufacture and from incineration of waste PVC in domestic garbage.

SOLVENTS HALOGENATED - VOLATILE ORGANIC COMPOUNDS Halogenated solvents are a general class of chemicals that have a variety of different properties and therefore end uses. Some of the more common uses include chemical intermediate (including dyes and pesticides), industrial cleaning (processing equipment, boilers, etc), spot cleaning, textile processing (scouring solvent, carrier solvent for preparations and functional finishes), urethane foam blowing agents and can be used as in the manufacture of plastics and PVC.

SOLVENTS - VOLATILE ORGANIC COMPOUNDS are organic chemical compounds that vaporize under normal conditions and enter the atmosphere. Common artificial VOCs include thinners and dry cleaning solvents.

SOLVENT- DI-METHYL FORMAMIDE The primary use of dimethyl formamide is as a solvent with low evaporation rate. Dimethyl formamide is used in the production of acrylic and aramid fibers and plastics. DMF has been linked to cancer in humans, and it is thought to cause birth defects. In some sectors of industry women are banned from working with DMF

UV STABILISER might be used as UV-protection agents in coatings, plastics, rubber and polyurethanes. These stabilisers are very persistent and very bioaccumulative. The primary function is to protect the substance from the long-term UV degradation effects from ultraviolet radiation.

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