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# **TEXTILE PROCESSING GUIDE:**

## **PRE-TREATMENT, COLOURATION & FINISHING**

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## ABOUT FASHION FOR GOOD

Fashion for Good is a global platform for innovation, made possible through collaboration and community.

At the core of Fashion for Good is their innovation platform. Based in Amsterdam with a satellite programme in Asia, the global accelerator programmes gives promising start-up innovators the expertise and access to funding they need to grow. The platform also supports innovators through its scaling programme and foundational projects, driving pilots and supply chain implementation with partner organisations. The Good Fashion Fund catalyses access to finance to shift at scale to more sustainable production processes.

As a convener for change, Fashion for Good houses the world's first interactive museum dedicated to sustainable fashion and innovation, a Circular Apparel Community co-working space, and creates open-source resources and reports.

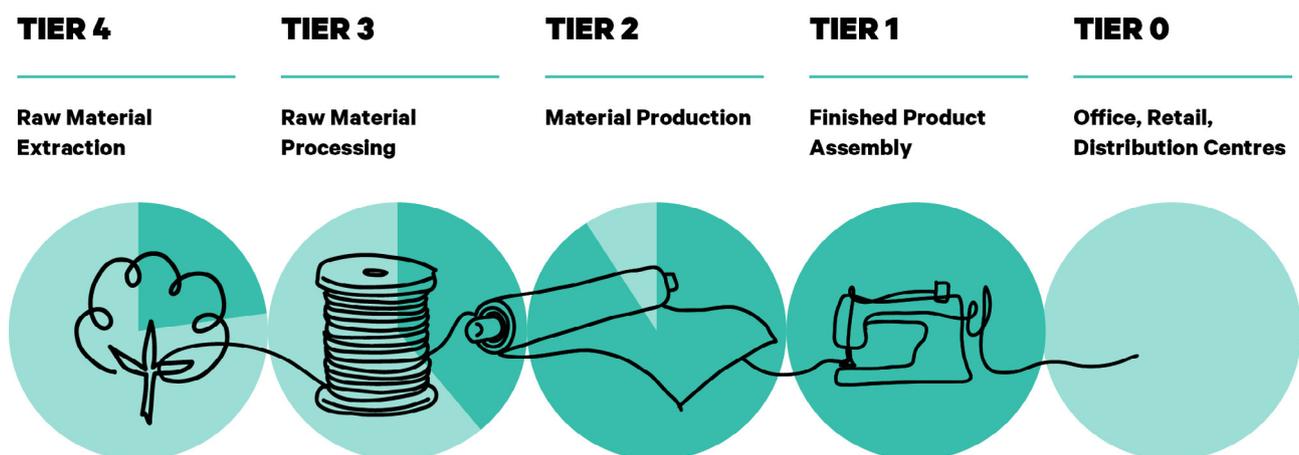
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# Introduction

The impact of today's fashion industry has far reaching environmental consequences. And while raw material production and end of use may spring to mind, the processing stage of the supply chain, including pre-treatment, colouration (dyeing and printing) and finishing, is often overlooked and a critical area for pivotal and positive change. This guide, based on industry and Fashion for Good research, is designed to provide an overview and deeper understanding of the processing stage, including innovative technologies that would help drastically reduce the water, energy and chemistry used, as well as replacing hazardous chemistry currently used<sup>1</sup>. A list of the definitions of key terms used in the report can be found in the appendix.

The textile industry's supply chain is commonly represented in four Tiers, this is used to describe the production process from raw material extraction to the finished product. Tier 4 includes the cultivation and extraction of raw materials from the earth, plants or animals. Tier 3, the processing of raw materials into yarn and other intermediate products. The processing stage, discussed in this report, falls into Tier 2, which is often referred to as material production. Tier 1 is the assembly and manufacturing of the final products<sup>2</sup>.

Tiers 3 and 4 are often cited as the main cause of the fashion industry's high environmental impact but actually make up 39% of all greenhouse gas (GHG) emissions in the fashion supply chain. Whilst Tier 2 equates to 52% of the GHG emissions, whilst also using a significant amount of chemistry and water<sup>3</sup>.



Four Tier Supply Chain Model. Source: WRI and Aii (2021)

As a result, there is ample opportunity to reduce impact in this stage of the supply chain. Fashion for Good works with brands, manufacturers and innovators to orchestrate collaborative projects and pilots aimed at accelerating innovation and implementation. The D(R)YE Factory of the Future, consortium project for example, was launched and orchestrated by Fashion for Good together with partners adidas, Kering, PVH Corp., Arvind Limited, and Welspun India and several innovators in textile pre-treatment, colouration and finishing. The project brings together several novel technologies with the aim of disrupting the current processing of textiles in the fashion supply chain.

# An Overview of Processing

During the processing stage, the fibres, yarns, fabrics or garments go through multiple steps to achieve the performance and aesthetic properties desired by brands and their consumers. These steps can be broadly categorised into pre-treatment, colouration and finishing treatments and make up most of the impact and processes taking place in Tier 2.

	PRE-TREATMENT	COLOURATION	FINISHING
Description	Pre-treatment is done before a dyeing and printing process. It's main purpose is to clean the fibre and make the dyeing or finishing step more efficient	Colouration is the application of dyestuff on textile materials such as fibres, yarns or fabrics with the goal of achieving colour with desired colour fastness	In textile finishing a treatment is applied to a textile to give it a specific desirable quality or functionality, making it more suitable for its intended end use
Processes & Functions examples*	Singeing, (De)sizing, Scouring, Bleaching, Neutralisation, Mercerising, Optical Brightening, Heat Setting, Bio-polishing	Dyeing (Batch, Continuous & Dope) Printing (Screen, Transfer & Digital) Different dye types are used for different fibres	DW(O)R, Flame Retardancy, Stain resistance, Easy Care, Softening, Antistatic, Antimicrobial, Biopolishing, Laser

\*A description of all processes and functions can be found in Appendix A

**FIGURE 1: OVERVIEW AND DEFINITIONS OF PROCESSING STEPS**

Traditionally pre-treatment, colouration and finishing are referred to as wet processes as they take place in large tanks or baths filled with water that is constantly kept at a high temperature<sup>4</sup>. Alongside the pre-treatment, colouration and finishing steps, a significant amount of water and chemistry is wasted as the fabrics also have to be washed off to remove excess dyes. Approximately 10-50% of dyes are washed out in this process, ending up in the effluent water<sup>5</sup>.

# An Overview of Processing

Fashion for Good divides the processing stage in two categories to help differentiate between the chemical applied i.e. chemistry and the process by which this chemistry is applied i.e. machinery. An overview is outlined below in Figure 2.

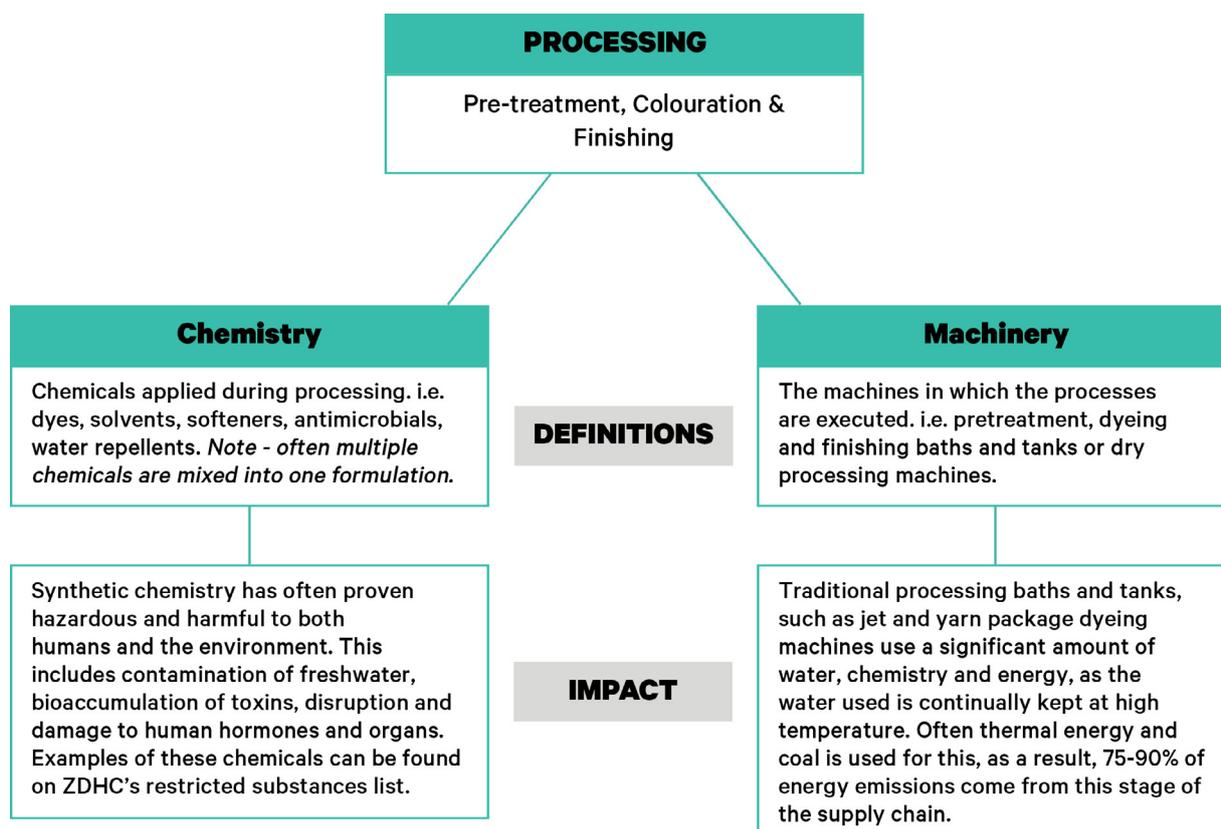


FIGURE 2: OVERVIEW OF CONVENTIONAL CHEMISTRY AND MACHINERY

## DW(O)R FINISH and PFCs

What are Durable Water and Oil Repellency (DW(O)R) and perfluorochemicals (PFCs)?

- DW(O)R finishes ensure fabrics repel water and oil.
- The performance of the repellency can be assessed through a variety of testing methods.
- Traditional DW(O)R finishes contain perfluorochemicals (PFCs) to achieve high performance.
- PFC refers to either perfluorooctanesulfonic acid (PFOS) or/and per- and polyfluoroalkyl substances (PFOAs)<sup>6</sup>:
  - PFOSs have been linked to kidney and testicular cancer, as well as a having negative impact on human thyroid function<sup>7</sup>
  - PFOAs are reprotoxic; decreasing fertility and having adverse developmental effects<sup>8</sup>
  - PFCs have shown to bio-accumulate in nature and are set to stay there forever, hence their nickname forever chemicals<sup>9</sup>.
- As a result, a significant effort is going into finding high performing PFC-free DW(O)R treatments, Fashion for Good is supporting innovators, such as OSM Shield ZERO and Dryfiber, who focus on this.

# An Overview of Processing

## ANTIMICROBIAL FINISH AND HEAVY METALS

What are antimicrobial finishes and heavy metals?

- Antimicrobial finishes are applied to inhibit the growth of bacteria, mould and fungi on fabrics. This keeps the fabrics hygienic and prevents odours. Antibacterial finishes are a kind of antimicrobial finish that can kill or inhibit the growth of bacteria such as E.coli. These finishes will not be effective against viruses (e.g. coronavirus)<sup>10</sup>.
- Antiviral finishes claim to kill or inhibit viruses, typically in addition to being antimicrobial<sup>11</sup>.
- Many antimicrobial and viral finishes have been proven to contain heavy metals such as silver, copper and zinc<sup>12</sup>. These can leach into water and impact aquatic life. Besides this, studies have shown they can be harmful to humans when ingested or exposed to skin. In fact, the extent of the effects of heavy metals on humans is still unknown<sup>13</sup>.
- Bio-based and/or heavy metal free antimicrobial finishes are being developed. Fashion for Good is supporting multiple innovators, such as Nordshield and OSM V-Shield, who focus on this.

A number of solutions exist that would help reduce the use of water, energy and harmful chemistry in this stage of the supply chain. Some of these are incremental solutions whilst others are disruptive innovations. The next section briefly touches on some of these incremental solutions, you can learn more about these solutions in Fashion for Good x Apparel Impact Institute (Aii)'s report '*Unlocking the Trillion - Dollar Fashion Decarbonisation Industry*'. The report charts a trajectory for the industry to meet its net-zero ambition, breaking down the funding needed and mapping the integral levers across existing and innovative solutions.

# Incremental Innovation

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## **MACHINERY**

There are opportunities to reduce GHG emissions by switching to renewable energy as well as implementing process efficiency improvements, including better insulation, heat recovery and metering. The Apparel Impact Institute focuses on implementing these improvements through their Clean by Design Programme. A recent case study from a facility who had implemented the Clean by Design Programme showed up to 10% CO<sub>2</sub> reduction (10% includes 4% reduction in natural gas, 5.8% in electricity, 5% in coal and 8% in steam use) can be achieved<sup>14</sup>. An advantage of this approach is that the projects are low risk, meaning the workflows of the textile mills are not disrupted and the performance of these technologies has already been proven.

## **CHEMISTRY**

A significant amount of effort from all supply chain stakeholders has been put into phasing out harmful chemistry. Many brands have implemented restricted substances lists (RSLs) defined by organisations like ZDHC and AFIRM and chemical manufacturers have developed chemistries that are non-hazardous and less harmful.

Certifications from organisations such as Bluesign and OEKO-TEX help verify the content of these products and are often a requirement of brands. Alongside this compliance with REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) legislation (European Union's legislation on chemicals) is required in order to be able to sell products in Europe.

However, there is still a long way to go to phase out all harmful chemicals as innovations need to also meet the necessary performance requirements. In order to achieve a real step change, the industry needs the disruptive innovations discussed later in this report.

# Disruptive Innovation - Machinery

The key solution to drastically reducing water and energy use in the processing stage of the fashion supply chain lies within moving from wet processes to mostly dry processes. In other words, moving away from processing in heated baths and tanks filled with water to machinery that require very little to no water, as well as significantly less energy and chemistry. An additional benefit to most of these technologies is that little to no wash off is needed.

Figure 3 and 4 below, show the potential impact this shift could have. Given wet processes' significant contribution to total CO<sub>2</sub> emissions and water consumption, transitioning to mostly dry processes has the potential to reduce emissions by up to 89%, and to cut water consumption by between 83% and 95%.

## CO<sub>2</sub>eq EMISSION REDUCTION POTENTIAL OF MOSTLY DRY PROCESSING

■ CO<sub>2</sub>eq EMISSIONS BEFORE IMPACT  
■ CO<sub>2</sub>eq EMISSIONS AFTER IMPACT

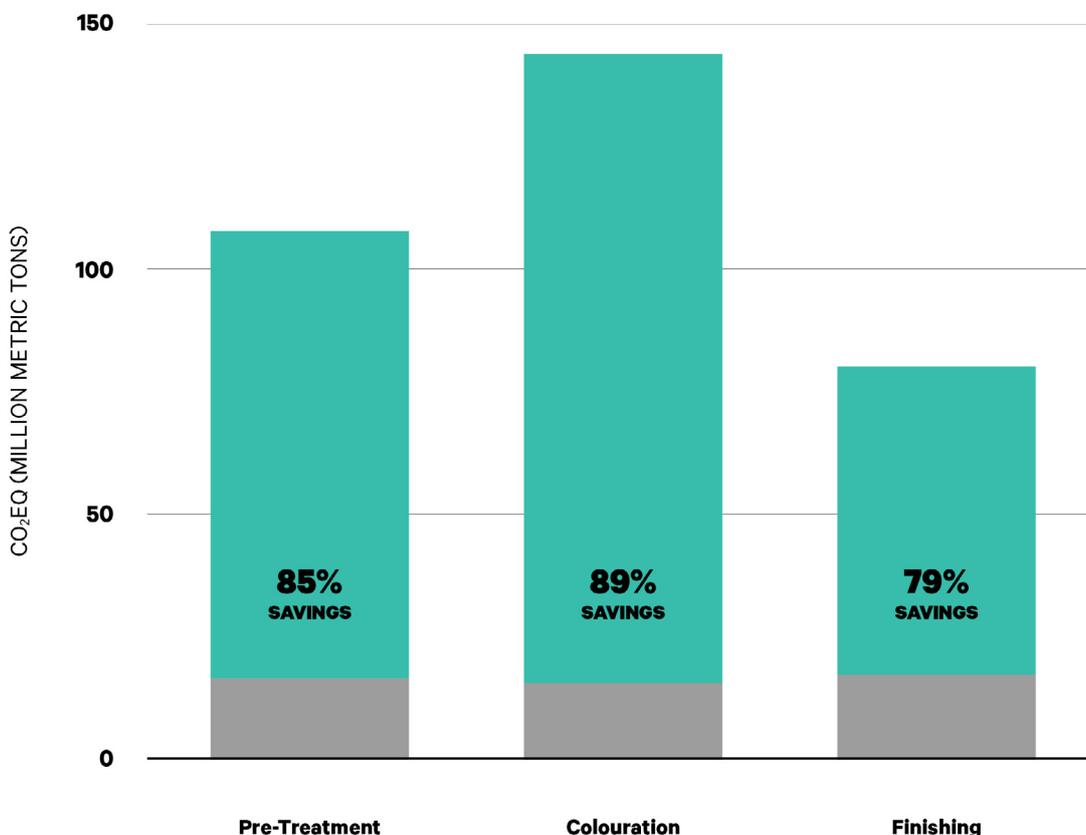


FIGURE 3: CARBON DIOXIDE EMISSION REDUCTION POTENTIAL OF MOSTLY DRY PROCESSING

# Disruptive Innovation - Machinery

## WATER REDUCTION POTENTIAL OF MOSTLY DRY PROCESSING

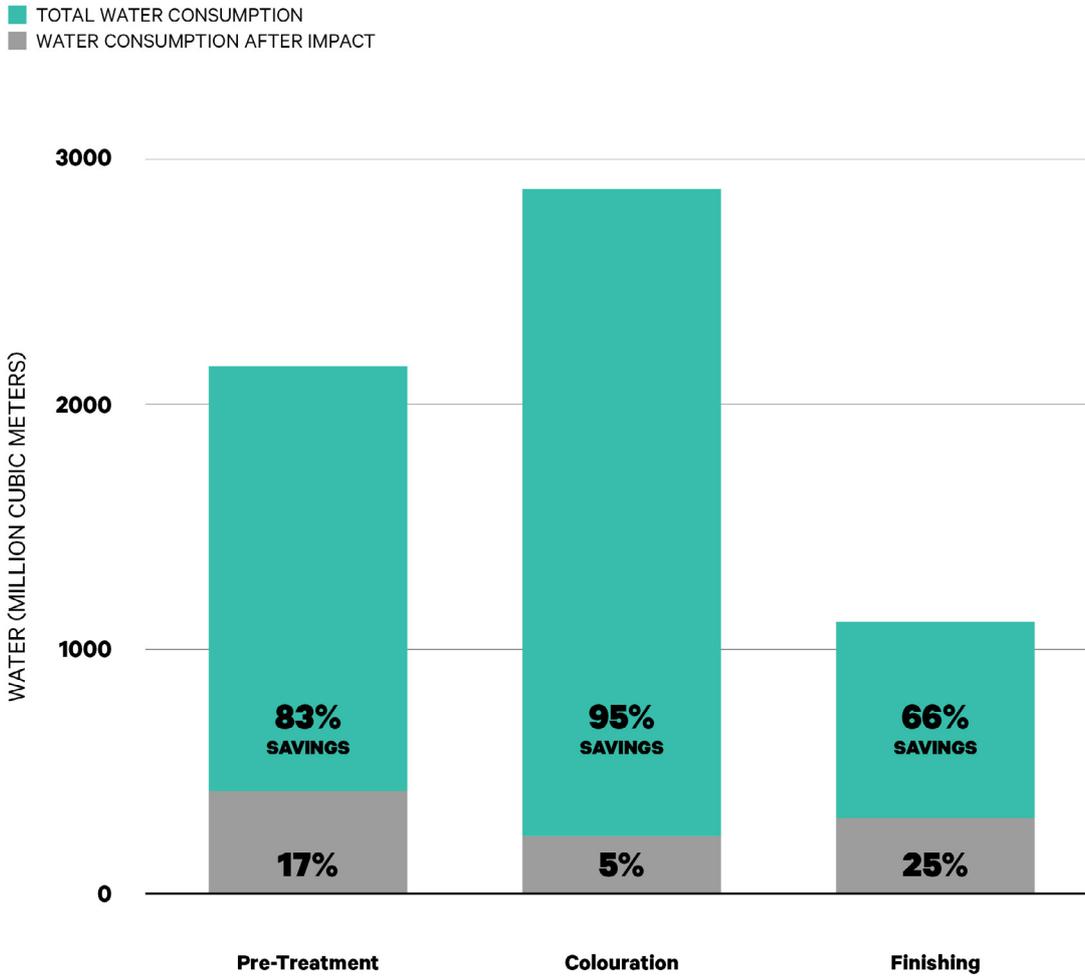


FIGURE 4: WATER USAGE REDUCTION POTENTIAL OF MOSTLY DRY PROCESSING

# Disruptive Innovation - Machinery

Figure 5 below illustrates some of these disruptive machinery innovations, including some of the innovative companies working in this space.

PROCESSING STEP	DISRUPTIVE TECHNOLOGY	INNOVATORS
<b>PRE-TREATMENT</b>	Plasma / Plasma & Laser	 
<b>DYEING</b>	Digital Spray	 
	Supercritical CO <sub>2</sub>	 
	Ultrasonic	
	Foam	
	Dope	
<b>PRINTING</b>	Gravure Printing	
	Digital Printing	
<b>FINISHING</b>	Plasma / Plasma & Laser	
	Digital Spray	 
	Ultrasonic	
	Ozone	 
	Laser	 

FIGURE 5: OVERVIEW OF INNOVATIVE MACHINERY SOLUTIONS

# Disruptive Innovation - Machinery

## TECHNOLOGIES AND INNOVATIONS

### Plasma / Laser

Plasma, the fourth state of matter, is formed when gas is ionised and becomes more reactive. When this ionised form of gas is applied to a substrate aka surface or fabric, it is able to alter its properties i.e. activating its surface, removing impurities, depositing a coating. It is a waterless technology, has low energy consumption and is effluent free.

### MTIX\*

MTIX has developed a multiplexed laser surface enhancement (MLSE®) system for textiles. The MLSE® system creates a unique quantum mechanical energy milieu with laser plasma that enables durable technical functionalities, finishes and pre-treatments on all fabric types in a high volume and continuous process.

### GRINP\*

GRINP develops and produces machines using their proprietary atmospheric plasma technology. Their industrial machines can replace traditional pre-treatments such as bleaching. The technology is fibre agnostic.



Image courtesy of MTIX

# Disruptive Innovation - Machinery

## Digital Spray Dyeing and Finishing

Nozzles spray the exact amount of dyestuff and finishing chemistry required directly onto the fabric. The process is digitally controlled and therefore highly efficient. As a result, it uses very little water and much less dyestuff and chemistry than traditional processes. This process is not the same as digital printing (explained below), digital printing focuses on creating artworks on the surface of a fabric while spray dyeing mostly focuses on dyeing fabrics in solid colours with deep penetration. As a result, the nozzle openings in digital printers are significantly smaller than those used in spray dyeing. This means that digital printing often needs expensive speciality inks while spray dyeing can work with traditional dyes.

### Alchemie\*

Alchemie has developed a digitally enabled spray/jetting technology which in combination with their proprietary airflow technology is able to deeply penetrate the fibre. Their dyeing machine is called Endeavour and their finishing machine is called Novara. In addition to these two machines, Alchemie has developed a proprietary fixation process consisting of infrared radiation/heat which fixes the dyes to the fabric. Their high precision means they can dye to shape as well as simple patterns. The technology is compatible with traditional dyes and chemistry and can be used on polyester and cotton fabrics.

### imogo\*

imogo has developed a digitally enabled spray dyeing and finishing technology, which is used in their Dye-max (dyeing) and F-max (finishing) machines respectively. They use the capillary forces in the materials and the fibre's natural absorption to get deep penetration. Both machines are compatible with traditional dyes and chemistry and they are currently focusing on cellulosics. Fixation is done by traditional methods such as cold batching.



Image courtesy of imogo

\* Fashion for Good Alumni - Fashion for Good have supported over 135 innovators through our projects and programmes. They continue to be a part of our alumni network with Fashion for Good providing continued ongoing support

# Disruptive Innovation - Machinery

## **Supercritical CO<sub>2</sub> Dyeing**

In conventional dyeing, water is used as a solvent but in supercritical CO<sub>2</sub> (scCO<sub>2</sub>) dyeing, scCO<sub>2</sub> replaces water as the solvent. In a supercritical state, CO<sub>2</sub> gets the dual advantages of having solubility like a liquid and flow properties like a gas. Due to its gaseous properties the scCO<sub>2</sub> can circulate in the dyeing vessel and deposit the dyes onto the textile yarn or fabric. When dyeing is complete, the high pressure vessel containing the scCO<sub>2</sub> is depressurised. As a result, the CO<sub>2</sub> reverts to its gaseous state and the dye, which cannot stay dissolved in a normal gas, drops to the bottom of the dyeing vessel. Both can be recovered and it is a closed loop waterless dyeing process. As a result, there is no water effluent and the process uses less energy and chemicals.

### eCO<sub>2</sub>Dye\*

eCO<sub>2</sub>Dye has developed a dyeing technology using scCO<sub>2</sub>. The equipment is designed to dye a variety of yarns and threads on conventional cones or packages using scCO<sub>2</sub>. Traditional dyes which are compatible with scCO<sub>2</sub> have been identified. The process uses existing CO<sub>2</sub> which is recycled after each dyeing process cycle. Pre-treatment (e.g scouring) and dye removal from waste textiles with supercritical CO<sub>2</sub> is in research and development (R&D). The technology can be used to dye polyester and wool yarns.

### Deven Supercriticals\*

Deven Supercriticals has developed a dyeing and finishing technology using scCO<sub>2</sub>. Rather than only introducing the dye in the dyeing vessel, they precoat the fabric with dyes and chemicals before it enters the dyeing vessel, using the scCO<sub>2</sub> to improve their solubility in scCO<sub>2</sub> with it before it enters the dyeing vessel. This makes their technology compatible with traditional dyes and can be used to dye polyester, cotton and cotton-polyester blends.

## **Ultrasonic Dyeing and Finishing**

Ultrasonic waves are acoustic waves that create thousands of microscopic bubbles in a formulation which, when burst, release large amounts of energy. The pressure from the bursting of these tiny bubbles generates powerful jet-streams that are used to physically inject the fabric with the desired chemistries. This process means less water and chemistry is needed as well as fewer additional chemistries like binders.

### Sonovia\*

Sonovia has developed a compact ultrasonic finishing machine and process that embeds Sonovia's customised chemistries for finishing applications directly into the fabric. To date, Sonovia has developed antimicrobial and viral finishes as well as DWR, their technology is fabric agnostic.

### Indidye\*

Indidye uses sound waves to bind their proprietary natural plant based dyes to cellulosic fibres. The dyes are extracted with a water based extraction process and then applied using the ultrasonic technology.

\* Fashion for Good Alumni - Fashion for Good have supported over 135 innovators through our projects and programmes. They continue to be a part of our alumni network with Fashion for Good providing continued ongoing support

# Disruptive Innovation - Machinery

## **Foam Dyeing**

Large foam bubbles carry dyestuff and when the bubbles burst, the pressure deposits the dye on the fabric/yarn. This results in lower water and chemistry usage and as a result it is a more efficient process than traditional dyeing.

### Indigo Mill Designs\*

Indigo Mill Designs has invented a novel way of applying indigo to cotton yarns, called IndigoZERO™. The dye is applied to the fibre using a foam system that minimises the uptake of water.

## **Dope Dyeing**

Dope dyeing is where pigments are added to the liquid solution before the fibres are spun or extruded into yarn. It can be used for synthetic fibres like polyester and acrylic as well as for cellulose. This process uses less chemicals and energy and as the process is short, less wastewater is generated.

### We aRe SpinDye\*

We aRe SpinDye orchestrates the dope dyeing of polyester yarns for fashion brands. Brands get a quality, compliance & traceability We aRe SpinDye®-certificate for all products they take off. This certificate also states Life Cycle Assessment (LCA)-based impact savings compared with traditional dyeing processes.

## **Gravure Printing**

Gravure is different from other printing processes as it prints from depressed, ink-filled cells that are produced on the surface of a cylinder that is copper plated. The ink in these cells is transferred onto the fabric. The process is digitally controlled to engrave the roller and therefore highly efficient. Traditionally the gravure roller requires a transfer of the artwork onto a paper or film which is then transferred onto the material substrate. It is a mostly waterless process that uses less energy than conventional dyeing.

### NTX: Cooltrans\*

NTX: Cooltrans provides a digitally enabled gravure printing method for both artworks and block colours. Their technology is faster and more precise than other printing technologies and they use proprietary inks (material restricted substance list (mRSL), ZDHC and RSL compliant) that are manufactured in-house. Alongside this, for solid colour applications, their technology transfers from gravure to the material without paper or film. It can be used on all fibre types except polyolefins.

## **Digital Printing**

Digital textile printing is an inkjet-based printing method which enables printers to print high-quality designs from a digital data file onto different fabrics. The ink is deposited in the form of minuscule droplets by the digitally controlled printing heads. It is a mostly waterless process and reduced energy use as no dye bath is needed.

### Kornit

Kornit is an established digital printing technology company. They are classified as an innovator/innovative company as they have developed a single step printing solution which combines fixation, dry softening and full curing. It is fabric agnostic.

\* Fashion for Good Alumni - Fashion for Good have supported over 135 innovators through our projects and programmes. They continue to be a part of our alumni network with Fashion for Good providing continued ongoing support

# Disruptive Innovation - Machinery

## **Ozone**

Ozone, which is an alternative form of oxygen and a strong oxidising agent, can be used to clean / bleach the garment, it's most effective when used inside a washing machine to prevent the gas escaping and to allow for its correct neutralisation. At the end of the process, any remaining ozone is converted back into oxygen. Ozone pre-treatment and finishing reduces water, chemistry and energy consumption and as a result there is also less effluent. Ozone is often used for finishing jeans and also has enhanced performance benefits such as achieving the right shade of blue faster and with lower costs.

## **Laser**

Laser technology is most commonly used as an alternative to manual scraping in denim production; it can also be used to create vintage effects, whiskers, patterns, patches, and even intentional holes and tears in a (denim) garment. Used in combination with other technologies such as ozone, it can replace traditional processes like sandblasting and bleaching which are hazardous to workers' health.

## Tonello and Jeanologia

Tonello and Jeanologia are both established players selling multiple industrial dyeing and finishing technologies with a strong focus on sustainability and denim. They both have ozone and laser technologies as well as several other more efficient washing and finishing processes that have enhanced performance benefits as well as environmental savings.

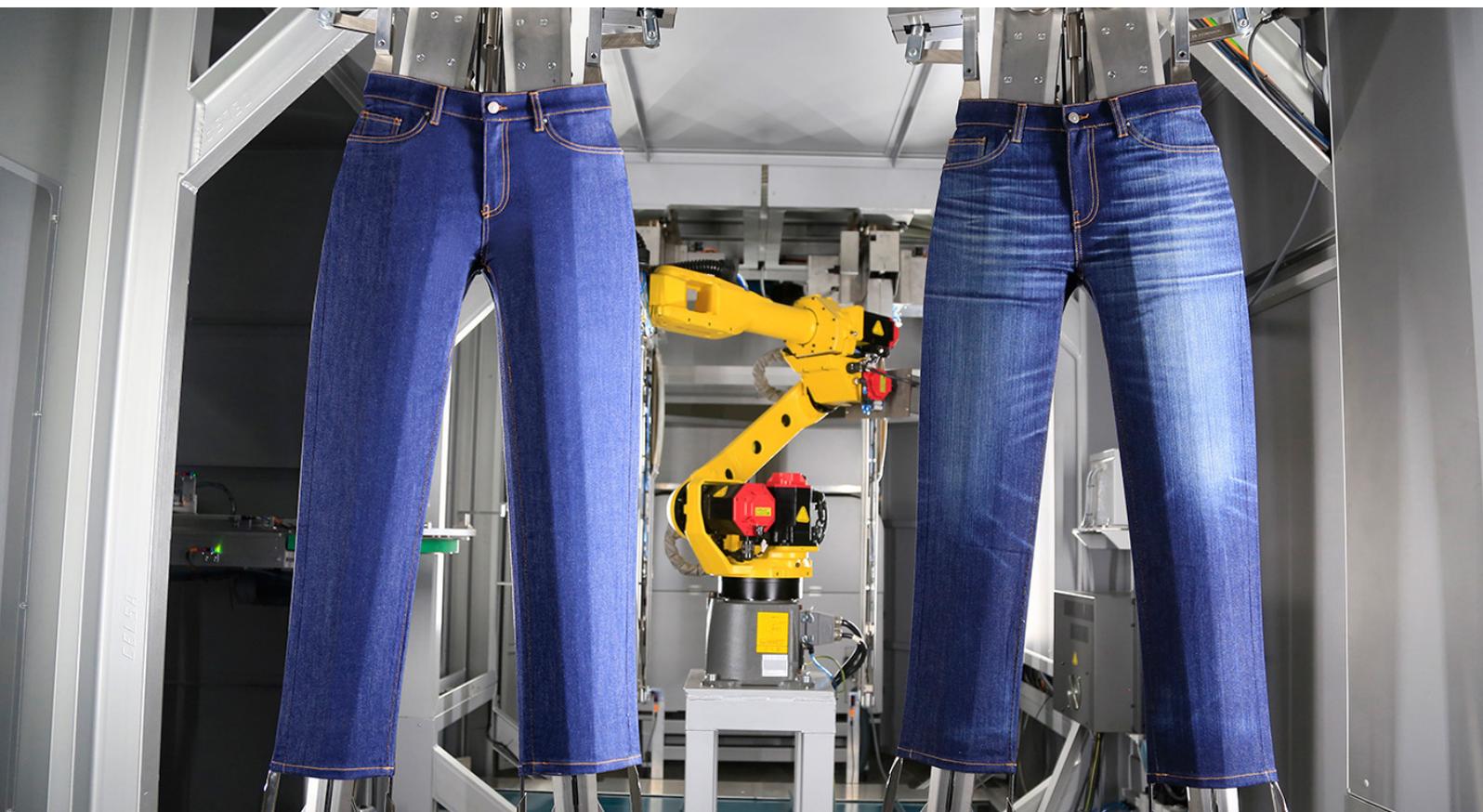


Image courtesy of Jeanologia

# Disruptive Innovation - Machinery

## **CHALLENGES OF SCALING DISRUPTIVE MACHINERY INNOVATIONS**

The impact savings mentioned above raise the question as to why more textile mills have not switched to mostly dry processes yet. Below we will elaborate on the challenges of this transition.

### **Misaligned Incentives and Unequal Power Relations**

Although brands have the greatest incentive and the most pressure to drive towards sustainability, efforts are often limited, and the industry expects the upstream supply chain to account for the costs and risks. This results in a misalignment of incentives for major innovation along the supply chain.

### **High Initial Investment**

Investing in new processing technologies is expensive. Fashion for Good has evaluated machine technologies ranging from 150k to 20M USD. Alongside this, the investment often falls to the manufacturers who do not always have committed offtake from brands. Increasingly, brands and manufacturers sign letters of intent (LOI), which include a commitment from the brand that they will purchase a certain number of products made using the new technology. Or recent collaborations include an innovator, manufacturer and brand partners jointly investing in a novel machine through a joint venture (JV) structure. The machine is installed at the manufacturer who is part of the JV.

That said, while initial capex for some technologies are high, payback times can be as short as 1 to 2 years as variable costs, from water, energy, and chemistry, are reduced<sup>15</sup>.

### **Performance**

As with all new technologies, there are risks around the technology's ability to meet minimum performance requirements for different applications at scale. In addition, mostly dry technologies can impact the handfeel of materials differently than wet technologies. Therefore it is important that the technologies are optimised to achieve the same handfeel as the industry is accustomed to after wet processing.

### **Incremental vs. disruptive innovation**

Brands/manufacturers might feel they have to choose between investing in either incremental or disruptive technologies. Once they have gone down the route of incremental changes, this may form a barrier to invest money in disruptive technologies. Investments in new innovations have the potential to generate higher savings in environmental impact, however it comes with a greater risk. As a result, the direction taken by the brands/manufacturers depends on their strategic priorities and internal risk appetite.

# Disruptive Innovation - Chemistry

Although great progress has been made when it comes to innovation in sustainable chemistry there are still a number of hazardous chemicals which can be found on ZDHC's RSL and mRSL lists to which no similar performing, less harmful alternative has yet been found. As such, disruptive innovation in this space mostly focuses on finding competitive alternatives that could either replace a specific chemical in a solution or by replacing a solution with a new formulation. Examples of this could include formulations that are bio-based or based on a non-harmful chemistry like silicone. Figure 6 shows an overview of the disruptive technologies and innovators. Below an overview of some of the most used processes in the pre-treatment, dyeing, printing and finishing.

PROCESSING STEP	DISRUPTIVE TECHNOLOGY	INNOVATORS
PRE-TREATMENT	Cationic treatment	 Nano-Dye
	Enzymatic treatment	 novozymes
DYEING/PRINTING	Natural dyes/pigments	 STONY CREEK COLORS  LIVING INK  NATURE COATINGS  IndiDye
	Microbial pigments	 Colorifix  AKB Colors  huueo
	Dyes from Carbon Capture and Utilisation	 GRAVIKY LABS
	Recycled dyes	
FINISHING	PFC-free DW(O)R finish	 OSM  DRYFIBER
	PFC-free waterproof membrane	 dimpora
	Bio-based antimicrobial treatments	 NordShield

FIGURE 6: OVERVIEW OF INNOVATIVE CHEMISTRY SOLUTIONS

# Disruptive Innovation - Chemistry

## TECHNOLOGIES AND INNOVATIONS

### **Cationic treatment**

Chemistry innovations in pre-treatment are more limited than in dyeing and finishing. An example of an incremental innovation in this space is cationic treatment. With this treatment, cotton is modified to have a permanent cationic, or positive charge, making the cotton “friendlier” to dye and so increases its dye uptake. Cationic treatments have the opportunity to enhance the dyeability of cotton but require advanced effluent treatment as they can cause eutrophication.

### Nano Dye

Nano dye has a salt-free cationic treatment that potentially does not result in high eutrophication. Salt is commonly used in the pre-treatment process which then ends up in the effluent water, impacting the local environment. Nano Dye’s technology is a drop-in solution that changes the charge of a cotton molecule to the opposite charge of the dye to enhance dye uptake. It is used with cotton, other cellulosic fibres and blends.

### **Enzyme treatment**

Conventional scouring is harsh on fabrics and the environment. Enzymes can be used to modify the fabric to become more receptive to dyes through processes such as bioscouring, they can be used in both pre-treatment and finishing<sup>16</sup>. It is a more sustainable solution that allows savings in water, time and energy as well as a reduction in the usage of harmful chemicals which improves worker safety.

### Novozymes

Novozymes produces and develops biological solutions for textiles including enzymatic scouring, also known as biopreparation or bioscouring.

## **NATURAL DYES/PIGMENTS**

Natural dyes and pigments, from sources like algae and plants, have existed for centuries but have historically been overlooked by the fashion industry due to inferior performance, limited colour palette and higher prices than synthetic dyes. However, new disruptive cultivation, extraction and application processes have the potential to overcome these barriers and enable the (re)implementation of natural dyes at scale. Using natural dyes and pigments enables a shift away from synthetic chemistry and in some instances the feedstock used ie: plants, algae or waste means the dyes and pigments have the potential to be carbon negative.

# Disruptive Innovation - Chemistry

## DYES VS PIGMENTS

What is the difference between a dye and a pigment?

- Traditionally dyes are described as molecules holding colour, while pigments are described as particles of colour. Because of their respective nature, dyes dissolve in a medium similar to how salt dissolves in water, while pigments only disperse in a medium like sand disperses in water.
- Traditionally dyes are said to chemically bind themselves to a material, thus becoming part of it while pigment requires a binder to enable it to fix onto material.

## Plant based dye

Stony Creek Colors\*

Stony Creek Colors creates a pre-reduced plant-based indigo that can replace petrochemical based synthetic indigo dyes. They optimise indigo production in a renewable (and aniline - free) closed loop process. It can be applied on cotton, cellulose, wool and silk.



Image courtesy of Stony Creek Colors

\* Fashion for Good Alumni - Fashion for Good have supported over 135 innovators through our projects and programmes. They continue to be a part of our alumni network with Fashion for Good providing continued ongoing support

# Disruptive Innovation - Chemistry

## Algae-based pigment

### Living Ink\*

Living Ink transforms waste microalgae material into a bio-based carbon black that can replace petroleum derived carbon black. The pigment is jet black and UV stable. It can be used for screen printing on cotton, cellulose, blends, leather and polyester. Dope dyeing applications are in Research & Development (R&D).

### Algaeing™\*

Algaeing uses microalgae to manufacture dyes and inks in a closed system that can be used with existing production machinery. It can be used to dye and print all types of fibre.

## MICROALGAE VS MACROALGAE

What is the difference between microalgae and macroalgae?

Algae can be used as an input to create fibres and chemistries. It has received a lot of attention lately as products derived from algae have the potential to be carbon negative. Algae can be divided into two types; microalgae and macroalgae, the differences are explained below.

<b>Microalgae</b>	<ul style="list-style-type: none"><li>• Unicellular microorganisms, living in saline or freshwater environments, that convert sunlight, water, nutrients and carbon dioxide to algal biomass</li><li>• It can be grown everywhere if nutrients can be provided (e.g. can grow in tubes on arid land)</li><li>• Final material chemistry and volume can be changed by controlling growth nutrients and other conditions (e.g. light)</li></ul>
<b>Macroalgae</b>	<ul style="list-style-type: none"><li>• Macroalgae is a term used for seaweed and marine algae attached to the sea bed. Outside of the textile industry, it has been used in other areas to produce biofuels, cosmetics and soil fertilisers to name a few.</li><li>• It can only be grown in certain locations with specific conditions and usually grows in coastal areas</li><li>• There are three types of macroalgae: brown, red and green</li></ul>

**FIGURE 7: OVERVIEW OF MICROALGAE VS. MACROALGAE**

Source: Khan et al. (2018); FAO (2009), Usher et al. (2014), Campbell et al. (2019)

# Disruptive Innovation - Chemistry

## **Woodwaste-based pigment**

### Nature Coatings\*

Nature Coatings transforms Forest Steward Council (FSC) certified wood waste into high performing and cost competitive black pigments. Their pigments are a direct replacement for petroleum-based carbon black pigments. The pigments and 100% bio-based dispersions can be used for screen printing on cotton, cellulose, blends, leather and polyester. Dyeing applications are in R&D.

## **Microbial pigments**

Microbial pigments are either naturally occurring in organisms or artificially grown in genetically modified organisms (GMO). Once the naturally occurring microbe is identified or a genetically modified microbe strain has been engineered, the microbes get multiplied via fermentation by feeding them sugars and other feedstock. After this process the pigments are extracted to be used in traditional dyeing processes. Microbial pigments can replace synthetic pigments, and thereby reduce GHG emissions as well as the amount of potentially harmful chemistry used.

### Colorifix\*

Colorifix uses microbial pigment technology to produce, deposit, and fix colour onto textiles. They genetically modify microbes to produce a wide range of naturally-occurring pigments and ferment them using renewable feedstocks. Rather than extract the dye from the bacteria, a costly downstream processing step, Colorifix uses the broth the bacteria are fermented in as dye liquor. The technology can be used to dye all fibres and fibre blends.

### Huue\*

Huue uses microbial pigment technology to produce dyes and pigments (GMO), with indigo dye as its first product. After extracting the pigment from the bacteria and processing it, the bio-based dye can be used as a drop-in replacement for synthetic Indigo, with high purity and with the same performance. The pigments can be used to dye cotton fibres and any other substrates typically dyed with indigo.

### KBCols Sciences\*

KBCols Sciences use microbial pigment technology, using non-GMO naturally occurring coloured microbes sourced from the soil, water and air, to extract different natural colours that can be applied in textiles and other applications. The pigments can be used to dye most natural and synthetic fibres.

\* Fashion for Good Alumni - Fashion for Good have supported over 135 innovators through our projects and programmes. They continue to be a part of our alumni network with Fashion for Good providing continued ongoing support

# Disruptive Innovation - Chemistry

## **ALTERNATIVE DYES/PIGMENTS**

There are many alternative more sustainable dyes and pigments on the market or in development. These include pigments made from captured carbon and recycled dyes made from old textiles.

### **Pigments from Carbon Capture and Utilisation**

Turning carbon emissions from industrial pollutants into industrial grade products. Using captured carbon as a feedstock means a shift away from synthetic chemistry as well as a reduction in greenhouse gas emissions.

#### Graviky Labs\*

Graviky's first product AIR-INK® is a range of inks and dyes made by end-of-use carbon emissions. The black pigment can be used for different printing processes such as screen, sublimation and digital. Graviky has tested AIR-INK on different surfaces such as paper, polyester and textiles. Dope dyeing applications are in R&D.

### **Recycled dyes**

Recycled dyes can either be produced through creating a very fine crystallised powder out of textile waste and dyeing with this or chemically recovering dyes from fashion waste and redyeing other fabrics with it. Using textile waste as a feedstock reduces the amount of synthetic chemistry used and allows for a more circular process.

#### Officina +39 : Recycrom\*

Recycrom is a dyestuffs range created by making used clothing, fibrous material and textiles scraps made from cellulosic fibres into a very fine powder to dye with. The dyestuff can colour any cellulosic and natural fibre as well polyamide.



Image courtesy of Algaeing

# Disruptive Innovation - Chemistry

## **PFC-free DW(O)R finish**

One of the biggest priorities of the fashion industry (and other industries) is finding PFC-free high performing durable water (and oil) repellency DW(O)R treatments. Instead of PFCs other synthetic chemistries (e.g. silicone) or bio-based chemistries (e.g. waxes, wood, bio-based solutions) can be used. PFCs need to be phased out as they have proven to be toxic and harmful to both humans and the environment, so shifting to these alternative solutions has multiple environmental benefits.

### OSM Shield: ZERO\*

OSM Shield's ZERO chemistry solution is a non-Perfluoro alkyl (PFAS) high performance durable water and oil repellency technology which is free from all PFAS compounds and associated toxins. This chemistry technology will be available in a standard emulsion and can be applied using traditional application methods on all fibre types, but the focus is on cotton and polyester.

### Dryfiber\*

Dryfiber provides a completely fluorine free, and hence also PFC-free DW(O)R textile finish. The solution is silicon-based and can be applied through traditional finishing processes. The current focus is on synthetic fabrics.



Image courtesy of OSM Shield

# Disruptive Innovation - Chemistry

## PFC-free waterproof membrane

A microporous membrane is a very thin layer containing many tiny pores (thousand times smaller than a drop of rain). These membranes have waterproof and breathable properties; while they do not let water come through from the outside, they do allow water vapour, emitted through perspiration, to evacuate. Innovation lies within the production technology to provide high performance without using PFCs.

### Dimpora\*

Dimpora creates more sustainable, highly breathable and waterproof membranes. Based on polymers, the technology is PFC free and uses no Dimethylformamide (DMF) solvent. The company is further developing recyclable, bio-based and biodegradable membranes to close the loop for high performance gear.

## DW(O)R FINISH VS WATERPROOF MEMBRANE

What is the difference between a DW(O)R finish and a waterproof membrane?

Both technologies are used in increasing the protective properties of garments, mostly focusing on shielding from water but also from dirt and oil. The technologies can be combined for optimal performance.

<b>DW(O)R finish</b>	<ul style="list-style-type: none"><li>• The effective DW(O)R ingredient is applied via a liquid by running the fabric through and immersing all its surface in the active substances. The chemistry binds to the surface of the fibres. DW(O)R finishes make fabric water repellent, meaning that water landing on fabric will form drops that can be easily wiped off. However, longer contact with water or at a high pressure means the fabric will likely absorb the water and/or let it pass through.</li><li>• One can think of a DW(O)R finish as a form of protection, like sunscreen applied to human skin to protect it from the sun. The finish wears off over time through movement, dirt and water, and therefore needs to be reapplied from time to time to remain effective.</li></ul>
<b>Waterproof membrane</b>	<ul style="list-style-type: none"><li>• A certain polymer (often polyurethane) is formed into a laminating layer (membrane or foam) which is then applied on to the textiles using adhesives. It is very durable, but therefore also difficult to recycle.</li><li>• Membranes make fabrics waterproof, meaning that they are impervious to water even when pressure is applied.</li><li>• One can think of a membrane as the human skin, that protects us from filling up with water when swimming in the sea.</li></ul>

**FIGURE 8: OVERVIEW OF COATINGS VS. MEMBRANE**

Sources: Williams J. (2018), Loghin et al. (2018), Choudhry (2017)

# Disruptive Innovation - Chemistry

## Heavy metal free antimicrobial treatments

Creating antimicrobial finishes with the use of antimicrobial polymeric materials (e.g. chitosan) derived from bio-based sustainable sources (e.g. flax or wood, crab or shrimp shell waste from seafood industry).

### Nordshield\*

Nordshield creates antibacterial, antiviral, antimould and insect repellent finishes based on waste from the forestry industry. Nordshield forms a physical barrier on surfaces treated with their finish and therefore prevents microbial growth at the sources. The finish can be applied to cotton, viscose and blends.

## CHALLENGES OF SCALING DISRUPTIVE CHEMISTRY INNOVATIONS

As seen in the previous chapter, there are many more sustainable chemistry solutions available. Some of the reasons these have not yet been implemented in the supply chain relate to the following challenges.

### Performance

Finding innovations in chemistry with the same performance characteristics as traditional chemistry is challenging. If the performance of the more sustainable chemistry does not meet that of its traditional counterpart, it will in most cases not be adopted on a large scale. Some of the key performance characteristics challenging the fashion industry are listed below:

- **Colour fastness of natural dyes** - Performance of most natural dyes has often not met that of synthetic dyes. In addition, due to common impurities in natural dyes it has shown to be difficult to consistently reproduce a shade particularly across batches. As with synthetic dyes, natural dyes often need other chemicals to bond with the substrate and usually more dye is required to achieve the same depth of colour. As a result, 'natural' does not automatically equal better. Aside from challenges around colour fastness, natural dyes are generally available in fewer colours and shades than synthetic dyes.
- **Durability** - Some treatments meet performance requirements immediately after application but lose their effectiveness after wear and washing. Maintaining effectiveness after dry cleaning is especially challenging.
- **Durable Water and Oil Repellency** - DW(O)R is a key property for textile materials, especially for the outdoor industry. Historically, high performance has been achieved with the use of hazardous PFCs. The non-hazardous or bio-based solutions currently available have not shown to yet meet this performance across multiple testing criteria. Securing high oleophobicity scores has been particularly challenging.

\* Fashion for Good Alumni - Fashion for Good have supported over 135 innovators through our projects and programmes. They continue to be a part of our alumni network with Fashion for Good providing continued ongoing support

# Disruptive Innovation - Chemistry

## COLOUR FASTNESS

What is colour fastness?

Colour fastness is used as a key performance indicator to test the efficiency of dyes. It is defined as the ability of a dye to preserve the original colour throughout the manufacturing process and subsequent customer use.

The main forms of colour fastness include:

- **Washing fastness:** the extent to which dye comes off a fabric in contact with a water
- **Rubbing/crocking fastness:** the extent to which dye on a dry fabric rubs off on another dry fabric
- **Light fastness:** the extent to which the colour on the fabric fades when exposed to light
- **Perspiration fastness:** the extent to which the colour on the fabric fades when exposed to human perspiration

To rate the washing, rubbing/crocking, and perspiration fastness the Grey Scale for Colour and/or the Grey Scale for Staining, Rated from 1 (very poor) to 5 (excellent), are used. For light fastness, the Blue Wool Scale, rated from 1 (very poor) to 8 (excellent), is to be used<sup>17</sup>.

## Supply Chain

The supply chain for the chemical formulations currently available is well established and allows for large scale production, while the supply chain of more innovative formulations is less developed and does often not yet allow for large scale production. Therefore, although performance on a pilot scale has been proven, it can sometimes still be timely and challenging to scale these new technologies. This can cause difficulties when working with brands and manufacturers as they need large quantities (in the thousands of tonnes) for mass adoption. One potential solution to this is for innovators to collaborate with established chemical manufacturers or toll blenders with large production capacities and expertise in scaling.

## Externalities and Pricing

Given the low prices of most commodities used in this industry and the industry's focus on economics, many sustainable alternatives struggle to present attractive business cases due to their higher costs. Tighter regulation could enable the industry to take into account the significant environmental externalities of current production processes.

# Driving the Transition

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This document provides a snapshot in the processing innovation landscape, touching briefly on incremental solutions and diving into the disruptive technologies that exist in both chemistry and machinery.

It is evident that there are a number of solutions that have the potential to save significant amounts of water, energy and chemistry which results in a positive environmental impact as well as long term cost savings. It is an area that is constantly evolving and one in which it is clear that collaboration is key to success. Fashion for Good is pleased to be working together with our brand and manufacturing partners as well as our global network of innovators to accelerate the adoption of these technologies into the apparel and footwear supply chain.

If you would like to learn more about our current projects in this space please visit our website - [www.fashionforgood.com](http://www.fashionforgood.com)



# Appendix

Below an overview of commonly used processes in pre-treatment, dyeing, printing and finishing can be found.

## Pre-treatment

PRE-TREATMENT TYPE	DESCRIPTION	FUNCTION
<b>Sizing</b>	Applying size material (a gelatinous, film forming substance, in solution or dispersion form) on yarn.	To provide abrasion resistance during weaving.
<b>Singeing</b>	Burning projecting, loose and hairy fibre ends away with gas flames or a hot plate.	To get rid of small fibres. It makes the fabric smoother, aids in better application of dye and printing and improves rubbing and washing fastness.
<b>Desizing</b>	Removing of sizes and other substances applied as weaving aids. Uses enzymes, oxidising agents, other chemicals or hot washing, depending on the type of size.	To increase absorbency and reduce chemical consumption in subsequent processes. Usually only used for spun yarns.
<b>Scouring</b>	Removing of natural or foreign impurities, or processing aids (waxes, lubricants, marker dyes) applied during yarn and fabric production.	To increase absorbency and improve handle.
<b>Bleaching</b>	Removing of colour with a bleaching agent that destroys chromophores via oxidation or absorption.	To remove coloured impurities from the fibre and increase the whiteness of the fabric.
<b>Neutralisation</b>	Applying detergent, after any process that takes place in an alkaline medium to adjust the pH to neutral (i.e. after bleaching, mercerising and dyeing).	To halt the reaction at the desired stage of the process.
<b>Mercerising</b>	Treating cotton yarn or fabric, under tension, in a concentrated solution of caustic soda. Makes fibre cross section swollen and more rounded.	To make the yarn stronger, more lustrous, and capable of being dyed or printed to a much deeper shade for a given amount of dyestuff.
<b>Optical Brightening</b>	Treating of fibre with a chemical that can absorb UV radiation and re-emit the energy at the blue end of the visible spectrum, which makes it look brighter.	To make a fabric retain its whiteness.
<b>Heat Setting (incl. washing)</b>	Passing fabric through a heating zone for a time to make it dimensionally stable.	To stabilise the dimensions of synthetic fibres so they will not shrink or become distorted during wet processing or consumer use.
<b>Bio-polishing</b>	Hydrolysing fibre with enzymes making a small physical abrasion force sufficient to break and remove small fibres. Can also be classified as finishing.	To remove protruding fibres, slubs, hairiness, fluffs, pills; softens fabric, improves handle and smoothness.

Sources: *Textile learner Jan 2022, Textile Engineering an Introduction By Yasir Nawab, Clothing Technology, 6th edition, Hannelore Eberle, Europa Lehrmittel 2013*, Proprietary research with privileged access, contact Fashion for Good for more details if needed

FIGURE 9: OVERVIEW OF DIFFERENT PRE-TREATMENTS AND FUNCTIONALITIES

# Appendix

## Colouration

COLOURATION METHOD	DESCRIPTION
<p><b>Dyeing</b></p>	<p>Dyeing is the application of dyestuff on textile materials such as fibres, yarns and fabrics with the goal of achieving colour with desired colour fastness.</p> <p>The dyestuff used is either a dye or pigment. The key difference between these two is that dye chemically binds to the substrate while pigment does not. In Figure 11 below an overview of the most commonly used dye types can be found.</p> <p>The most used dyeing processes can be found below:</p> <ol style="list-style-type: none"> <li><b>1. Batch dyeing:</b> Batches of material are treated in large machine baths of various types, e.g. jet, jig, paddle, winch, pad-batch</li> <li><b>2. Continuous dyeing:</b> In continuous dyeing, textiles are continuously fed through a dyeing range. The process is done in stages: dye application, dye fixation, and washing</li> <li><b>3. Dope dyeing:</b> A relatively new technology (when compared to batch and continuous dyeing). Dope (also known as solution or spun) dyeing is done by adding dyes to the polymer during melt stage, or cellulose pulp. Fibre is spun or extruded already coloured</li> </ol>
<p><b>Printing</b></p>	<p>Textile printing is the controlled process of applying defined areas of colour onto fabric. While the main feature is pattern creation, it can also be applied for solid, all-over colours.</p> <p>The printing process usually includes:</p> <ol style="list-style-type: none"> <li>1. Dyestuff application to fabric surface, usually in the form of dye or pigment ink. Pigment inks are applicable to almost every fibre, while different dye inks are needed for different fibre types. See Figure 11 below for different dye types which can be made into an ink</li> <li>2. Pre-treatment and fixation of colourant</li> </ol> <p>The most widely used printing processes can be broadly divided into three categories:</p> <ol style="list-style-type: none"> <li><b>1. Screen Printing:</b> a print paste is passed onto a substrate through a mesh or screen which has some open and some blocked areas. The eventual design obtained on the substrate depends on the open areas of the screen</li> <li><b>2. Transfer Printing:</b> A design is first (digitally) printed onto a flexible non-textile substrate and later transferred by a separate process to a textile</li> <li><b>3. Digital Printing:</b> A relatively new technology (when compared to screen and transfer printing) which prints from a digital image directly to a substrate with speciality inks</li> </ol>

Sources: *Textile Engineering an Introduction* By Yasir Nawab, *Environmental aspects of textile dyeing, Clothing Technology, 6th edition, Hannelore Eberle, Europa Lehrmittel 2013*, Proprietary research with privileged access, contact Fashion for Good for more details if needed

**FIGURE 10: OVERVIEW OF COLOURATION PROCESSING**

# Appendix

## Colouration

DYE TYPE	DESCRIPTION
<b>Reactive</b>	Most common, ~35% of all dyes used. Dye unites with fibre through a coupling agent with heat. Excellent fastness to light and washing, brilliant shades. Requires soaping to remove unfixed dyes. Mostly used for dyeing cotton and linen and sometimes wool and silk.
<b>Dispersion</b>	Added to water with a surface active agent since they are insoluble. Heat is applied to allow the fibre to swell and dye to penetrate. Mostly used for dyeing polyester and sometimes viscose.
<b>Acid</b>	Usually applied under acidic conditions. Dissolve in water. Good light and heat fastness, poor washing fastness. Brilliant colours on silk and sometimes also used for dyeing viscose and polyester.
<b>Alkaline</b>	Basic in character, can neutralise acids. Used on cellulose with the help of a mordant. Poor light fastness, good pressing fastness. Mostly used with acrylics.
<b>Vat</b>	From old-fashioned indigo dyeing: insoluble compounds that cause accelerated degradation of cotton. Resistant to light, acids and bleaches. Mostly used for dyeing denim and sometimes also wool and silk.
<b>Direct</b>	Also called substantive colours. Applies through absorption rather than chemical reaction. Salt is added as an electrolyte. Poor fastness unless treated. Mostly used for cotton and linen and sometimes wool and silk.
<b>Sulfur</b>	Insoluble and must be used with the help of caustic soda and sodium sulphide. Done at high temperatures and large salt quantities. Only used for dyeing cotton and linen.

Sources: *Textile Engineering an Introduction* By Yasir Nawab, *Environmental aspects of textile dyeing*, Proprietary research with privileged access, contact Fashion for Good for more details if needed

**FIGURE 11: OVERVIEW OF COMMONLY USED TRADITIONAL DYES**

# Appendix

## Finishing

FINISHING TYPE	DESCRIPTION <sup>18</sup>
<b>Durable Water and Oil repellency DW(O)R</b>	<ul style="list-style-type: none"> <li>Applied to make the fabric water/oil-resistant</li> <li>Achieved by giving the fabric a hydrophobic/low surface energy finish</li> </ul>
<b>Flame retardancy</b>	<ul style="list-style-type: none"> <li>Applied to make the fabric non-flammable or difficult to ignite</li> <li>Achieved by suppressing the release of inflammable volatiles, so that instead of flaming, the materials will degrade and char</li> </ul>
<b>Stain resistance</b>	<ul style="list-style-type: none"> <li>Applied to make fabric resistant to stains</li> <li>Achieved by changing the surface energy of the fibre so as to discourage stain particles from clinging</li> <li>A degree of water and oil repellency is also important</li> </ul>
<b>Easy care</b>	<ul style="list-style-type: none"> <li>Applied to reduce wrinkling and shrinking when textiles are laundered</li> <li>Achieved by the application and fixation of chemicals which reduce the sensitivity of the fibre to moisture and to creasing</li> </ul>
<b>Softening</b>	<ul style="list-style-type: none"> <li>Applied to impart softness, smoothness and flexibility (for manufacturers as well as consumers)</li> <li>Achieved by applying softening agents, either as a temporary dressing or as a durable polymer finish</li> </ul>
<b>Antistatic</b>	<ul style="list-style-type: none"> <li>Applied to reduce or eliminate the buildup of static electricity</li> <li>Achieved by applying a hygroscopic chemical or by a treatment that renders the surface hydrophilic</li> </ul>
<b>Antimicrobial</b>	<ul style="list-style-type: none"> <li>Applied to inhibit the growth of bacteria, mould and fungi on fabrics. This keeps the fabrics hygienic and prevents odours</li> <li>Achieved by depositing biocides and/or solutions containing heavy metals on fabric</li> </ul>
<b>Biopolishing</b>	<ul style="list-style-type: none"> <li>Applied to enhance fabric quality by decreasing the pilling tendency and fuzziness of (cellulose) knitted fabric</li> <li>Achieved by applying enzymes to cellulose fabrics</li> </ul>
<b>Laser</b>	<ul style="list-style-type: none"> <li>Applied to create engravings, certain washes or worn-out looks</li> <li>Achieved by applying laser technology to fabrics</li> </ul>

Sources: *Textile Engineering an Introduction* By Yasir Nawab, Proprietary research with privileged access, contact Fashion for Good for more details if needed

**FIGURE 12: OVERVIEW OF COMMONLY USED TRADITIONAL FINISHES**

# Key Terms

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- **AATCC** - The American Association of Textile Chemists and Colorists develops the test methods the textile industry uses to ensure product quality.
- **AFIRM** - the Apparel and Footwear International RSL Management Group is a brand driven membership organisation of apparel and footwear companies collaborating to promote chemicals management in the global supply chain. AFIRM's focus is on the continuous advancement of chemicals management including phasing out or limiting restricted substances to established limits in apparel, footwear, and accessories.
- **Apparel Impact Institute** - (Aii) is a collaboration of brands, manufacturers and industry associations – including the Sustainable Apparel Coalition (SAC), the Sustainable Trade Initiative (IDH), Target, PVH Corp., Gap and HSBC Holdings plc. - that have come together to select, fund and scale high impact projects that dramatically and measurably improve the sustainability outcomes of the apparel and footwear industry.
- **Low pressure vs atmospheric plasma** - Cold plasma technologies can be divided into low pressure plasma and atmospheric plasma. The former happens in a vacuum chamber and therefore provides higher performance and reproducibility, while the latter is more compatible with the textile industry as it does not require a vacuum chamber and thus allows for continuous processing
- **Azo dyes** - a large class of synthetic dyes whose molecules contain two adjacent nitrogen atoms between carbon atoms. Studies have shown there are harmful effects of azo dyes on humans and aquatic life which has aroused calls for effluents containing azo dyes to be treated to eliminate them or convert them into useful and safe products.
- **Bio-based** - wholly or partly derived from materials of biological origin, excluding materials embedded in geological formations and/or fossilised.
- **Bioscouring** - application of living organisms and their components to remove natural and added impurities.
- **Binder** - add or stick to something any substance that causes the components of a mixture to hold together.
- **Bluesign** - Bluesign eliminates harmful substances at each step of the supply chain. It certifies that textile products are safe for the environment, workers, and customers. The Bluesign certification applies to chemicals, processes, materials, and products.
- **Capillary force** - Capillary force is the process of a liquid flowing in a narrow space without the assistance of, or even in opposition to, any external forces like gravity.
- **Chemical Manufacturer** - a workplace where chemicals are produced for use or distribution. A chemical manufacturer has a legal obligation to evaluate the hazards of chemicals that they produce or distribute.
- **Chitosan** - an environmentally friendly agent that is used to achieve the antimicrobial properties of textiles. Nowadays, the binding of chitosan to the textiles has been thoroughly researched due to the increasing demands on the stability of achieved properties during the textile care processes.
- **Chromophores** - the part of a molecule responsible for its colour.
- **Clean by Design Programme** - Clean by Design is a programme to use the buying power of multinational corporations as a lever to reduce the environmental impacts of their suppliers abroad. Clean by Design focuses on improving process efficiency to reduce waste and emissions and improve the environment.

# Key Terms

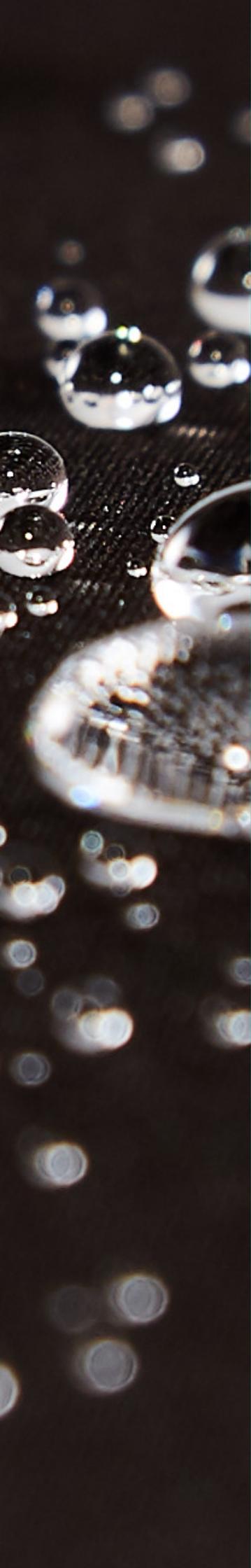
- **Colour Fastness** - The ability of a dye to preserve the original colour during industrial processing and subsequent customer use.
- **Curing** - the process by which resins or plastics are set in or on textile materials, usually by heating.
- **Dimethylformamide (DMF) solvent** - a colourless, water soluble liquid with a faint ammonia like odour that is readily absorbed through the skin, inhaled, or ingested; a potent liver toxin.
- **Drop-in solution** - solution that is easily integratable or requiring only insertion to be ready for use.
- **Drying** - liquid is vaporised from a product by the application of heat. Heat may be supplied by convection (direct dryers), by conduction (contact or indirect dryers), radiation or by placing the wet material in a microwave or radio frequency electromagnetic field.
- **Dry softening** - softening process that does not require water or produce waste.
- **Durability** - How long and in what conditions a treatment stays effective on the garment.
- **Effluent** - liquid waste or sewage discharged into a river or the sea.
- **Energy Milieu** - In the context of MLSE®, Energy Milieu refers to the highly reactive molecular soup created by quantum mechanical forces acting within specific reaction zones, where fabric gets treated. This milieu consists of photons (a particle representing a quantum of light), bosons (a subatomic particle), gluons (a hypothetical massless subatomic particle) and quarks (any of a number of subatomic particles carrying a fractional electric charge) mixed with nano sized constituent particles, virtually instantaneously, ablated from the fabric substrate itself and reconstituted within the fabric.
- **Enzymes** - An enzyme is a substance produced by a living organism which acts as a catalyst to bring about a specific biochemical reaction.
- **Eutrophication** - Eutrophication is when there are too many nutrients in a body of water which can then disrupt the ecosystem.
- **Fermentation** - The chemical breakdown of a substance by bacteria, yeasts, or other microorganisms, typically involving effervescence and the giving off of heat.
- **Fixation (dye)** -crosslinking between fabric and dye molecules. Fixer is used on the textile to hold the unfixed dye molecules on fabric through polymerisation between fabric and dyes.
- **Forest Stewardship Council (FSC)** - FSC is a non-profit organisation that promotes responsible management of the world's forests. FSC certifies forests all over the world to ensure they meet the highest environmental and social standards. Products made with wood and paper from FSC forests are marked with their 'tick tree' logo.
- **Full Curing** - a process during which a chemical reaction (such as polymerisation) or physical action (such as evaporation) takes place, resulting in a harder, tougher or more stable linkage (such as an adhesive bond) or substance.
- **High Frequency Electric Discharge** - electrical conduction through a gas in an applied electric field.
- **Hydrolysing** - break down (a compound) by chemical reaction with water.
- **Ionised** - converted (an atom, molecule, or substance) into an ion or ions, typically by removing one or more electrons.
- **ISO** - International Organization for Standardization is an independent, non governmental international organisation with a membership of 165 national standards bodies.
- **Joint Venture** - a business arrangement in which two or more parties agree to pool their resources for the purpose of accomplishing a specific task.
- **Metering** - Accurate measurement of on-site energy and water use, which is critical in accounting for current costs and recognising the benefits of efficiency measures.
- **Microbe** - A microorganism or microbe is a microscopic organism, which may be single-celled or multicellular. The microbes most commonly associated with the production of materials for consumer textiles include yeast, bacteria, fungi and algae.

# Key Terms

- **Microporous** - characterised by very small pores or channels with diameters in the micron or nanometre range.
- **Mordant** - a chemical that fixes a dye in or on a substance by combining with the dye to form an insoluble compound.
- **Neutralisation** - the act of making a substance neutral.
- **Nozzle** - an attachment to the end of a spray rod or hose that causes the liquid to be delivered finely and evenly as a spray.
- **OEKO-TEX** - International Association for Research and Testing in the Field of Textile and Leather Ecology consists of 17 independent research and test institutes in Europe and Japan. They are responsible for the joint development of test methods and limit values which form the basis for our standards.
- **Oleophobicity** - refers to the physical property possessed by a material that is characterised by a lack of affinity to oils.
- **PFAS** - Per- and polyfluoroalkyl substances are a diverse group of human-made chemicals used in a wide range of consumer and industrial products. Many PFAS are resistant to grease, oil, water, and heat.
- **PFC** - Perfluorochemicals (PFCs) are a group of chemicals used to make fluoropolymer coatings and products that resist heat, oil, stains, grease, and water
- **Quantum Mechanical Energy** - quantum mechanics, science dealing with the behaviour of matter and light on the atomic and subatomic scale. It attempts to describe and account for the properties of molecules and atoms and their constituents—electrons, protons, neutrons, and other more esoteric particles such as quarks and gluons. These properties include the interactions of the particles with one another and with electromagnetic radiation(i.e., laser light, X-rays, and gamma rays).
- **Polymeric material/polymer** - materials made of long, repeating chains of molecules. The materials have unique properties, depending on the type of molecules being bonded and how they are bonded.
- **REACH** - Registration, Evaluation, Authorisation and Restriction of Chemicals is a European Union regulation which addresses the production and use of chemical substances, and their potential impacts on both human health and the environment.
- **Reactive** - capacity of an atom or molecule to undergo a chemical reaction with another atom, molecule, or compound.
- **Substrate** - the surface or material
- **Supercritical/pressurised gas** - A supercritical fluid is a highly compressed fluid that combines the properties of gases and liquids.
- **Surface Activation** - alter the chemistry of surface introducing chemical groups or charges on the surface.
- **Toll Blender** - a service whereby the production of (complex) chemical products is outsourced to a third party company (blender).
- **Wash off** - With traditional wet processing, regardless of the dye type chosen, all dyeing ends with washing baths to remove excess dyes not fixed to the fibre.
- **ZDHC** - Zero Discharge of Hazardous Chemicals Foundation oversees implementation of the Roadmap to Zero Programme and is a global multi-stakeholder initiative of more than 160 contributors within the fashion and footwear industry.

# Notes & References

- 1 Note, it is not possible to dive into all technologies in great detail and Fashion for Good acknowledges that this is a complex space
- 2 WRI and Aii (2021). Roadmap to Net Zero: Delivering Science-Based Targets in the Apparel Sector. Available at: [https://apparelimpact.org/wp-content/uploads/2021/11/21\\_WorkingPaper\\_RoadmapNetZero\\_.pdf](https://apparelimpact.org/wp-content/uploads/2021/11/21_WorkingPaper_RoadmapNetZero_.pdf)
- 3 WRI and Aii (2021). Roadmap to Net Zero: Delivering Science-Based Targets in the Apparel Sector. Available at: [https://apparelimpact.org/wp-content/uploads/2021/11/21\\_WorkingPaper\\_RoadmapNetZero\\_.pdf](https://apparelimpact.org/wp-content/uploads/2021/11/21_WorkingPaper_RoadmapNetZero_.pdf)
- 4 Except for printing
- 5 [IntechOpen Textile Dyes: Dyeing Process and Environmental Impact](#)
- 6 [ZDHC Impact Report](#)
- 7 [ZDHC Roadmap to Zero, Jan 2022](#)
- 8 [ZDHC Roadmap to Zero, Jan 2022](#)
- 9 [ZDHC Impact Report](#)
- 10 [‘What Brands Need to Know About Antimicrobial Fabrics and Textiles’, ‘Disinfecting for Covid-19: The role of the US EPA’, ‘Hand Sanitisers and face masks’](#)
- 11 [‘What Brands Need to Know About Antimicrobial Fabrics and Textiles’, ‘Disinfecting for Covid-19: The role of the US EPA’, ‘Hand Sanitisers and face masks’](#)
- 12 [Antimicrobial Textiles from Natural Resources: Common and nano-antimicrobial textile finishes](#)
- 13 [NanoImpact: In vitro skin toxicity of CuO and ZnO nanoparticles: Application in the safety assessment of antimicrobial coated textiles](#)
- 14 Fashion for Good and Apparel Impact Institute [‘UNLOCKING THE TRILLION-DOLLAR FASHION DECARBONISATION OPPORTUNITY: Existing and innovative solutions’](#)
- 15 Innovator Reported
- 16 [Enzymes for biopreparation, Nozoymes](#)
- 17 [Chapter 31 ‘The Care of Apparel Products’, Rin Textile Fashion; Materials, Design and Technology. .K.NayakR.Padhye, 2015, Pages 799-822](#)
- 18 Proprietary research with privileged access, contact Fashion for Good for more details if needed



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