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# Innovations in Textile and Apparel Dyeing

Technology and Colour

# Foreword

I am delighted to present the 'Innovations in Textile and Apparel Dyeing' report, which highlights the latest global innovations in dyeing within the textile and apparel supply chain. The aim of this report is to encourage innovators, brands, retailers and manufacturers to work together so that the industry can collectively achieve our environmental impact reduction goals.

The global landscape of textile and apparel dyeing presents significant opportunities for addressing the environmental impact of the sector with its focus on decarbonisation and circularity. Innovation in textile dyeing technology is advancing rapidly with new methods such as water-free dyeing, the use of supercritical carbon dioxide, plasma technology and nanotechnology. There have also been innovations in synthetic biology, sustainable chemistry and other fields that are revolutionising colour production.

Another significant development highlighted in the report is the recycling of dyes at the end of product's life cycle which could help the transition towards fibre-to-fibre recycling. While many of these innovations are still in the early stages of development, they hold great potential to positively reshape the industry.

For a sustainable future in textile dyeing, it is essential that manufacturers, brands and innovators collaborate to capitalise on the benefits of these innovations. However, it is equally important to address fundamental challenges, such as improving industrial efficiency and promoting cleaner production methods.

This report has been produced through the Circular Fashion Innovation Network. CFIN is an industry-led programme led by the UK Fashion and Textile Association and the British Fashion Council in partnership with UK Research and Innovation to help the UK accelerate towards a circular fashion and textile ecosystem.

**Adam Mansell, CEO UKFT**

# Acknowledgements


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UK Research & Innovation (UKRI) as part of the Circular Fashion Innovation Network (CFIN) to accelerate the UK towards a Circular Fashion Ecosystem.

## SUPPORT

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# Introduction & background

## INTRODUCTION

The climate crisis is reshaping the fashion and textile industry. There is an urgent challenge to reduce its environmental impact and align with global sustainability goals, such such as the Sustainable Development Goals (SDGs), decarbonisation targets for 2030 and net-zero ambitions for 2050.

This pivotal moment offers the UK fashion and textile industry a chance to lead the way in innovative, responsible and forward-thinking practices. With its significant global socio-economic impact, it is in a unique position to meet climate targets, focusing on decarbonisation and circularity (1).

Manufacturing accounts for about 71% of the supply chain's Greenhouse Gas (GHG) emissions, making it evident that impactful strategies begin at the pre-consumer level (2,3). There is therefore an opportunity for the manufacturing sector to transition towards greener capacity, with the ability to operate in an environmentally sustainable manner. This involves implementing processes, technologies, and practices that reduce environmental impact, conserve natural resources, and minimise waste and emissions.

The UK's pre-consumer footprint, particularly, extends beyond domestic borders, influencing both local and international regions.

Domestically, UK textile and apparel manufacturing is historically significant and vital for local economies. However, the sector faces competition from low-cost global producers and post-Brexit socio-economic challenges. There is an opportunity to modernise and innovate in order to lead the sustainable transformation and remain competitive (4,5).

On an international scale, the UK's retail sector reliance on global supply chains, with countries like China, India and Bangladesh, which underscores the need for a global sustainability perspective (6). Offshoring has led to complex supply chains, dominated by fast-fashion retailers, which has contributed to significant environmental impacts and social responsibility issues. By addressing these challenges, the UK can influence global practices and champion sustainability.

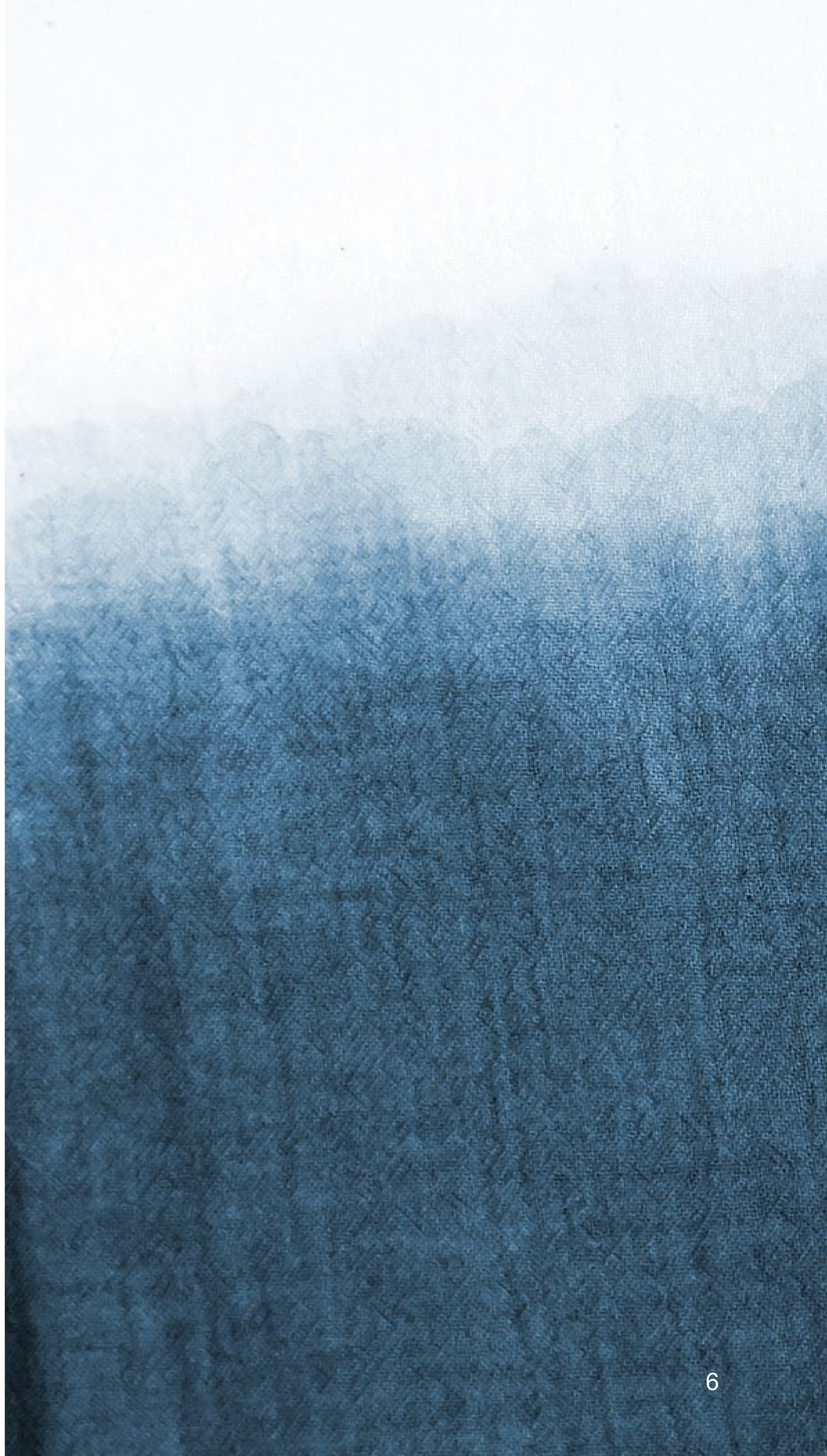
Therefore, cleaner production methods, decarbonisation, and circularity are not just essential for meeting the UK's sustainability agenda but also for supporting global climate ambitions and and SDGs (7,8,9).

The Circular Fashion Innovation Network (CFIN) is at the forefront of this ambition, committed to promoting innovative sustainable practices. This report showcases the latest sustainable innovations in apparel and textile manufacturing, with a focus on the dyeing stage, as part of CFIN's Sustainable Manufacturing pillar.

***Refer to all references on page 57**

*The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. At its heart are the 17 Sustainable Development Goals (SDGs), which are an urgent call for action by all countries - developed and developing - in a global partnership.

*Currently, the Earth is already about 1.1°C warmer than it was in the late 1800s, and emissions continue to rise. To keep global warming to no more than 1.5°C – as called for in the Paris Agreement – emissions need to be reduced by 45% by 2030 and reach net zero by 2050.



## BACKGROUND & CONTEXT

The projected increase in the production and consumption of textiles and apparel means that the quantum of textiles to be processed are only expected to grow (10).

Within textile and apparel manufacturing, the wet processing stage is recognised as one of the most polluting (11). It contributes to 15% of the GHG emissions of textile and apparel supply chains (Figure 1). Plus, the process requires huge amounts of water and energy, leading to resource consumption and waste production at each step. Additionally, it involves the use of numerous dyes, chemicals and auxiliary substances. Thus, wet textile processing yields various waste streams that include liquid, gaseous and solid byproducts that are potentially hazardous for both the environment and humans (12).

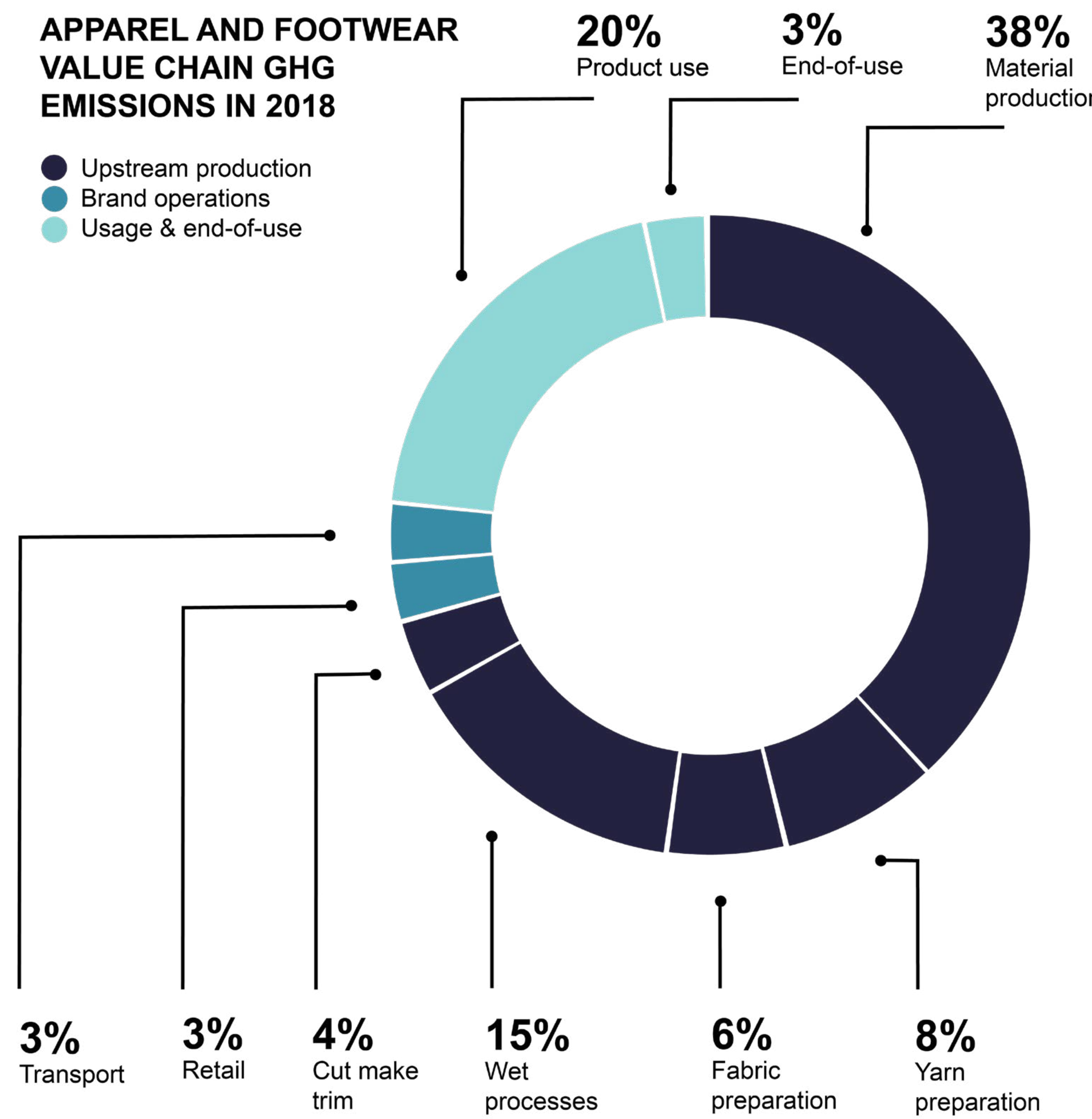



*Figure 1: Adapted from source 1, p. 5*

The wet processing stage generally involves pre-treatment, dyeing, printing and finishing (11).

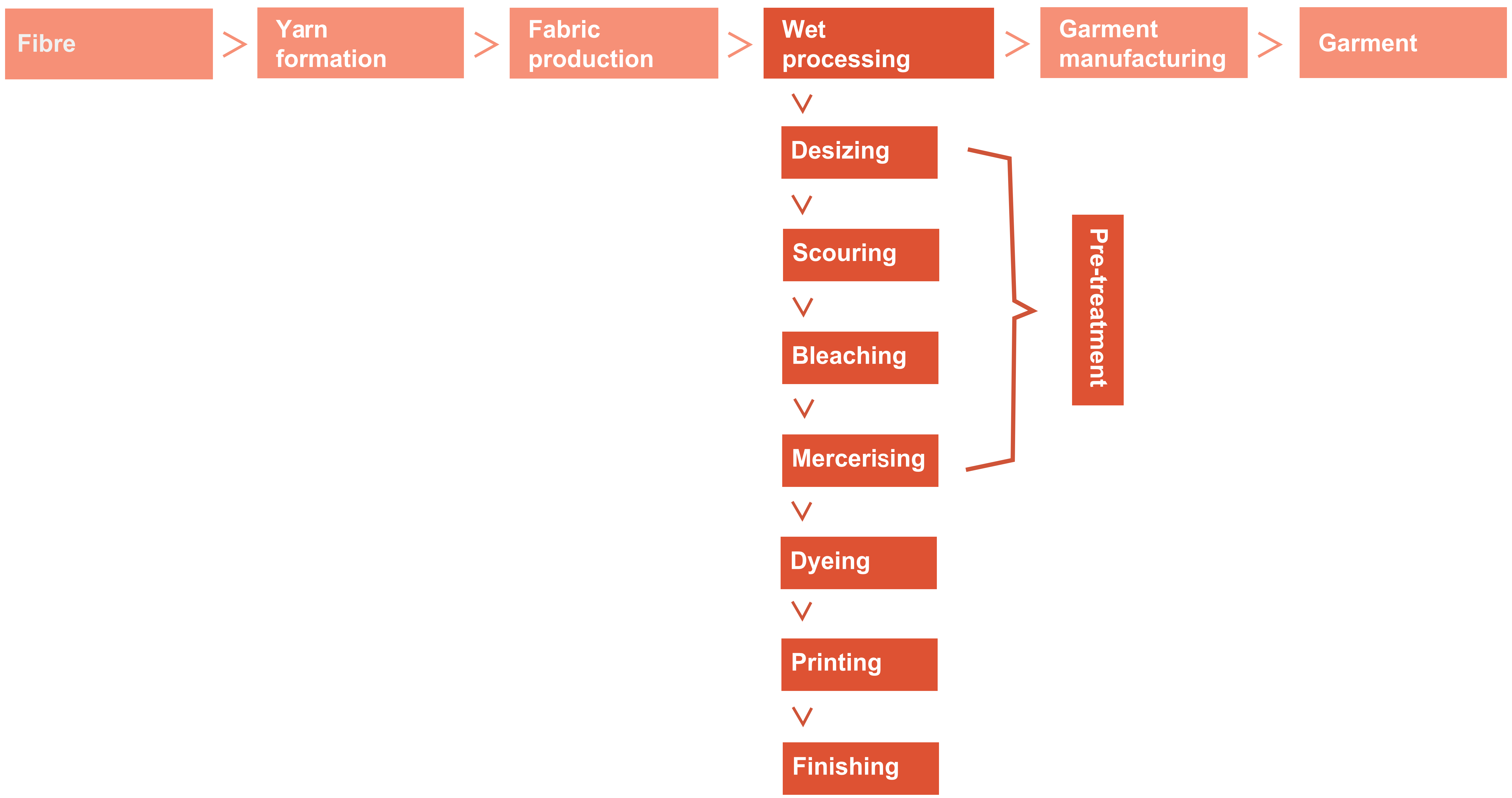



*Figure 2: Adapted from source 11, p. 32*

Within the wet processing stage, there is a need to steer the attention towards textile and apparel dyeing. The actual dyeing can happen at multiple stages of the supply-chain, from dyeing fibres, yarns, fabrics or garments. Plus, there exist multiple dyeing types and techniques that will vary depending upon the type of dye and its chemical structure (i.e. natural, synthetic), and the method of industrial application (i.e. disperse dyes, direct dyes, reactive dyes, acid dyes, vat dyes, basic dyes) (13, 14, 15).

> **The textile and apparel dyeing industry has a history of over 4000 years, with natural dyes being used for most of that time (16). This changed in 1856 when William Henry Perkin discovered Mauveine, the first synthetic dye. This revolutionised colour use, and today, synthetic dyes dominate the textile and apparel sector (13,14)**

**The most commonly used textile and apparel dyeing processes are batch, continuous and semi-continuous dyeing (17).** These processes usually require the dye to reach good product characteristics such as good fixation with respect to light, perspiration and washing, both initially and after prolonged use. Usually, the traditional textile and apparel dyeing process involves these three steps (17, 18):

### Preparation

The step in which unwanted impurities are removed from the fabrics before dyeing.

### Dyeing

The aqueous application of colour to the textile substrates, mainly using synthetic organic dyes and frequently at elevated temperatures and pressures in some of the steps.

### Finishing

This involves treatments with chemical compounds aimed at improving the quality of the fabric.

Traditional dyeing colouration methods and processes present significant opportunities for improvement in environmental impact areas (19):

| | |
|---|---|
| **Energy** | The actual textile and apparel dyeing stage requires high amounts of energy and high temperatures. Energy is used to heat the water and in the dyeing and drying process. |
| **Water** | The dyeing stage of wet processing consumes significant quantities of water, which serves multiple roles: as a medium, a washing-off agent, a solvent for dissolving chemicals, and in the production of vapour for heating process baths.<br><br>The large volumes of water used result in a large amount of wastewater. |
| **Chemicals** | Organic and inorganic chemical pigments and auxiliaries are traditionally used in the textile and apparel dyeing stage. |

## INNOVATION

Sustainable innovations offer a promising avenue for transforming the impact of textile and apparel dyeing. Exploring new technologies, colours and techniques can lead to more eco-friendly and efficient dyeing processes. By adopting these innovations, the textile and apparel industry can significantly reduce its environmental footprint while improving resource efficiency and production quality. In fact, the innovation landscape of textile and apparel dyeing is incubating globally.

We asked Amy Tsang, Head of Europe at The Mills Fabrica: **why is innovation needed in the textile and apparel dyeing landscape?**

“Textile dyeing and finishing accounts for 20% of global clean water pollution, and wet processes account for 15% of the fashion industry’s overall GHG emissions. These are staggering figures which highlight the detrimental effect that this part of the fashion production process has on the planet. Innovations in dyeing technologies and colouration have the potential to not only keep our waters cleaner, but also reduce the amount of water and energy consumed compared with the industry’s current and historic methods of dyeing. There are some ground-breaking solutions that exist today that can be easily implemented in the manufacturing process, resulting in a more sustainable industry when applied at scale. Over the past seven years, The Mills Fabrica has discovered innovations that are paving the way in the dyeing space such as Colorifix, which through its biological process, can successfully dye textiles that generate zero toxics.”

**The Mills Fabrica** is a go-to solutions platform accelerating techstyle and agrifood techinnovations for sustainability and social impact. The mission of their incubation programme is to accelerate sustainable innovation in Hong Kong and UK’s start-up ecosystem through supporting techstyle (textile & apparel) and agrifood technology startups in their scale-up process.

## OBJECTIVE

This report focuses on the crucial sub-sector of textile and apparel dyeing, which is essential for decarbonisation and resource circularity in the textile and apparel industry. While recognising the importance of cleaner production and circular practices in reducing environmental impact during yarn, textile and garment manufacturing (3), the report provides a global overview of innovations in textile and apparel dyeing.

The report is intended as a point of reference for the textile and apparel industry, with the end goal of encouraging greener dyeing capacity in domestic and international textile and apparel manufacturing facilities. It is aimed at:

- **Textile and apparel manufacturers** looking to stay ahead in terms of innovation and raise competitiveness and productivity through sustainability integration in their supply chains.
- **Textile and apparel retailers** looking to understand the innovation landscape in textile and apparel dyeing and its applications, and encourage greener dyeing capacity among their domestic and international suppliers.
- **Innovators** to get an overview of the current innovation landscape and identify Research and Development (R&D) gaps and opportunities for further innovation in the space.
- **Legislators** to get up-to-date knowledge on the current textile and apparel dyeing innovation space, identify funding opportunities and target a sub-sector of strategic importance in terms of environmental impact reduction in the industry.

Overall, the report aims to motivate global collaboration networks between innovators, brands/retailers, and textile and apparel supply chains to meet climate targets. It encourages the industry to imagine a shift in traditional methods and foster innovation.

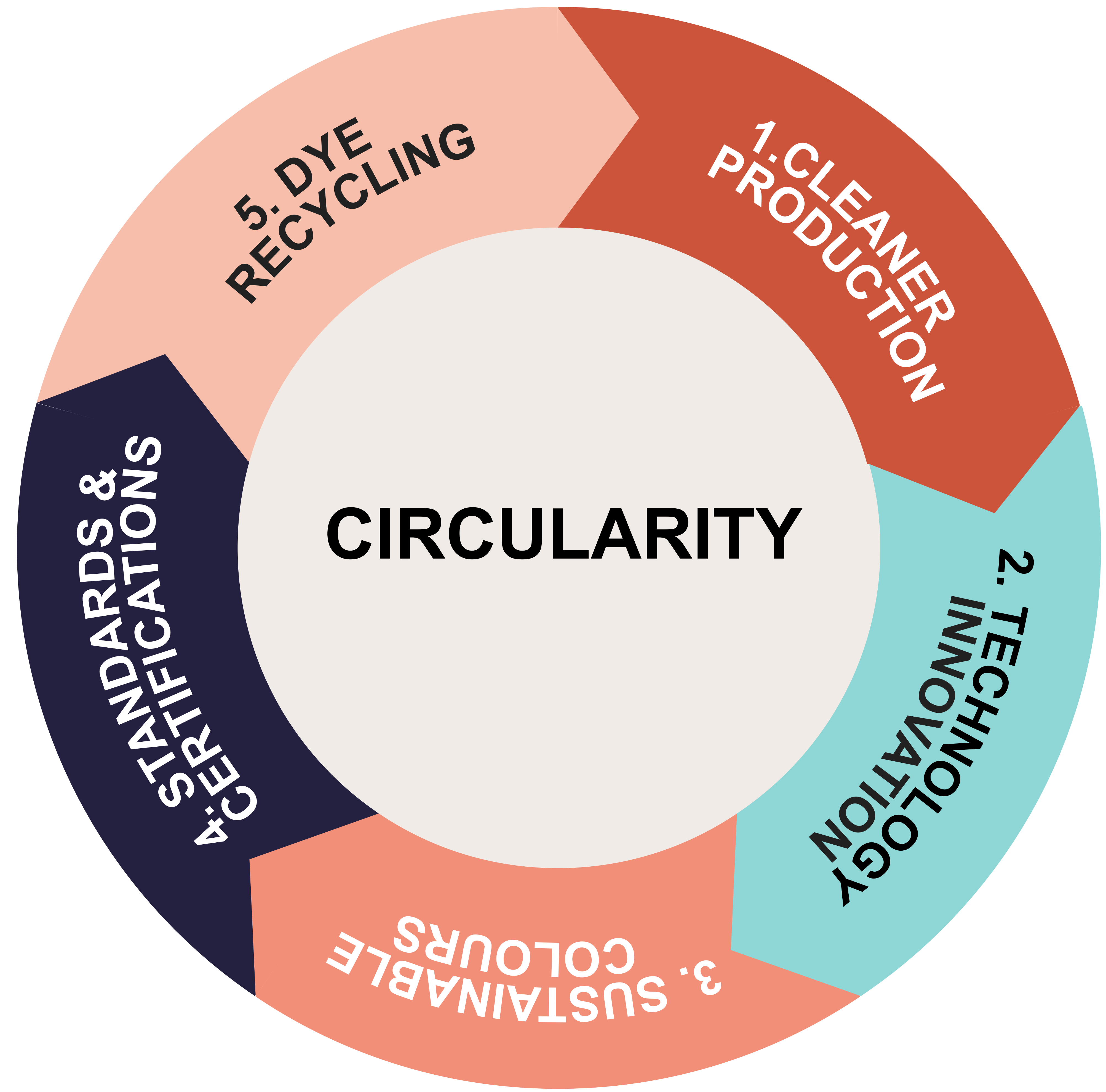
> **Brands and retailers must take responsibility for their manufacturing practices, irrespective of geographical locations. Acknowledging the hidden consequences of globalisation, we must ensure that offshore production does not translate to offshore pollution. It’s crucial for brands to prioritise responsible manufacturing, emphasising environmental concerns and recognising the impact of their operations on a global scale**
>
> - Jason Hallett, Professor of Sustainable Chemical Technology within the Department of Chemical Engineering at Imperial College London

## ENVIRONMENTAL IMPACT REDUCTION IN TEXTILE AND APPAREL DYEING

The journey towards environmental impact reduction requires significant advancements in domestic and global supply chains. This report provides a 'journey' towards environmental impact reduction in textile and apparel dyeing. Firstly, it acknowledges the need to achieve a cleaner production outlook and efficiency in industrial facilities, recognised as a key step for environmental impact reduction prior to implementing innovation.

Secondly, the report presents key innovations in both technological processes and colouration methods. Standards and certifications related to environmental management and chemical management are also presented to guide the industry. Finally, the report dives into the concept of dye recycling. Circularity is emphasised as crucial for reducing environmental impact in textile and apparel dyeing, spanning from dye production through manufacturing, use and disposal phases.

The report uncovers some of the latest expertise, innovations and best practices to promote cleaner production and green growth in textile and apparel manufacturing supply chains. The research methodology followed can be found in **Appendix 1**.



# Cleaner production

## INTRODUCTION

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**There is still far too much attention paid to the types of materials that are manufactured rather than the methods employed in their manufacture**

- Phil Patterson, Managing Director of Colour Connections Textile Consultancy

Adopting cleaner production practices consists of taking actions that can minimise the risk towards humans and the environment across supply chains (20). Cleaner production practices include: reducing GHG emissions, using water and energy more efficiently (i.e. reduction in water and electric power consumption) and reducing and reusing waste (i.e. minimising wastewater) (20, 21). In a textile and apparel manufacturing context, this could mean: energy efficiency, the reduction in carbon intensity of energy supplies, switching from non-renewable to renewable resources, increasing the efficiency of existing technologies, substituting existing machinery to one that is more efficient or optimising/replacing chemicals, among others (20, 22, 3, 23). Overall, fashion-industrial efficiency is one of the biggest areas of intervention to reduce supply chain GHG emissions (3) and can help achieve sustainable development goals (21).

Cleaner production in the dyeing stage is of particular importance to reduce environmental impact (22). Overall, implementing Integrated Pollution Prevention and Control (IPPC) principles in management, machinery modification and chemical optimisations/replacements and improving wastewater recovery and reuse, help achieve environmental impact reduction at this stage (22).

## INTERVIEW WITH PHIL PATTERSON

We interviewed Phil Patterson, Managing Director at **Colour Connections Textile Consultancy**, to understand the importance of cleaner production, with a focus on industrial efficiency and chemical management at the dyeing stage.

Refer to the bio in **Appendix 2.**

**Q. Considering the current negative environmental and social impact of the textile and apparel dyeing stage, which of the existing issues do you think the textile and apparel industry should prioritise and target in the next 5 to 10 years?**

A. There are many potentially harmful impacts, such as consumer safety, the overuse of water in areas where it's scarce, the pollution linked to effluent discharge, and GHG related to energy use. The priorities are somewhat driven by legislation and the particular focus of multi-brand industry initiatives. Over the years, textiles that are placed on the market have undergone significant improvements in terms of chemical safety, driven by groups such as Apparel and Footwear International RSL Management (AFIRM) and legislation - but **scrutiny has never been higher**.

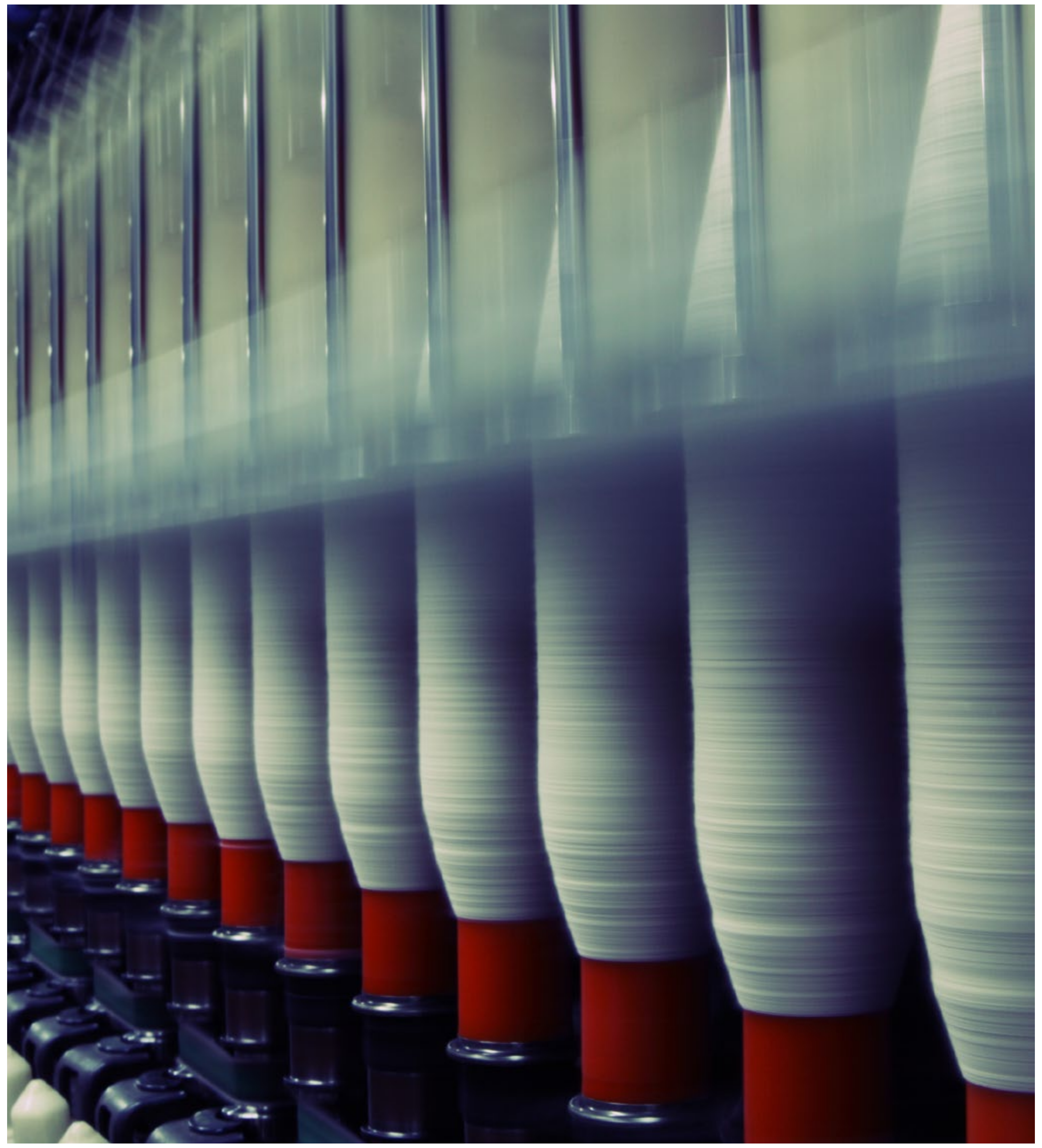
More recently, there has been far more focus on environmental impacts, with increased attention being paid to water pollution and scarcity, and energy management.

Water and energy resource use, to some extent, have been managed well in developed regions, mainly for economic reasons but there is still a massive need for improvement.

Despite the existence of published standards, pollution remains a serious global issue because of inadequate policing of those standards in many parts of the world.

In many respects, **we're still focused on avoiding the worst rather than promoting best practices**. 'Green' innovation is happening in the fashion industry, some of it in textile dyeing, but sometimes this actually diverts attention from unresolved fundamental issues like inefficient use of resources, pollution and unsafe working conditions in current factories in manufacturing countries.

If I had to pick one longer term priority for greater attention, it would be a reduction in greenhouse gases from energy use in wet processing, but immediate problems like pollution and worker safety cannot be pushed aside.





*The views, thoughts, and opinions expressed in this interview belong solely to the individual being interviewed and do not necessarily reflect the official policy or position of UK Fashion & Textile Association. The content provided is for informational purposes only and is not intended to provide specific advice or recommendations for any individual or entity.*

**Q. How do you envision the transition to more sustainable practices in textile and apparel dyeing processes, particularly in terms of water, energy use, carbon footprint, wastewater and chemical pollution?**

A. To answer this, it is helpful to look at the past and consider what 'more sustainable' practices look like. **There are some unsubstantiated blanket criticisms of synthetic dyes and growing calls to revert to natural colourants but this, as a potential solution, is both flawed and too narrow in its outlook.** I recommend a biography, Mauve, by Simon Garfield on William Perkin, who invented synthetic dyes. It provides insights into the significant technical limitations of natural dyes, the horrendous negative health effects of some inorganic pigments and the flagrant disregard for worker safety and environmental stewardship after the boom in the synthetic dye and dyeing industry. **Over the past few decades, we've made significant progress with restrictions on harmful dyes and chemicals, and, although there is always room for improvement, these are reasonably well managed by brands and responsible legislators.** My personal view is that the dyeing industry will continue to be driven by synthetic dyes and chemicals, but these may well be augmented by some dyes and chemicals that are of natural origin, bio-based or natural-synthetic hybrids of some sort. However, the meaningful transitions will be in terms of pollution control and water and energy use.

Pollution should be legally controlled. In terms of water and energy efficiency, it has been treated as 'nice-to-have' and is only managed in any meaningful way by a tiny handful of brands. **Lack of supplier transparency is one problem and I have been pushing for this in the industry for the past couple of decades.**

As a retailer or brand, if you are genuinely committed to transparency, you can easily establish a preferred supplier list and assess those suppliers that you are looking to use, through established environmental assessment procedures.

> “
> **Looking at achieving excellent absolute eco-efficiency figures rather than just aiming for percentage reductions from unknown starting positions**

**There is still far too much attention paid to the types of materials that are manufactured rather than the methods employed in their manufacture.** Instead, we need to promote best practices that prioritise efficiency and also emphasise the importance of understanding both what is made and how it's made. Brands are starting to recognise this distinction, **making projects like CFIN essential in highlighting why the manufacturing process matters.**

There is a welcomed increase in research and development in lower impact dyeing methods, but it is necessary to look at the overall picture in a factory rather than individual processes if we are to make a significant reduction in the impacts of wet processing.

**A new individual machine or process may be fantastic - but it is often just a single machine in a big factory.** From a textile product sales and marketing perspective it may be attractive to a brand but, from an environmental impact perspective, it makes far more sense to **optimise the efficiency of boilers and generators that affect every single machine and process in the factory. Bizarrely, getting the basics right and achieving world class eco-efficiency in large-scale facilities is seemingly not held in the same high regard as spray dyeing 10 t-shirts using crushed petals!**

**Many brands tend to prioritise eco-labelling over improving how non-eco-labelled products are manufactured, leading to token gestures rather than system change.**

Another interesting aspect is the focus on percentage savings. Simple, common-sense initiatives could probably halve water and energy use in textile dyeing and printing, but we often overlook where we started. We need to start from the bottom up, **looking to achieve excellent absolute eco-efficiency figures rather than just aiming for percentage reductions from unknown and probably terrible - starting positions.**

A step-by-step approach is required, focusing initially on avoiding the worst scenarios, like fixing leaks and recycling cooling water. As mentioned previously, the efficiency of boilers and generators are critically important, and this should be optimised as a priority, if need be, by investing in new kit. **Dyers should mothball any old, horrendously inefficient, equipment and then review all processes in existing equipment to ensure they minimise water, energy and chemical use – but also consider investing in latest generation production equipment where possible.** Going from good to world class eco-efficiency generally requires investment in additional items such as **heat recovery, water recycling and renewable energy.**

> “
> **Many brands tend to prioritise eco-labelling over improving how non-eco-labelled products are manufactured, leading to token gestures rather than system change**

**Q. You mentioned brands coming together to create the AFIRM Restricted Substances List (RSL). How do you envision collaboration in the textile and fashion industry especially in the UK market, to foster cleaner production, such as reducing wastewater, water usage, enhancing energy efficiency, and minimising carbon footprint? Do you believe the industry should prioritise collaborative efforts?**

A. As a brand, there is a considerable influence you have on defining the terms in supply chains and manufacturing. **What's needed is CEOs, not just sustainability teams, to demand full transparency from supply chains, down to wet processes and beyond. Chief Executive Officer (CEO)s should refuse to engage with any supply chain lacking transparency or wet processing facilities failing to meet effluent discharge requirements and other basic standards.**

We also need strict criteria for energy and water usage and, if **brands could agree to enforce compliance with agreed eco-efficiency standards in the same way that they enforce restricted substances standards, the industry would have to improve.**

My personal view is that brands have to collaborate to drive the dyeing industry to improve – **agreeing and enforcing tough standards will be far better for the planet than endorsing specific technologies.**

**Q. What legislative initiatives have impacted cleaner production in textile and fashion supply-chains positively, especially regarding chemical use?**

A. The first RSL was created by M&S in 1998. At that time, very few brands were urging their suppliers to prioritise chemical safety, as there was minimal chemical legislation in place. Then in 2004, M&S, Nike, Adidas and Levi's collaborated after recognising the challenge in getting suppliers to take chemical safety seriously. **They decided to unite their efforts instead of individually pushing suppliers, understanding the limitations of their influence as single brands and this led to the formation of the highly respected AFIRM Group.**

**Subsequently, legislation has begun to catch up, with initiatives such as the EU REACH regulations emerging to address chemical concerns**. However, there remains an ongoing effort to introduce more comprehensive chemical legislation in many jurisdictions.

**The EU REACH regulation (Registration, Evaluation, Authorisation, and Restriction of Chemicals)** is a legislative framework aimed at ensuring the safe use of chemicals within the European Union. The regulation entered into force on 1 June 2007 and applies to all chemical substances, including those in everyday products like clothes, furniture, etc.

Under REACH, companies must identify and manage risks associated with the substances they manufacture and market in the EU. They must demonstrate to European Chemicals Agency (ECHA) how these substances can be safely used and communicate risk management measures to users. If you manufacture chemicals for use or supply, even for export, you have significant responsibilities under REACH. Companies outside the EU are not directly bound by REACH, but importers or an appointed representative in the EU must fulfil the regulation's requirements.

Under the European Union Withdrawal Act (2018), REACH and related legislation were replicated in the UK with the changes needed to make it operable in a domestic context. While the general principles of REACH remain the same between the two regulations, companies that manufacture or use chemicals in both the UK and EU will need to comply with two different sets of regulations that overlap in many areas but diverge in some critical areas.

**Furthermore, because ultra-detailed toxicological assessments are required, the process of introducing new chemicals to the market has become increasingly burdensome, discouraging innovation.** This is particularly evident in the stagnation of initiatives like green chemistry over the past two decades. **The high costs associated with bringing novel products to market have acted as a barrier, incentivising businesses to stick with existing solutions rather than pursuing more sustainable alternatives.**

I believe while legislation has undoubtedly played a crucial role, there is room for improvement.

Legislation is quite fragmented. While EU laws are generally robust and largely unified across the region with few country-specific variations, global legislation varies widely. For instance, whilst Chinese laws are unified, American laws are developed within federal, state, and even county variations making it a difficult market to navigate.

For any chemical, there may be legislation covering the chemicals themselves, how they are handled in a factory, workplace exposure limits, effluent discharge limits and maximum allowable limits on products at point of sale. There may even be different laws for different product types, such as clothing, shoes, sportswear or baby care items.

It's almost impossible to comprehend all the complexity and this is where industry-wide schemes come in.

## PINCROFT DYEING AND PRINTING CO. LTD

> **Investing time, resource and investment in newer, cleaner technologies will ultimately drive sustainability in the sector**
>
> - Ian Rawcliffe, Technical Manager at Pincroft

The UKFT team visited **Pincroft Dyeing and Printing Co. Ltd** to understand how a dyeing and printing mill has made sustainability interventions.

Pincroft is a commission dyer, printer and finisher, primarily focusing on the workwear, uniform and Personal Protective Equipment (PPE) sectors. They have also worked for the automotive and furnishings sectors. The main production processes include pretreatment, continuous dyeing, rotary printing and stenter pad and spray finishing.

We interviewed Ian Rawcliffe, Technical Manager at Pincroft to understand the sustainability journey of a dyeing and printing mill in the UK.

**Q. What are the primary environmental hotspots typically associated with dyeing and finishing mills, and what responsibilities do you think dyeing mills have in terms of reducing this impact?**

A. Emissions both to water and air, energy use and water consumption are hotspots that dye houses should be focused on and they should be held accountable for minimising these aspects. Unfortunately, a large volume of the textile market is supplied from regions where pollution controls are less rigorously enforced. This creates significant cost disparity in what is a highly competitive market. This can be evidenced in the decline in numbers of textile dyers and finishers in the UK and EU where costs are significantly higher than Asia.

**Q. Have you noticed a demand for sustainable dyeing in recent years? How have you adjusted your practices to meet this demand and transition towards sustainability?**

A. There has been an increase in sustainability holistically, **as a dyer and finisher that has led us to look at dyes and chemicals used. But also, our water, energy and chemical consumption, heat recovery systems, chemical recycling and water reduction schemes,** and it has all fed into an overall drive for sustainability. Measuring and monitoring these allows targets to be defined and aspired to, all of which ultimately have financial benefits to the business and how it is viewed by all stakeholders.

**Q. Could you elaborate on where the sustainability demand has originated from - clients, policy and legislation or your own environmental impact reduction targets?**

A. This tends to be a mix, **clients will ask for sustainable products, quite often they don't know what it is they want, they just want it to be sustainable.** Increasing legislation and policies are further pushing sustainable goals, but perhaps these are more high level and at a hands-off distance. We hold ISO 14001 (environmental management) and ISO 50001 (energy management) which has helped also to give momentum to our own sustainable goals. As an organisation, sustainability features highly in our business strategy and receives support at all levels of the business.

**Q. What challenges, if any, have you encountered in the transition towards becoming more sustainable? How did you overcome them?**

A. Primarily the cost, investment in new technologies and products is extremely expensive. Reluctance from customers to accept additional cost of producing more sustainable products. Recycling/reuse is more challenging when using multiple fibre blends as the technology and equipment to separate fibre types is still in its infancy. As we are commission dyers, we have limited control over the substrate/blend and, therefore, its ability to be recycled. There have been a number of start-ups that have ceased trading due in part to these difficulties. Chemical and performance issues, such as reduced strength, have also been difficult to sell to clients.

**Q. We are curious to learn what steps Pincroft has taken to ensure that the machinery used in your operations is energy-efficient and environmentally friendly?**

A. We believe that compared to industry standards we have some of the most efficient machinery and process set-ups, albeit it is now ageing. Profitability determines a business's ability to invest and innovate, without customer acceptance (pricing) or financial assistance in the form of funding the journey is slower than we would like.

**Q. Have you explored any alternatives to traditional dyes?**

A. We are constantly on the lookout for more sustainable dye options and where possible have conducted trial work on 'greener' dyes. Examples would be **Earth Colours and Diresul from Archroma**. These are biosynthetic dyes derived from **natural waste** products of the agriculture and herbal industries, leaving the edible part still available for food consumption. The challenge for our sector is the **restricted shade gamut and durability to industrial laundering.** These types of dyes are more suitable for fashion apparel. More recently we explored dyes synthesised from bacteria, however, this is in its infancy and cannot be up-scaled commercially currently.

**Q. Do you have any environmental standards currently in place?**

A. We are currently certified to ISO9001, 14001, 45001, 50001 and OEKO-TEX® Standard 100 with a view to pursue OEKO-TEX® STeP. We were a Bluesign System partner until last year, however, the excessive costs and lack of pull from customers led us to leave this.

**Q. Do you assess the environmental impact of your dyeing processes, including the emissions generated and the carbon footprint associated with production?**

A. We use Poweradar from Centrica to understand and monitor our energy and water footprint site wide in real time. All dyes and chemicals are dispensed automatically, and consumption logged. Monitoring and measurement are a must.


# Technology innovation

## INTRODUCTION

Replacing current technology in industrial facilities to achieve cleaner production is crucial. Consequently, technological innovation in the textile and apparel dyeing sector is emerging.

UKFT approached the Manufacturing Technology Centre (MTC) to identify novel technologies (developed in the last 10 years) for the dyeing stage of textile and apparel manufacturing that help reduce environmental impact. This review was conducted through desk-based research, primarily focusing on energy savings, water conservation and chemical pollution control.

The following 13 technologies were reviewed:

| Technology / Company | Origin | Year |
|---|---|---|
| AIRDYE | Japan | 2020 |
| AUSORA | Australia | 2023 |
| COLORBOX | Spain | 2020 |
| DYECOO | Netherlands | 2019 |
| D(y)ENIM | Israel, Italy | 2022 |
| ECO2DYE | US | 2018 |
| ENDEAVOUR | UK, Taiwan | 2019 |
| EVER DYE | France | 2021 |
| HI-PRECISION SPRAY | Sweden | 2018 |
| INTELLICOLOR | India | 2024 |
| NANODYE | US/Bangladesh | 2019 |
| SUPRAUNO | India | 2021 |
| We Are Spin Dye (WRSD) | Sweden | 2015 |

The map showcases the global distribution of the innovation landscape in dyeing technologies for the textile and apparels sector:

## AirDye

**ABOUT**

The technology is owned by Japanese-based Debs Textile Corporation. This technology enables water-free dyeing and printing on synthetic textiles, addressing the environmental issues of excessive water use and pollution associated with traditional dyeing methods. It offers customers an easy, fast, sustainable and cost-effective way to colour and print fabrics.

**HOW IT WORKS**

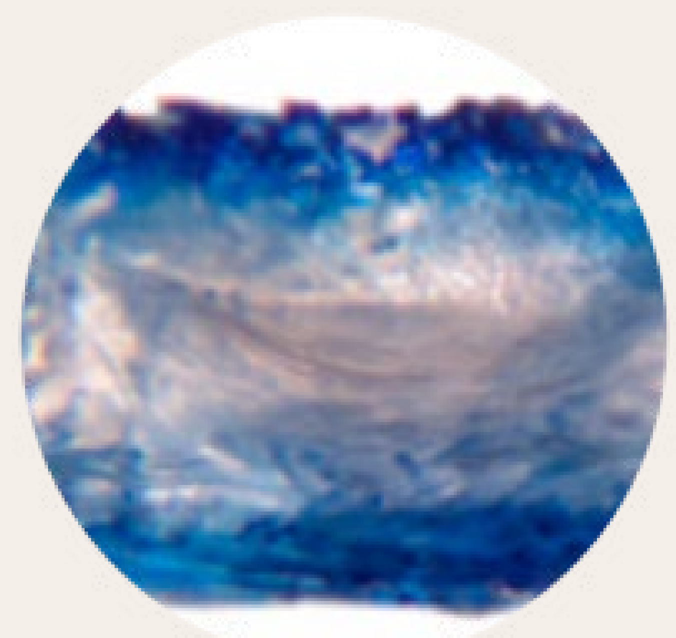
With AirDye, textile dyeing and printing can be performed using a single machine, eliminating the need for post-processes like steaming and washing, thereby conserving significant amounts of water and energy. Whether working with stretch fabrics or delicate chiffon, AirDye opens design possibilities, allowing for the colouration of both sides of the fabric with solids or prints.

AirDye operates on innovative, patent-pending software that ensures precise, custom colouration in dyeing and printing across various fabric types. This software enables AirDye to achieve rapid and highly efficient colour matching, seamlessly transitioning from colour/ print development to sampling and bulk production.

AirDye employs the process of sublimation, transferring inks to fabrics using transfer paper combined with heat and pressure. Although the application method resembles traditional heat transfer printing, AirDye incorporates various proprietary technologies that make it superior to similar methods.

AirDye technology is highly advanced, allowing dyes to penetrate deeply into the yarn filaments, resulting in rich, vibrant, and brilliant colours with excellent colorfastness and performance.

**Conventional heat transfer method**



**AirDye**

**SUSTAINABILITY**

AirDye technology saves 95% of water, 86% of energy, and 84% of carbon emissions compared to conventional dyeing and printing methods. The technology:

- Uses air instead of water to penetrate dyes into fabric.
- Uses no pre or post chemical treatments necessary.
- Uses no screens in production.

**95%** of water is saved

**86%** of energy is saved

**84%** of carbon emissions is saved

## Ausora

**ABOUT**

Ausora by Xefco, is creating a sustainable dyeing solution developed in collaboration with Deakin University and supported by funding from the Innovative Manufacturing Cooperative Research Centre (IMCRC) which provides a manufacturing solution that utilises an advanced plasma coating process which is water-free, producing no water discharge.

**Significance of plasma technology in textile dyeing:**

Plasma technology uses plasma or ionised gas to improve the dyeing process of textiles. This treatment modifies the surface of textile fibres to increase dye uptake and fixation. It is a dry process that can be conducted under atmospheric or low-pressure conditions in an energy efficient manner without the need for additional chemicals. Also, plasma-treated textiles exhibit better colour fastness and are suitable for various fibres.

**HOW IT WORKS**

Ausora's innovative shower plasma process generates plasma at atmospheric pressure using electricity and argon gas. By introducing a small amount of precursor chemistry to plasma, Ausora systems can apply coatings with strong covalent bonds to a wide variety of textiles, including both natural and synthetic materials. The plasma coatings hold a series of functional properties:

- Durable water repellency
- Moisture wicking
- Fire retardancy
- Self-cleaning
- Anti-odour

Plasma dyeing process applies vibrant colours to textiles, producing a broad colour gamut with excellent colour fastness properties. By applying dyes and functional coatings to textiles using plasma-enhanced chemical vapour deposition, it also helps in high efficiency waterless dyeing and avoids waste-water discharge preventing pollution.

**SUSTAINABILITY**

The efficient process is completely water-free, producing no water discharge.

**100%**
water-free

**100%**
no discharge of pollutants to water sources

**97%**
less chemicals used

**90%**
less energy used

## Birla Viscose - Intellicolor

**ABOUT**

In February 2024, Birla Cellulose, India, unveiled its latest innovation, Birla Viscose – Intellicolor, designed to address the challenges of conventional reactive dyeing. Intellicolor represents an advancement with its use of cationic or basic dyes that achieves a dye exhaustion rate of over 95% and therefore surpasses conventional methods. It also eliminates the need for salt and soda ash in the dyeing process and thereby reduces environmental impact.

**HOW IT WORKS**

Cationic dyes work by utilising positively charged molecules to bond directly with the negatively charged fibres of textiles, such as cotton or wool. This significantly reduce the amount of water, salt and alkali needed in cotton dyeing by tenfold.

**SUSTAINABILITY**

In traditional reactive dyeing processes, the use of reactive dyes often requires large amounts of salt to achieve adequate dye fixation on fabrics, due to lower dye bath exhaustion. This results in high concentrations of salt and unreacted dye in the effluent, posing environmental risks and increasing effluent treatment costs.

Intellicolor reduces post-dyeing washes and eliminates fixing steps. This conserves water, lowers energy consumption and decreases operating costs for Effluent Treatment Plants. By utilising Basic dyes, Intellicolor enhances dye uptake and improves wash fastness compared to traditional Reactive dyes.

## ColorBox

### ABOUT

ColorBox, developed by Jeanologia in Spain in 2020, provides a range of garment dyeing technologies aimed at transforming the dyeing sector. These technology solutions save water and costs by ensuring optimal dilution with minimal resources through precise dosing of colour and chemicals. This helps ensure product outcome at a low production cost with minimal environmental impact.

### HOW IT WORKS

ColorBox offers ColorBox 420 and ColorBox 60.

ColorBox 420 simplifies garment dyeing processes and ensures perfect reproducibility. It can dye loads ranging from 50 to 200 kg, accommodating all types of garments, especially delicate materials.

ColorBox 60 is designed for samples and small productions with a load capacity of 4 to 30 kg. It simplifies dyeing processes and reduces costs by ensuring optimal dilution with minimal resources through precise dosing of colour and chemicals.

ColorBox's Orion machine management software offers various controls, including speed adjustments and facilitates communication between machines and the cloud to automatically convert recipe parameters from one machine to another, ensuring consistent results.

### SUSTAINABILITY

Jeanologia is working towards '*#Mission Zero*' and the company intends to eliminate 100% of the waste and pollution in every single pair of jeans around the world by 2025 from the fabric to the final garment, including commitments to:

- Reduce water usage to nearly zero.
- Water used back to nature in pristine condition.
- Eliminate the use of hazardous chemicals that are harmful to health and the environment.
- Measure, control and compensate for any unavoidable impact or process harm in a controlled and verifiable manner, no matter how small.
- Collaborate with other members of the denim community to share experiences, technologies and success stories.

**The average saving:**

**60%** for water and chemicals in garment dyeing

**45%** for energy

**76%** for salt

**"In 2021, Jeanologia saved 18.2 million m³ of water by using Colorbox"**

- said Enrique Silla, CEO of Jeanologia to UK Fashion Network (2022).

## DyeCoo

### ABOUT

DyeCoo, based in the Netherlands was founded in 2008, offers water-free and chemical-free textile processing $CO_2$-based dyeing technology. This technology provides geographical freedom from water sources, offering textile manufacturers an advantage in complying with legislation that restricts the use of hazardous process chemicals.

### HOW IT WORKS

As of 2019, DyeCoo uses patented technology based on reclaimed $CO_2$ as the dyeing medium in a closed loop process. When pressurised, $CO_2$ becomes supercritical (SC-$CO_2$). In this state $CO_2$ has a very high solvent power, allowing the dye to dissolve easily and transported deeply into fibres.

DyeCoo is the only company that has been able to scale up $CO_2$-based textile processing technology to a proven industrial scale and has received industrial and commercial endorsements from both textile mills and end users with its short batch cycles, efficient dye use and no requirement for waste-water treatment.

### SUSTAINABILITY

DyeCoo technology uses **100% pure dyes** with more than **98% uptake**, so minimal waste.

**In textile dyeing, "uptake" refers to the amount of dye that is absorbed and fixed onto the fabric or textile material during the dyeing process.**

## Dyeing Indigo Yarn Ultrasound Technology by Sonovia

**ABOUT**

The textile technology company Sonovia, based in Israel, collaborated with Italian denim manufacturer PureDenim in 2022 and leveraged ultrasonic textile application technology for indigo dyeing. The new indigo dyeing process is reported to save more water and energy and cut down on chemical usage compared to traditional methods.

**HOW IT WORKS**

The technology uses ultrasonic cavitation jet-streams to colour textiles and forms cavitation bubbles which generates 1,000 metre/sec jet-streams through the machine named Sonofix. Manufactured by their partners at Bruckner Trockentechnik GmbH Germany, the technology offers durability and performance, non-toxic chemistry and is 100% agnostic to fibre type.

The current project led by Sonovia named ‘D(y)enim’ is the indigo dyeing system that uses indigo pigment dispersion to limit water wastage.

**SUSTAINABILITY**

Traditional indigo yarn dyeing processes are water intensive requiring on average 60,000 litres of water per process and relying on polluting chemicals such as hydrosulfite. Sonovia’s D(y)ENIM indigo yarn dyeing ultrasound technology dramatically reduces the usage of water in the textile dyeing process by up to 85% and is 100% hydrosulfite free with its use of non-toxic chemicals.

### Sonovia’s Solution for the Denim Industry

- Only 1-2 dye baths
- Non-toxic water-based dye chemicals
- No pre- post dyeing preparation and wash
- Reproducible and controllable dye shade
- Simple integration into existing lines

## eCO2Dye

**ABOUT**

In 2018, Supercritical Applied Separations, a US-based company specialising in DNA-free and supercritical fluids technology, introduced eCO2Dye, a waterless textile dyeing process and equipment. This process uses $CO_2$ as the dyeing solvent instead of water, offering a cycle time of 60–90 minutes depending on colour and dye selection.

**HOW IT WORKS**

The process begins by loading dry textiles and dyes into a pre-heated vessel. $CO_2$ is then pumped into the vessel at the desired pressure, and supercritical $CO_2$ (SC-$CO_2$) circulates through the system for about 30 minutes, completing the dyeing process. After dyeing, the textile is levelled, $CO_2$ is de-pressurised and recycled. This saves over 95% of the $CO_2$. The dyed textile is then removed, and the system is prepared for the next cycle.

The process operates at temperatures between 80 to 120ºC and pressures of 200 to 250 bar, with specific conditions adjusted based on the desired textile colour.

**SUSTAINABILITY**

eCO2Dye offers several environmental benefits: it eliminates the need for water, significantly reducing water usage. The process operates efficiently within a moderate temperature and pressure range, using fewer chemicals compared to conventional dyeing processes. It generates no waste streams as the $CO_2$ is recycled and not vented. Additionally, it reduces the number of process steps and simplifies dyeing chemistry.

## Endeavour

**ABOUT**

Alchemie, based in Cambridge, UK, launched the Endeavour waterless dyeing technology in 2019. The system can deliver any colour shade required and enables on-demand digital colour changeovers in any run length from a few meters to several kilometres.

**HOW IT WORKS**

Endeavour digital liquid application technology delivers fluid nanodroplets deep into textile fabrics. A combination of high fluid droplet velocity and precisely controlled airflow enables full penetration of fluid droplets into dense fibre structures. Liquid application is precisely controlled, achieving a good dose accuracy within the fabric structure.

The process utilises thermal and infra-red energy to activate dye penetration and drive chemical fixation. This combination of highly dispersed colourants and targeted energy ensures complete fixation. The energy accelerates dye diffusion and reaction, achieving high colour fastness in a single step and eliminating the need for downstream washing.

**Significance of nanotechnology in textile dyeing:**

Nanotechnology uses nanoparticles to penetrate fibres more effectively. This improves dye uptake and reduces the amount of dye that is typically used. The process is energy and resource-efficient, requiring lower temperatures and fewer chemicals. Plus, textiles treated with nanotechnology also gain additional properties such as antibacterial, UV protection, and water and stain resistance.

**SUSTAINABILITY**

Endeavour's technology is reported to:

- Reduce water usage by up to 95% compared to a traditional jet exhaust dyeing process.
- Achieve throughputs of over 1500 m² per hour.
- Lower operational costs by 50% and provide supply-chain savings through significantly more flexible production.

**95%**
less water

**85%**
less energy

**50%**
lower operational cost

## Ever Dye

### ABOUT

Founded in 2021, Ever Dye is a French company that has developed a sustainable dyeing technology using recyclable and reusable dyes. The process is greener, faster and more energy-efficient, promising zero waste and improved circularity.

### HOW IT WORKS

Ever Dye technology solves two problems at once: the synthesis and the attachment of dyes.

Traditional textile dyeing processes are energy-intensive, typically requiring textiles to be immersed in dyestuffs for hours in autoclaves at temperatures up to 130°C. In contrast, Ever Dye’s process uses a non-toxic bio-sourced pigment made from vegetable waste and minerals. This pigment is applied in just 30 minutes at room temperature.

By combining the pigment with a bio-sourced organic polymer binding agent, Ever Dye achieves electrostatic attachment without the need for heat and with minimal time. Additionally, water cleaning after the dyeing process is simplified, requiring only a mechanical filter to return fresh water back into the system.

**Two chemical solutions that act like a magnet:**

**A pretreatment and a pigment**

- The negatively charged pretreatment acts on the surface of the fibre and creates anchoring sites
- The positively charged pigment made of vegetal waste and minerals attaches on anchoring sites
- Based on 5 years of academic research

### SUSTAINABILITY

Ever Dye, a member of Tech For Good, is committed to reducing the environmental impact of the dyeing process and significantly lowering GHG emissions. Their process uses, on average, 10 times less energy than conventional dyeing methods, reduces the required heat from 95°C to ambient temperature and operates about five times faster. Ever Dye does not use any petrochemicals in the process.

Further, the process requires no changes to existing infrastructure.

## Imogo

**ABOUT**

Established in 2018, Swedish start-up Imogo AB has developed a high-precision digital spray application technology for dyeing and finishing textiles. Their patented Pro Speed valve technology allows for controlled application of functional liquids, thereby significantly reducing water consumption.

**HOW IT WORKS**

Imogo has adapted spray applications, common in other industries, to meet the specific needs of textile dyeing and finishing. The high-frequency Pulse-Width Modulation (PWM) control (up to 80Hz) of the valve ensures a very controlled spray application that seamlessly adapts to changes in speed, resulting in a uniform application along and across the fabric.

**SUSTAINABILITY**

The Dye-Max unit reduces water and chemical consumption through its high-precision controlled spray application. It is equipped with an exhaust and filtration system to keep the environment around the unit free from sprayed particles. Reduced water usage also decreases the energy needed for heating and lowers $CO_2$ emissions.

**Water saving**
Water consumption reduced up to 90%. Savings in water are due to the low liquid ratio of less than one litre per kilo fabric.

**Energy saving**
Energy savings up to 90%. Savings are due to the low liquid content in the fabric that minimise the energy required for the heating and shorten the time for fixation.

**Chemistry saving**
Chemical savings up to 90%. Savings in chemistry are due to the low liquid ratio and the spray process requiring considerably less chemicals.

**Dye savings**
Dye savings uo to 30%. Savings are dye is due to the precise application and efficient fixation of dye.

## Nano-Dye

**ABOUT**

Nano-Dye LLC, based in USA, launched its cationic eco-friendly Nano-Dye System in 2019. The system aims to revolutionise exhaust dyeing by significantly reducing pollution, water usage and energy consumption in cotton textile dyeing plants worldwide.

**HOW IT WORKS**

Nano-Dye’s process involves a single ‘drop-in’ pre-treatment step applied directly to unprocessed knitted fabrics. This modifies the exhaust dye jet cycle, enhances productivity and reduces overall dyeing costs. The resulting fabric exhibits cleaner tones, a softer hand feel, normal scent and improved colourfastness.

The patent-pending Nano-Dye turn-key system is designed to integrate seamlessly with existing exhaust dye equipment and dyestuff libraries in textile dye plants. The process alters the charge of cotton molecules to match the opposite charge of the dye, leveraging natural processes for dye fixation.

The company collaborates with Navis TubeTex, a US-based textile machinery manufacturer, and Esquire Knit Composites Ltd, a Bangladesh-based textile dyeing and finishing conglomerate to scale up the technology to industrial levels.

**SUSTAINABILITY**

Nano-Dye’s dyeing technology allows cotton exhaust dye jets to use no salt and exhaust up to 99% of dyestuff (eliminating solid waste). It uses 75% less water and 90% less energy while yielding greater shade reproducibility and consistent quality fabric in all colours and reducing effluent pollution.

# SUPRAUNO

## ABOUT

The technology was developed by Deven Supercriticals Pvt. Ltd. India. It is an internationally patented sustainable waterless dyeing and finishing technology that allows the use of conventional dyes and their traditional trichrome recipes, using supercritical $CO_2$. Suitable for both natural and synthetic textiles, it offers a simple, versatile and viable promising green technology for dyeing and finishing.

## HOW IT WORKS

A dyeing and finishing plant based on Supercritical Carbon Dioxide (SC-$CO_2$) would include dyeing vessels, a separator, a $CO_2$ hold-up tank, heat exchangers, an advanced Programmable Logic Controller (PLC), and a Human Machine Interface (HMI) terminal. It would also feature safety interlock logic software to ensure safe operation and consistent results. The dyeing process operates in a closed loop, maintaining a continuous circulation of $CO_2$, and typically takes 1.5 to 2 hours per semi-batch cycle.

The steps involved in the process are:

1. **Pre-coating a thin layer of the dye solution onto the textile,** which improves the efficiency of the interaction of the dyes and chemicals with the supercritical $CO_2$.
2. The processed textile **goes through a drying chamber and is rolled into a beam**, ready to be fed into the supercritical fluid vessel.
3. The dyeing process is completed using **Supercritical $CO_2$.**

**What is Supercritical $CO_2$?**

Supercritical Carbon Dioxide (SC-$CO_2$) is a promising technology for the replacement of water in the dyeing process. It works as follows:

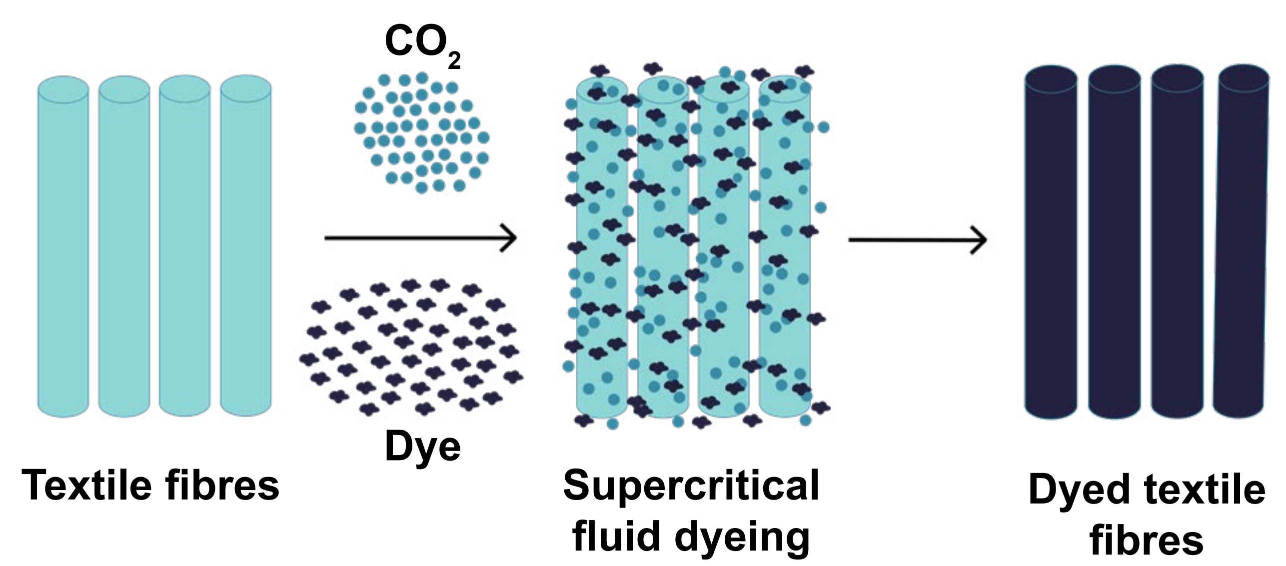



*Figure: Adapted from source 24*

Supercritical $CO_2$ allows for supercritical impregnation of active compounds or other actives in polymeric matrices, and it is a water-free (dry) process. This saves water, avoids the energy used in the subsequent drying stage and avoids the generation of polluted wastewater.

SUPRAUNO is suitable for various man-made and natural fabrics, including cotton, polyester, nylon, viscose, linen, silk, acrylic and their blends.

The potential economic viability of the SUPRAUNO technology is comparable to that of conventional dyeing with the advantage of substantially reducing pollution, water and energy wastage.

## SUSTAINABILITY

It requires no reduction clearing for polyester, uses no salt for cotton, improves overall dye utilisation, follows single bath dyeing of textile blends and uses up to 90% lesser auxiliary chemicals which otherwise would have ended up in the wastewater, allowing the following advantages:

- Better dye utilisation, stronger shade strength.
- Lower dyeing time.
- Less energy, pollution (ETP) Load.

**90%** Auxilary chemicals saved

**77%** water saved

**70%** time saved

**51%** energy saved

## We aRe SpinDye (WRSD)

**ABOUT**

In 2015, Swedish Fashion-Tech company We aRe SpinDye partnered with global specialty chemicals company Clariant to develop an efficient textile dyeing technology. This innovative process colours fibres using recycled polyester blended with Clariant's colour masterbatch which is then spun into yarn and woven or knitted into the desired fabric.

**HOW IT WORKS**

We aRe SpinDye utilises waste garments as raw materials for closed-loop production, certified by the Global Recycled Standard (GRS). Recycled polyester pellets are mixed and melted with Clariant's colour pigments during extrusion to form coloured fibres, offering up to 72 shades. These coloured fibres are then texturised into yarn and subsequently woven. By incorporating colour pigments before extrusion, the textile fibres achieve homogeneous colouring, ensuring high colour fastness throughout their lifecycle.

Clariant's masterbatches, known for their expertise in colour matching using non-hazardous chemicals and recycled plastics, play a crucial role in the SpinDye process. The collaboration between We aRe SpinDye and Clariant has been instrumental in developing a sustainable supply chain for this circular dyeing process.

**SUSTAINABILITY**

By melting colour pigments directly with the liquid polyester mass, SpinDye eliminates the need for water in the colouring process. The process reduces water usage in the entire fabric production chain by 75% and cuts chemical usage by 90%.

SpinDye developed a customised Life Cycle Assessment (LCA) process with the independent research organisation RISE (Research Institute of Sweden). This process defines key performance indicators (KPIs) for water usage, chemical usage, $CO_2$ emissions and energy consumption. These KPIs are measured at all production stages following the ISO 14040-series standards for LCA methodology, resulting in a total score that is benchmarked against conventional dyeing methods.

This approach enhances sustainability by significantly reducing waste and resource consumption.

**75%** less water consumption

**90%** less chemical consumption

**30%** less energy consumption

**30%** $CO_2$ imprint reduced

**100%** traceable

**5/5** colourfastness to light

## Other Technology Innovations

These are other innovations and developments at different Technology Readiness Levels (TRL) levels to keep an eye on.

### Grinp

**ABOUT:** For over 15 years, Grinp has specialised in plasma technology, developing the only industrial-scale system capable of treating textiles up to 4 metres wide.

**LOCATION:** Italy

**HOW IT WORKS:** Grinp offers many innovative solutions. Among these are the UltraFoulard impregnation system that rapidly and uniformly transfers chemicals onto fibres, and Zero Water Unit, a system for cotton preparation that eliminates wastewater by enabling circular water use.

**WEBSITE:** www.grinp.com

### NTX

**ABOUT:** NTX is a textile innovation and solutions company dedicated to developing sustainable textile solutions through ongoing research and innovation, focusing on both ecological and economic sustainability.

**LOCATION:** Singapore

**HOW IT WORKS:** Among others, NTX offers Cooltrans which is a waterless textile colouration solution capable of accurately colouring nearly any fabric material without heat and reducing water usage by up to 90%.

**WEBSITE:** www.ntx.global

# Sustainable colours

## INTRODUCTION

Sustainable colours refer to dyes and pigments used in textile and apparel that are produced and applied in ways that minimise environmental impact. This could mean that these colours use less water and energy usage, are free from harmful chemicals and often come with certifications that ensure the colours meet specific environmental and social criteria.

In this section, we provide an overview of innovations that have been identified to offer sustainable colour solutions. These innovations have been categorised into three groups:

**Established Innovations:** These have a high TRL and a strong market presence.

**Emerging Innovations:** These are businesses that have recently launched or are launching on the market.

**Other Innovations:** These are other innovations and developments at different TRL levels to keep an eye on.

## Established innovations

### COLORIFIX

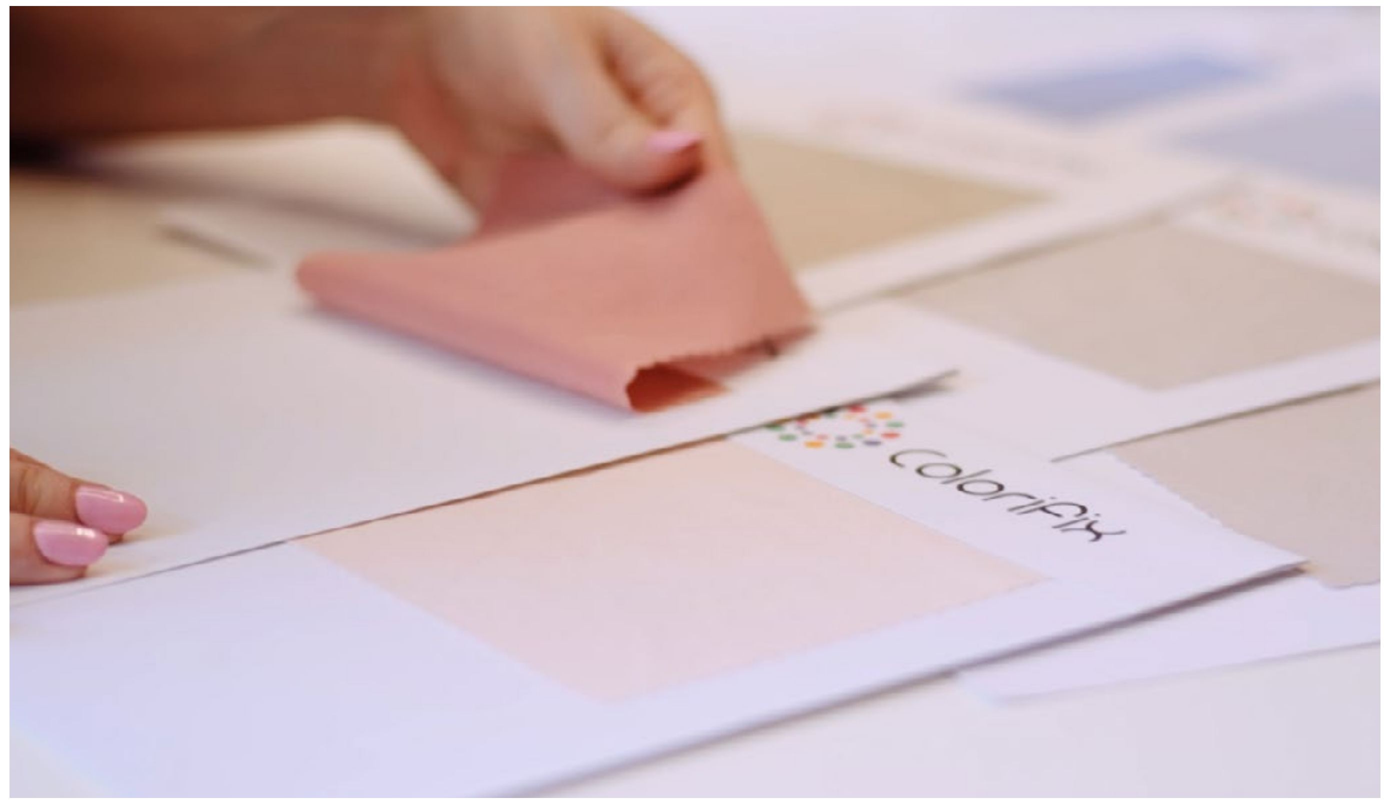
**Year founded:** 2016

**Location:** Norwich, United Kingdom

**Founding team:** Jim Ajioka (CSO) and Orr Yarkoni (CEO)

**Business size:** Medium sized (50-249 employees)

**Website:** www.colorifix.com



### ABOUT

Colorifix is a biotechnology company that has developed the first entirely biological process to produce, deposit and fix pigments onto textiles. Inspired by the way colours are produced in nature and engineered through synthetic biology, their process entirely cuts out the use of harsh chemicals and leads to huge reductions in water and energy consumption.

The textile industry uses over 70 chemicals in the dyeing process – these are contained in the dyes and the auxiliary chemicals that adhere the dyes to surfaces. The Colorifix solution displaces both of these elements, meaning that they offer not just eco-friendly pigments but also a process that entirely avoids toxic inputs, and accordingly, the outputs or waste are also non-toxic. The process runs using significantly lower temperatures and water consumption, which along with chemicals, are other areas of huge impact for industry.

Inspired by the way colours are produced in nature and engineered through synthetic biology, Colorifix is harnessing nature's colours at industrial scale, replacing synthetic dyes and sidestepping the intensive labour and agricultural requirements of scaling traditional natural dyes that have previously prohibited their uptake by the mainstream industry.

> **In simpler terms, the innovation takes all of the harsh chemistry required in conventional dyeing and replaces it with biology**
>
> - Colorifix

**The latest LCA comparing conventional dyeing to Colorifix process shows savings of at least 53% electricity, at least 31% in $CO_2$ emissions and 77% in water consumption**

### HOW IT WORKS

First, Colorifix identifies an organism that produces a desirable pigment. They then extract the genetic instructions responsible for this pigment from the organism's DNA and transfer these instructions into a safe microbe, effectively transforming it into a "microscopic dye factory". Next, a small vial containing the newly engineered, colour-producing microbe is shipped to a mill or dyehouse. Colorifix provide support to these facilities to cultivate the microbe on site through fermentation. The resulting dye liquor can then be utilised to dye natural and synthetic fabrics, yarns, and garments using standard dye machinery, all without the addition of petrochemicals.

The technology works on a broad range of fabrics from naturals to synthetics: Cotton, Wool, Silk, Polyester, Nylon, polyamide, Lyocell and Tencel. They are currently undergoing other material exploration.

> “We provide a plug-in solution for existing dye houses and mills around the world. The technology can be used with standard industry machines and works on a broad range of fabrics from natural to synthetics, allowing us to be cost-competitive and highly scalable
>
> - Colorifix

**MARKET PRESENCE:**

Colorifix is currently active on more than four customer sites across Europe where they have successfully demonstrated that their technology works across different stages of dyeing (yarn, fabric, garment and printing) and across a broad range of natural and synthetic fibres. This is all done using conventional industry dyeing machines.

They partner with fashion brands, such as H&M and Pangaia to bring products dyed with their technology to market and into consumers’ wardrobes. This collaboration with brands, they say, has been important to increase the demand throughout the supply chain as well as to educate and raise awareness amongst consumers.

In 2024, they will be expanding in Europe. They have also initiated the first step of their scaling model in Brazil and expect to be live on client sites there by the end of this year. Additionally, they are making their first steps into India which will be a key strategic hub. 2024 and 2025 will see further expansion into Asia.

PANGAIA LAB | POWERED BY COLORIFIX

Colorifix has worked with Pangaia Lab to break down barriers between science and society.

> Investing in sustainable innovations is crucial for long-term impact. Brands like H&M have been exemplary in this regard by supporting companies like Colorifix. Choosing suppliers and manufacturers that prioritise sustainability can drive industry-wide change. While microbial colourants are still emerging, working with companies investing in such innovation can pave the way for better choices. It's essential to collaborate with innovators and support their efforts to integrate sustainable practices into the industry
>
> - Ruth Lloyd, Textile design-led researcher and PhD candidate at Central Saint Martins with the Living Systems Lab

## INTERVIEW WITH RUTH LLOYD

We interviewed **Ruth Lloyd**, a textile design-led researcher and PhD candidate at Central Saint Martins with the Living Systems Lab. Her research is in partnership with and funded by Colorifix in collaboration with University of Arts London (UAL). The interview aimed to explore the potential of microbial colourants for dyeing and to understand how living colour systems could offer alternatives to the dependence on petroleum-based dyes and colourants. Refer to the bio in Appendix 3.

**Q: Can you tell us about yourself and the research you are doing within the field of textile dyeing and printing with Colorifix?**

A: I work as a creative resident at Colorifix. My PhD research focuses on developing microbial printing systems for textiles, leveraging their technology.

Living colour systems involve utilising microorganisms like bacteria, algae and fungi to produce colourants on an industrial scale as an alternative to synthetic or traditional natural dyes.

Currently, **over 90% of the dyes used in the textile and fashion industry, are synthetic. It's probably more than 90%, and then there are traditional natural dyes sourced from plants, insects and minerals. However, the latter pose challenges due to the large quantities of specific plants required, leading to issues such as monocultures, exploitation of labour, and environmental waste.** Some natural dyes can be harmful when used on a large scale.

**Microbial colourants offer a viable alternative. They can be produced in short timeframes, typically a few days, through fermentation processes. Unlike traditional dyes, microbial colourants can be cultivated in small land spaces using industrial bioreactors, reducing the need for massive plantations such as the ones needed in some conventional natural dyes production processes.** Additionally, their production involves lower temperatures and fewer toxic chemicals, making them environmentally favourable in comparison to some other dyeing alternatives.

**To fully replace synthetic dyes, however, you have to offer both dyeing and printing.** They work hand in hand and have separate requirements. Particularly, I am looking at how synthetic dyes can be replaced with microbial colours for printing.

> Unlike traditional dyes, microbial colourants can be cultivated in small land spaces using industrial bioreactors, reducing the need for massive plantations such as the ones needed in some conventional natural dyes production processes

**Q. What are the practical applications of this research in the current landscape of textile and apparel production, and how could it contribute to cleaner manufacturing processes?**

A. Colorifix has conducted lifecycle analysis, demonstrating their water, energy, and carbon savings in their dyeing process, which will also be applied to the printing methods we are developing. When replacing synthetic dyes with microbial colours for printing, the process of making the colourant is substituted. Unlike the high-temperature method involving petroleum sources and toxic chemicals, **microbial colourants are produced through fermentation at lower temperatures, requiring minimal water and producing waste that does not require specialised treatment.** Consequently, **the water waste can be integrated into the water system as its main contents is bacterial biomass, a natural product found in soil and water, and is not necessarily chemically polluted wastewater, as in traditional synthetic dyeing processes. This biomass could potentially be utilised in various applications such as fertilisers, agriculture, and the dried biomass for fuel production, contributing to a circular system with minimal non-recyclable or non-biodegradable waste.** Moreover, it is feasible to engineer bacteria to utilise waste from other industries, enhancing the circularity of industrial systems. Specifically concerning printing, the focus is on replacing the conventional method of producing colouring agents. **Synthetic printing involves the addition of chemicals to facilitate bonding with textiles, whereas traditional plant-based natural dye printing utilises heavy metal mordants, some of which are toxic both for the environment and for people.**

Currently, our focus does not involve adding any additional chemicals. Essentially, it's just the colourant produced through microbial fermentation and a natural thickener. Therefore, the process is quite straightforward. The actual printing process doesn't deviate much from traditional methods. You can use either hand screen printing, flatbed screen printing or rotary printing, followed by a fixation process involving heating and/or steam. Although energy is required for this, it's not more than what's typically needed for traditional printing. An interesting observation is that with synthetic dyes, there's often a significant amount of dye released into the water during washing, whereas with these colourants, we're not seeing as much dye coming out into the water.

Moving on to scalability, research is ongoing and shows promise despite being in its infancy. Regarding bio-based colouring frameworks and our research, scalability is a primary concern. **While plant-based natural dyes face challenges in scaling, microbial systems show greater potential due to shorter fermentation times and reduced energy requirements.** The challenge lies in innovating processes for scalability, but the groundwork is laid, drawing from the established use of microbial fermentation in pharmaceutical and food industries.

**The key advantage of microbial colours, particularly with Colorifix's synthetic engineering model, is the ability to achieve a wide range of colours beyond what's typically found in plant-based dyes.** By using a synthetic engineering approach, Colorifix and similar companies can engineer organisms to produce higher quantities of pigment, thereby enhancing scalability. This process, while involving genetic modification, is essential for expanding the colour palette and making production more efficient.

> **The key advantage of microbial colours is the ability to achieve a wide range of colours beyond what's typically found in plant-based dyes**

**Q. How do you propose integrating this system with the existing textile dyeing infrastructure?**

A. The main advantage of integrating microbial colourants into existing infrastructure is that it requires minimal modifications. The dyeing and printing processes can continue using the same machinery, ensuring a smooth, resource-efficient and cost-effective transition.

The transition will take time and may involve a hybrid system initially. However, as these bio-based colouring frameworks become more established in the industry, they will gradually replace conventional methods and offer a more sustainable approach to textile colouration.

Achieving circularity in sustainability will be challenging. While optimising feedstocks from other industries can help, it may lead to uneven supply. Ideally, all waste should be fully utilised and potentially converted into biofuel. However, implementing these solutions on an industrial scale poses challenges, highlighting the need for further research and development in this area.

**Q. Finally, what recommendations would you give to UK brands/retailers looking to transition to cleaner production/ reduce their impact/ meet their sustainability goals within the textile dyeing and printing stage?**

A. Investing in sustainable innovations is crucial for long-term impact. Brands like H&M have been exemplary in this regard by supporting companies like Colorifix. Choosing suppliers and manufacturers that prioritise sustainability can drive industry-wide change. While microbial colourants are still emerging, working with companies investing in such innovation can pave the way for better choices.

## DYSTAR

**Year founded:** 1995

**Location:** Headquarter in Singapore but presence in 50+ countries

**Founding team:** Günther Widler (Technology Manager for Denim)

**Business size:** Large (250+ employees)

**Website:** www.dystar.com

### ABOUT

DysStar was founded as a joint venture company, bringing together the expertise of Hoechst, Bayer, and Mitsubishi textile dyes. Building on the strategic collaboration and 150 years of textile heritage, DyStar offers a range of dyes, auxiliaries and services.

> **Key to the production of Denim is the utilisation of Indigo, as the primary dyestuff. There are two main forms of Indigo currently available for use. Globally, about 50% of the Indigo dyeing plants relies on indigo powder, which requires reduction chemicals during the dyeing process. This method often generates salts in the effluent, which are frequently disposed of in landfills, causing environmental harm. The remaining dyeing plants use eco-friendly pre-reduced indigo products which are free of the harmful by-products**
>
> \- DyStar

DyStar uses pre-reduced indigo as opposed to indigo powder. This offers several advantages - it reduces the salt loading in effluent by approximately 60%, thereby minimising environmental contamination. With the method, there is also more consistent production and the highest First Time Right (FTR) rates. DyStar also has an Eco-advanced Indigo dyeing technology that results in a 90% reduction in water usage during dyeing, leading to significantly lower effluent disposal and energy consumption.

**What is Right First Time or First Time Right rate in textile dyeing?**

The first-time right rate in textile dyeing is the percentage of processes that achieve the desired colour and quality on the first attempt without re-dyeing. A high FTR rate indicates an efficient dyeing process, resulting in fewer reworks, lower costs, reduced waste, and higher customer satisfaction.

### HOW IT WORKS

The process begins with synthesis of indigo from raw materials, followed by a hydrogenation stage to produce pre-reduced indigo. This indigo is stored in tanks with a nitrogen atmosphere to maintain its reduced state. Subsequently, it is fed into the dyeing range to colour the cotton warp yarns. Pre-reduced Indigo is applied to cotton warps from troughs, penetrating the fibre surface before undergoing oxidation to achieve the desired Indigo colour.

The process is repeated continuously until the desired depth of indigo colour is attained. Recent advancements in this impregnation stage include spray application, aimed at further reducing effluent disposal. After dyeing, the yarn is sized and prepared for weaving into denim fabrics. These fabrics are then supplied to garment manufacturers for the cut-and-sew operation.

### MARKET PRESENCE

The company caters to **more than 7,000** textile industry clients that make up **21%** of the global market share.

Natural Indigo Finland

## NATURAL INDIGO FINLAND

**Year founded:** 2017

**Location:** Nivala, Finland

**Founding team:** Pasi Ainasoja (Founder)

**Business size:** Micro sized (1-9 employees)

**Website:** en.naturalindigo.fi

### ABOUT

Natural Indigo Finland produces natural dyes on an industrial scale from woad and industrial by-products such as onion shells, willow, waste coffee and waste tea. The colours are used for textiles, different coatings and biodegradable products.

### HOW IT WORKS

#### Woad plant

The blue indigo colour is obtained by isolating the woad plant, i.e. the woad from the leaf mass. The woad plant contains the same colourant as the indigo plant.

The contract farmers supply the woad, from which they produce Indigo colour with extraction technology. After isolation, the paint can be used as a solution, or dried, making it also easier to store.

#### Coffee waste

The coffee waste from food and beverage company Paulig's carbon-neutral Vuosaari roastery is used in the dyeing process. Waste is generated as coffee production side stream, and it gets a new life as Natural Indigo produces natural dyes from it.

#### Onion shells

Natural Indigo works closely with Vehviläinen, a specialist in onion production and utilise their by-products. The extract concentrates from both red and yellow onions is used to obtain yellow, green, and orange colours.

### MARKET PRESENCE

Natural Indigo Finland develops their product and new applications for it in cooperation with different partners that enable the industrial dyeing of yarns. They provide companies with the opportunity to incorporate natural dyes into their products and offers blue indigo, green, yellow, and grey dyes. Additionally, if required, product dyeing services are available through their industrial partners too. The company also sells dye extracts to both large companies and smaller entrepreneurs.

## ERCA TEXTILE CHEMICAL SOLUTIONS (TCS)

**Year founded:** 2016

**Location:** Grassobbio, Italy

**Founding team:** Fabio Locatelli

**Business size:** Small-sized (10-49 employees)

**Website:** www.ercatcs.com

### ABOUT

ERCA TCS, a part of ERCA GROUP, develops a complete range of products from pre-treatment, dyeing to finishing. The company's flagship product is REVECOL (REcycled VEgetable Cooking OiL), a set of responsible, certified and high performing textile chemicals auxiliaries.

ERCA employs a process that transforms critical and abundant waste material such as exhausted vegetable oil into auxiliaries that fit any kind of textile fibres, both virgin and recycled and can simply substitute the conventional ones without any modification to the dyeing cycle.

**The Role of Auxiliaries in Textile Dyeing**

Auxiliaries play a crucial role in textile dyeing by enhancing the process and improving product quality. They help dyes penetrate fibres evenly, stabilise dye solutions, adjust pH levels, and improve dye fixation, which increases colour fastness and reduces wash-off. Auxiliaries also accelerate the dyeing process, reduce defects like streaks and uneven coloration, enhance wash and light fastness, and control foam formation.

### HOW IT WORKS

ERCA TCS transforms critical and abundant waste material like exhausted vegetable oil into safe auxiliaries that fit any kind of textile fibres, both virgin and recycled.

> **The goal of ERCA TCS is clear: Circular Chemistry for Textile Innovation. Our main goal is to work toward real solutions in the direction of circular chemistry for the textile market, and REVECOL is a significant first step that demonstrates our commitment**
>
> - ERCA TCS

### MARKET PRESENCE

The current REVECOL by ERCA Textile Chemical Solutions product range offers 18 chemical auxiliaries products for textile pre-treatment, dyeing and finishing processes. ERCA, YKK Vietnam and Patagonia recently partnered for the implementation of REVECOL in YKK's dyeing sites in Vietnam.

## Emerging innovations

huue.

### HUUE INC.

**Year founded:** 2018

**Location:** Berkely, Califonia

**Founding team:** Michelle Zhu (CEO) and Tammy Hsu (Chief Science Officer)

**Business size:** Small-sized (10-49 employees)

**Website:** www.huue.bio

### ABOUT

Huue is a biotechnology start-up set to introduce a clean and scalable alternative for the indigo dye solution. With its bio-based technology, Huue offers a high purity, indigo dye in powder form, acceptable as a 1:1 drop-in replacement for conventional synthetic and plant-based indigo. The 1:1 drop replacement means this product component that can be directly swapped with another without requiring any modifications or adjustments.

Each kilogram of synthetic indigo produces 75 times the amount of petroleum. Unlike traditional methods that rely on toxic inputs like aniline, sodamide, formaldehyde, and cyanide, Huue's process is fossil-fuel free and does not use these harmful substances. This not only addresses environmental concerns but also ensures a safer and environmentally friendly dye solution. Plus, Huue's indigo dye maintains performance standards comparable to conventional synthetic indigo, ensuring that partners do not have to compromise on quality for the sake of sustainability.

### HOW IT WORKS

Huue first looks to nature to observe how enzyme reactions naturally produce colours, like indigo blue for denim. Their team of scientists then uses bio-engineering to program microbes to replicate these pathways and create indigo blue. Once the proprietary microbial strains are optimised, they use fermentation to produce large quantities of indigo. During the downstream processing phase, the focus is on purifying the product by removing the liquid and minimal impurities, resulting in solid indigo, which is then milled into powder form. This indigo powder can be used in standard application processes, including rope dyeing, slasher dyeing and newer techniques like foam dyeing or electrochemical reduction.

Their proprietary bio-based technology eliminates the need for toxic chemicals traditionally used in indigo dye production. This not only addresses environmental concerns but also meets the growing demand for sustainable practices in the fashion industry.

> **Change is hard, but there is no better time to start than now. Many brands and manufacturers that we talk to are rightfully concerned with having to compromise product quality requirements for more sustainable solutions. At Huue, we want to remove that friction for adoption, and that is why our approach is making sustainable product that truly performs**
>
> - Huue Inc.

### NEXT STEPS

The company's initial focus is on transforming the production of indigo, a crucial dye in denim manufacturing. The team aspires to address other dye and colourant challenges across various industries. Huue is dedicated to building a cleaner spectrum of colour solutions and is currently working on disruptive Disperse and Acid dye applications for the recycled synthetic and protein-based fibre industries.

## KBCOL SCIENCES PVT. LTD.

**Year founded:** 2018

**Location:** Pune, India

**Founding team:** Dr. Vaishali Kulkarni (Founder and CEO), Dr. Arjun Singh Bajwa (Co-founder and CEO)

**Business size:** Micro-sized (1-9 employees)

**Website:** www.kbcolssciences.com

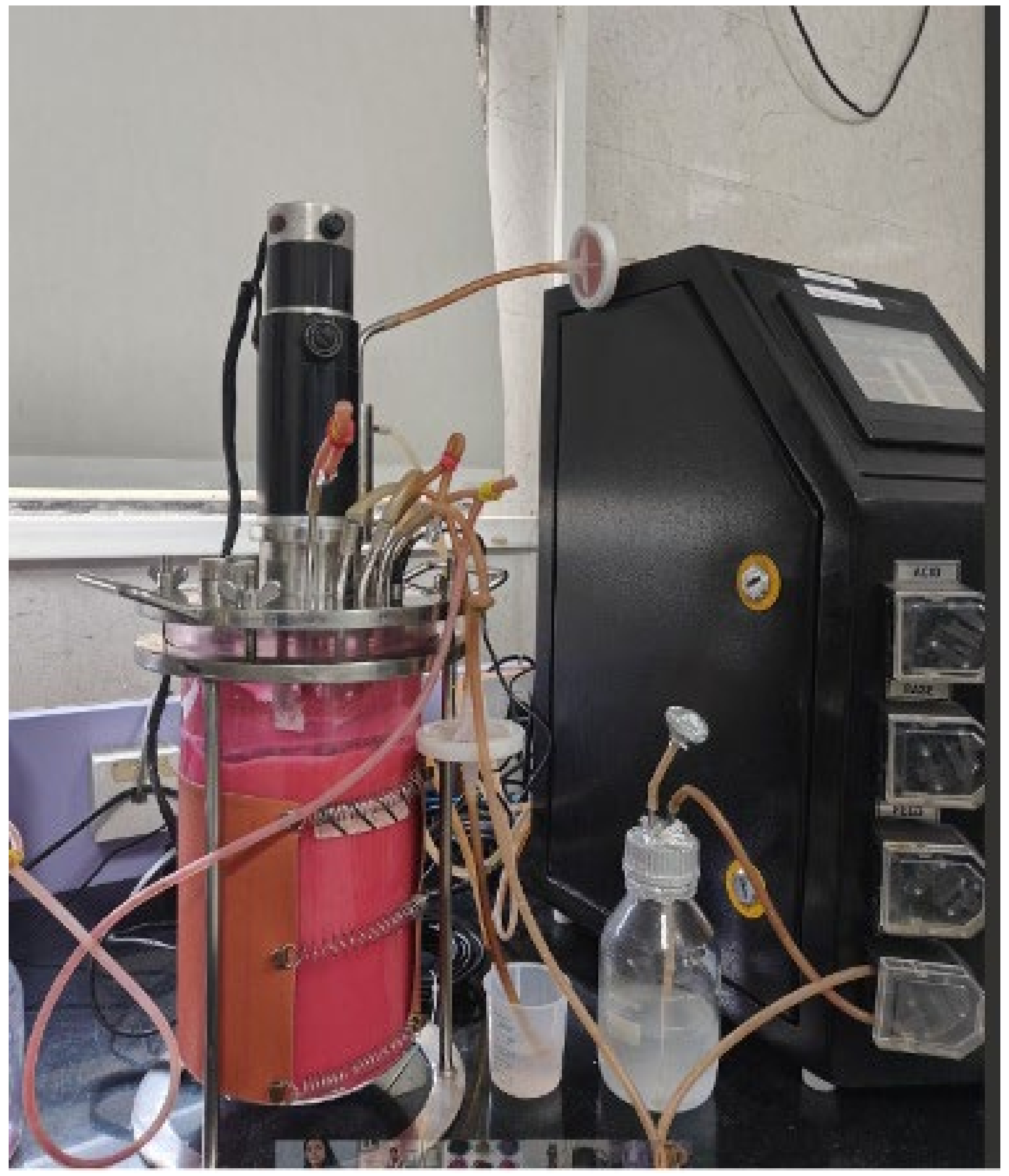


*Figure: The upstream fermentation process of colour production*

### ABOUT

KBCols is a biotech studio producing sustainable natural colours from renewable biomass. KBCols provides bio-colours and further acts as a complete solution provider (R&D support and technology translation) for brands and manufacturers by supplying the complete recipe of using their colours along with the product.

### HOW IT WORKS

KBCols sources microbes and utilise it to extract colours and develop applications across sectors. The bio-colours developed from the process can work in the existing setup and machinery and the manufacturers need not change any CapEx to apply KBCols bio-colours. The feed supplied for production of bio-colours is composed of waste resources, making it a circular production process.

KBCols bio-colours can be utilised for yarn dyeing, fabric dyeing and garment dyeing. The colours can be used to dye cellulosics (cotton, linen, viscose, ramie etc.), synthetics (polyester, nylon etc.) and proteinaceous fabric like silk, wool etc.

### NEXT STEPS

KBCols is presently running 20+ active pilots across the globe and working with apparel brands and manufacturing partners. In the next steps, they are looking at setting up a scaled-up demonstration plant to help with the initial commercialisation of the bio-colours and globally launching products in 2024 with leading brands around the world.

There are currently four primary colours in the advanced piloting stage: natural cornflower blue, natural green, natural pink and natural brown. These colours can also be mixed to create secondary shades, resulting in a palette of over 15 shades. The company has another six colours in the R&D pipeline, including black and red, which are expected to be ready for piloting with brands and manufacturing partners by the end of this year.

## PILI

**Year founded:** 2015

**Location:** Toulouse, France

**Founding team:** Jérémie Blache (CEO), Guillaume Boissonat-Wu (Chief Science and Industrial Officer) and Marie-Sarah Adenis (Creative Director)

**Business size:** Small-sized (10-49 employees)

**Website:** www.pili.bio

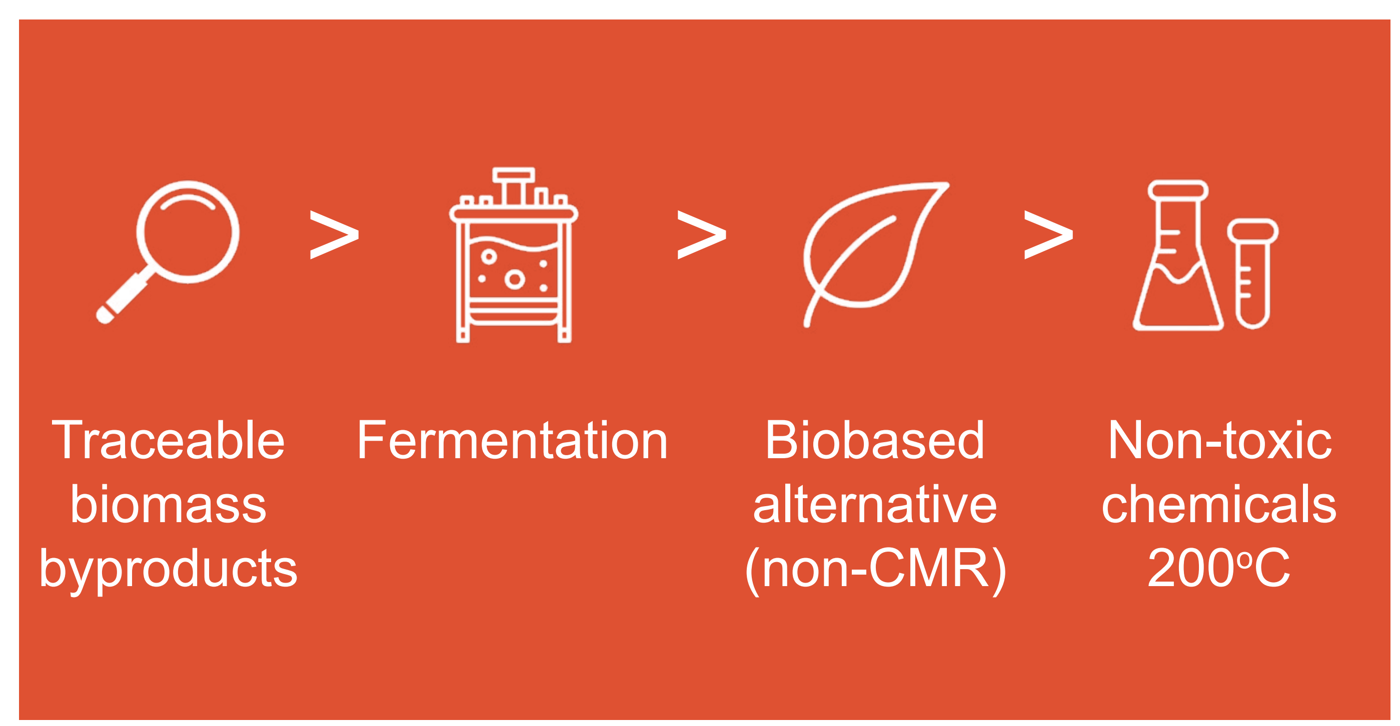
*Figure: Picture of bio-based pigment produced by Pili*

### ABOUT

Pili's mission is to decarbonise the colour industry while still providing vibrant colours through bio-based dyes and pigments. The company has developed a unique hybrid technology, combining industrial fermentation and sustainable chemistry processes, to produce high-performance and low carbon colours for textile, inks, paints and coatings, and plastics sectors.

Pili offers the first biobased and high-performance indigo with 90% purity and the same performance as conventional indigo. The product can be used as a drop-in without further investment by the dyehouse. The dye offers the same chemical structures and colour index but with a much lower environmental footprint.

Colours have been developed in the last two centuries from fossil resources, which made sense because these were cheap and abundant raw materials. But today, most colours are fossil-based, resulting in massive carbon emissions. The colour industry alone is responsible for 200 million tons of $CO_2$ emissions annually, which is equivalent to half of France's yearly carbon footprint.




### HOW IT WORKS

Petrochemistry provides the building blocks for dye synthesis. In the case of indigo, it's aniline, a CMR (carcinogenic, mutagenic, or toxic to reproduction) compound, which is converted by heavy chemistry, using toxic chemicals, into high-purity indigo powder.

At Pili, to obtain the same product, they developed a process called hemi synthesis.

The first step is industrial fermentation starting from industrial sugar (from traceable biomass) to produce a molecule of interest. This is a 100% biobased intermediate, non-CMR. This intermediate is then chemically converted into indigo, applying the principles of green chemistry. The result is a bio-based indigo powder with over 90% purity and the same performance as conventional indigo.

By leveraging industrial fermentation and green chemistry processes to produce biobased indigo, the process reduces dependence on synthetic dyes and enables large-scale and cost-effective dye production without compromising quality. Also, the process reduces the consumption of chemicals used in the production process. More importantly, by replacing petro-based indigo with a biobased alternative, there is a reduction in oil dependence and a decrease in $CO_2$ emissions.

### MARKET PRESENCE

Pili has successfully industrialised the production of anthranilic acid, a 100% biobased mono-aromatic intermediate, which the company already converts into dyes and pigments. This substance is REACH registered and ready to be commercialised as an intermediate. Additionally, Pili is developing a biobased organic pigment range (blue, red, and yellow) for the inks, paints, and coatings industry.

# Other innovations

## Archroma

**ABOUT:** Archroma is a specialty chemicals company with innovative solutions in textile dyeing and sustainable chemistry. The company offers eco-friendly alternatives to traditional dyeing processes, serving markets including branded and performance textiles, packaging and paper coatings and adhesives.

**LOCATION:** Switzerland

**HOW IT WORKS:** Archroma offers a range of dyes including- EarthColors, bio-synthetic dyes made from non-edible agricultural or herbal industries' waste; Denisol Pure Indigo 30 liq, aniline-free indigo dye; FiberColors, created by dyes from pre-and post-consumer textile waste among others.

**WEBSITE:** www.archroma.com

## AIR-INK®

**ABOUT:** AIR-INK is an innovative technology developed by Graviky Labs (based in India) that captures particulate matter from vehicle exhausts and industrial emissions, converting it into usable ink and other materials.

**LOCATION:** India

**HOW IT WORKS:** Particulate matter (PM) air pollution waste is sequestered and transformed into usable pigments and ink. In collaboration with globally accredited third-party labs, Graviky Labs analyses and segregates the pollution particulates for recycling. This analysis ensures that the resulting AIR-INK formulations are safe for consumer use.

**WEBSITE:** www.air-ink.com

## Octarine Bio

**ABOUT:** Octarine Bio is a biotechnology company that harnesses the power of microbial fermentation to develop bio-based compounds. Through cell factory engineering and precision fermentation, they design custom-made microbes to produce a wide array of bio-based ingredients, including textile dyes, skincare ingredients and health supplements.

**LOCATION:** Denmark

**HOW IT WORKS:** Octarine Bio employs an innovative approach that combines genetic engineering, metabolic pathway optimisation and advanced fermentation techniques to create high-value ingredients in an environmentally-friendly manner compared to traditional methods. Their modular manufacturing process allows for efficient and cost-effective exploration without needing to restart at each step.

**WEBSITE:** www.octarinebio.com

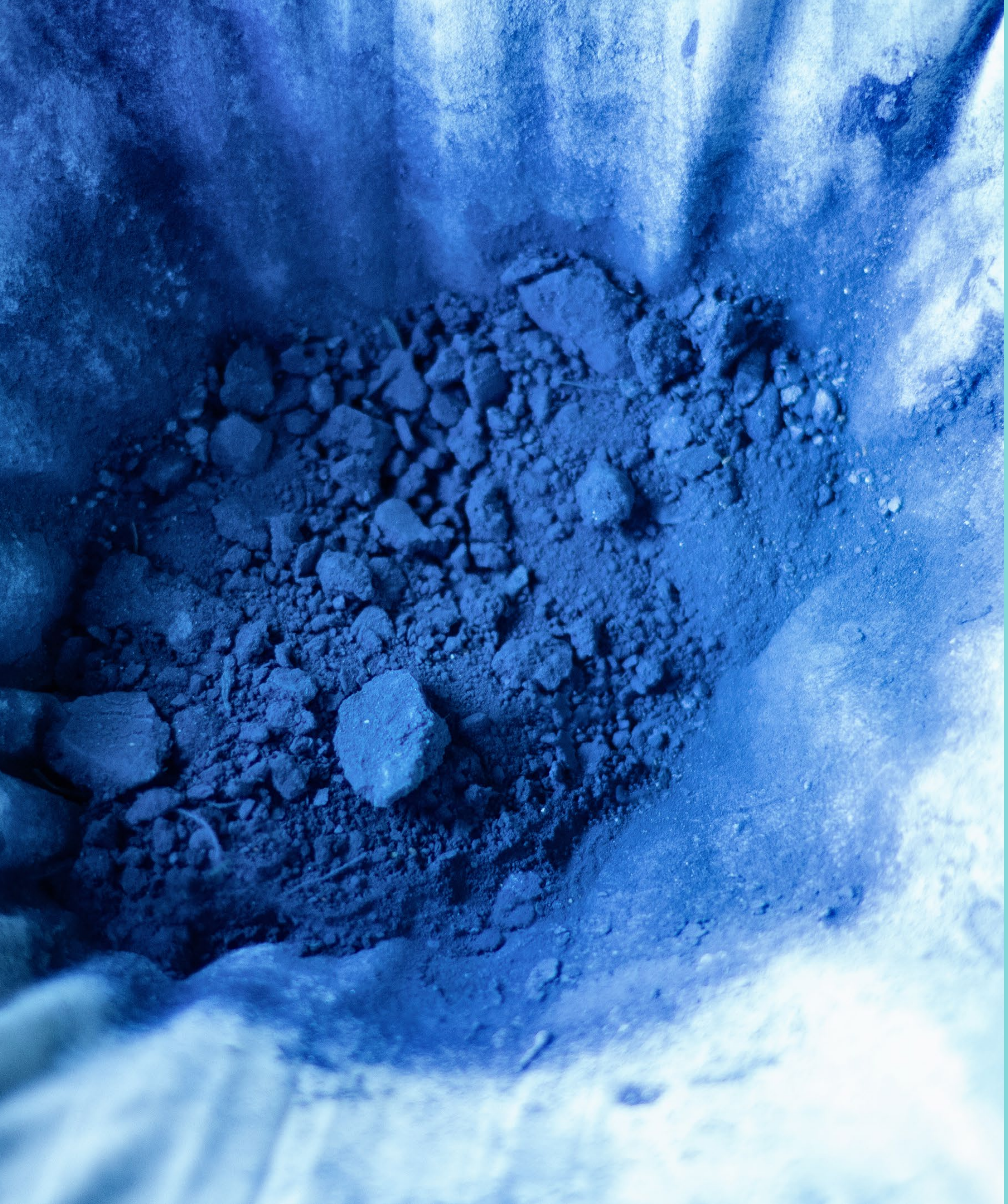
## SeaDyes

**ABOUT:** SeaDyes is a dye innovation for the textile and fashion industries made from seaweed.

**LOCATION:** Scotland

**HOW IT WORKS:** SeaDyes applies nature-based solutions from provenance to product. It aims to apply leading marine science and sustainable aquaculture from the beginning of the supply chain, down to blue chemistry for processing and application methods.

**WEBSITE:** www.seadyes.com



# Standards & certifications

## INTRODUCTION

Standards and certifications refer to established guidelines that ensure products and processes meet specific criteria for quality, safety, environmental sustainability and social responsibility. These serve as benchmarks for product and process quality assurance and performance. By adhering to recognised standards, companies can enhance market competitiveness, attract consumers and build credibility in their brand.

Standards and certifications are typically set by private-sector organisations and accessible for adoption by any entity, whether private or governmental. Adherence to standards demonstrates a company's commitment to responsibility; however, it should be noted that standards are different from regulations, and compliance with a standard does not guarantee compliance with applicable laws.

**Does 'Standards' and 'Certifications' mean the same thing?**

Standards are guidelines that define specific requirements to ensure products and processes meet certain quality, safety and performance levels. These are not laws but offer technical requirements to follow. After meeting the standard requirements, entities receive a compliance certificate. Hence, certifications are formal recognitions issued by independent bodies to verify compliance with the standards.

Here are some commonly used standards and certifications in the textile and apparel sector:

**Bluesign** is a system that sets comprehensive criteria and guidelines for sustainable textile production, focusing on eliminating harmful substances from the beginning of the manufacturing process. This includes raw material production, textile manufacturing and finishing processes. Manufacturers can be recognised as Bluesign System partners if they comply with the standard's requirements and undergo assessments to ensure ongoing adherence to these criteria.

**The Global Organic Textile Standard (GOTS)** establishes criteria ensuring the organic authenticity of textile. Applicable throughout the supply chain, it includes processing, manufacturing, packaging, labelling, trading and distribution of all textiles made from at least 70% certified organic natural fibres. The GOTS version 7.0 was released in March 2023 and is applicable for all Certified Entities and approved chemical inputs beginning in March 2024. The version brings new requirements for risk-based due diligence in operations and supply chains.

REVECOL product range by ERCA TCS has the following certifications- Global Recycled Standard (GRS), Recycled Claim Standard (RCS), ZDHC Chemical Gateway, Bluesign and GOTS. ERCA TCS is also the first company in the world to have GRS certified chemical products. Further, with Bluesign Academy, ERCA TCS is calculating the Product Carbon Footprint (PCF) for some REVECOL products, certifying the reduction of $CO_2$ emissions compared to the use of conventional chemistry. **See page 37 for information on REVECOL.**

**ISO 14001:2015** is an international standard for environmental management systems (EMS) that does not state specific environmental criteria, but rather helps organisations to establish and implement effective environmental policies and practices. ISO 14001:2015 is applicable to all types of organisations, regardless of their industry or sector.

**ISO 50001** is an international standard for energy management systems (EnMS). It provides a framework for organisations to establish, implement, maintain and improve energy management practices, with the goal of enhancing energy efficiency, reducing energy consumption and improving overall energy performance.

OEKO-TEX® CONFIDENCE IN TEXTILES DETOX TO ZERO

**OEKO-TEX DETOX TO ZERO** strives to eliminate hazardous chemicals from textile and leather production. It is not a certification, but a management system determining and analysing Manufacturing Restricted Substances List (MRSL) compliance of chemicals used in textile and leather production, reporting the conformity status and outlining improvements. DETOX TO ZERO helps manufacturers and purchasers, as well as brands and retailers, monitor and fulfil the Greenpeace Detox Campaign objectives. The system targets wet facilities in the textile and leather industry supply chains.

**Restricted Substances List (RSL):** The AFIRM Group have created what is the de facto global RSL that allows brands to trade globally without risking the placement of harmful substances in the apparel and footwear supply-chains. RSL is a list of chemical substances restricted or banned from manufacturing products due to their potential harmful effects on human health or the environment.

**Manufacturing Restricted Substances List (MRSL):** MRSL is a specific subset of RSL that focuses on chemicals and substances restricted during the manufacturing process, particularly in textile and footwear industries.

OEKO TEX® ECO PASSPORT

**OEKO-TEX ECO PASSPORT** aims to ensure the safety and sustainability of chemicals used in textile and leather production by verifying that chemicals (such as dyes, pigments and auxiliaries) meet specific ecological and toxicological criteria. Chemicals used for the manufacture of textiles and leather materials can be certified. The standard is designed for textile and leather chemicals only.

Colorifix dyes are certified with OEKO-TEX ECO PASSPORT. **Please see page 31 for information on Colorfix.**

OEKO TEX® STANDARD 100

**OEKO-TEX STANDARD 100** aims to ensure textile products are free from harmful substances and safe for human health by setting criteria for the testing and certification of textiles at all stages of production. Certification applies to all textile articles in every stage of processing, starting from raw materials and threads to finished fabrics and garments or home textile products. STANDARD 100 considers relevant requirements as per the SVHC Candidate List from REACH. It promptly updates its requirements to incorporate important discussions and developments. This standard is for textiles and textile accessories.

**SVHC** stands for "Substances of Very High Concern," and it refers to chemicals that are identified as potentially harmful to human health or the environment according to the REACH regulation. Once a substance is included on the SVHC Candidate List, companies are required to provide information about its use in products if the concentration exceeds specific thresholds and to communicate safe use practices down the supply chain.

OEKO TEX® STeP

**OEKO-TEX Sustainable Textile & Leather Production (STeP)** standard aims to promote environmentally friendly production processes throughout the textile and leather supply chain. The standard applies to facilities at all processing stages of textile and leather production. STeP differs from other standards because it includes a comprehensive analysis of overall production conditions (environment, safety, social and efficiency), rather than just isolated aspects.

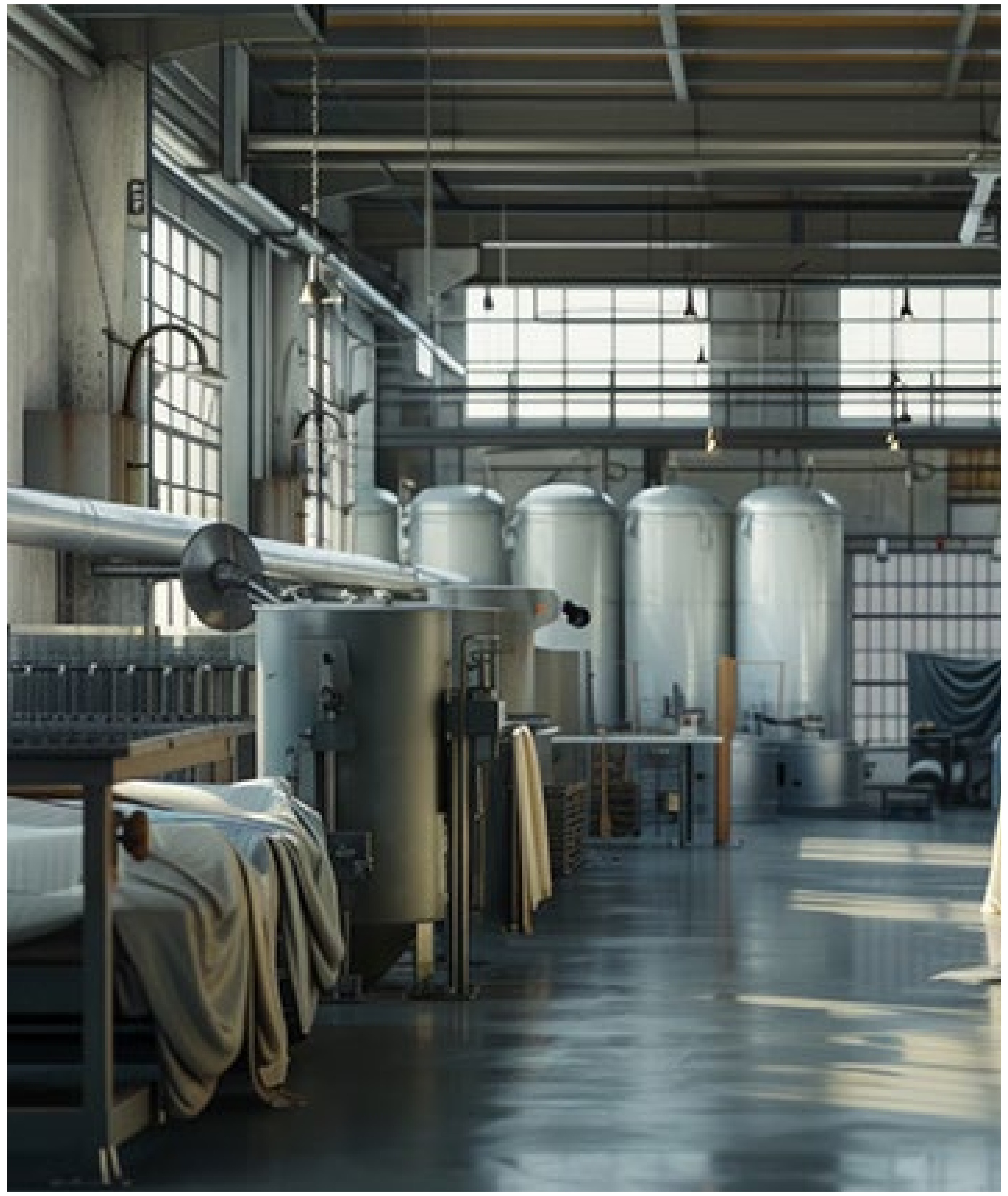
Ø ZDHC

**ZDHC (Zero Discharge of Hazardous Chemicals)** is a collaboration of major brands, suppliers, and associations in the textile, apparel and footwear industries. ZDHC Gateway is an online platform that provides chemical suppliers with a centralised resource to submit and share chemical information for compliance with ZDHC's MRSL. The platform aims to promote the adoption of safer chemicals and practices within the textile industry.

# Dye recycling

## INTRODUCTION

Dye recycling involves the recovery and reuse of dyes from textile waste and wastewater in textile manufacturing and dyeing processes. This practice is important as it reduces environmental impact by preventing the discharge of untreated wastewater containing dyes into water bodies and extending the life cycle of dyes through recycling. Moreover, dye recycling can also facilitate the recycling of textiles.



DYE RECYCLE

## DyeRecycle

**Year founded:** 2022

**Location:** London, United Kingdom

**Founding team:** Dr. Aida Abouelela (Founder and CEO), Prof. Jason Hallett (Founder and Chief Scientific Officer CSO)

**Business size:** Micro-sized (1-9 employees)

**Website:** www.dyerecycle.com

### ABOUT

DyeRecycle is dedicated to leading the charge for chemical circularity in the fashion sector along with fibre circularity. DyeRecycle is the first-to-market technology to provide a chemical circularity concept in the textile industry. The process involves decolourising textile waste and reusing the extracted dyes. They offer recycled synthetic dyes as a product or circular dyeing using recycled dyes as a service.

Their holistic approach simultaneously tackles two key challenges spanning the textile supply chain: the environmental harm from dyeing processes and the mounting problem of textile waste.

### HOW IT WORKS

The DyeRecycle technology utilises a non-volatile solvent to recycle the dyes from textile waste, and the process operates at moderate temperatures and near ambient pressure. These unique process conditions translate to plug-in configuration to existing supply chains and the use of the same equipment rated for water-based systems.

### MARKET PRESENCE

Currently operating at a pilot-scale, DyeRecycle produces fibres and fabric at the kilogram and metre levels, respectively. These paid pilots are conducted with two of the largest textile manufacturers/retailers in the world along with a mechanical and chemical polyester fibre recyclers, aiming to produce 250,000 tons/year of recycled polyester by 2031.

“

**In terms of future exploration, the current emphasis is on the market integration of innovations, working towards seamlessly incorporating circular technologies into existing manufacturing processes. This presents notable challenges, particularly in terms of adapting supply chains for circularity. Striking a balance between creating circular supply chains and operating alongside existing systems poses a considerable technical challenge.**

**Also, the adaptability of these technologies to handle both existing materials and new materials entering the market remains a crucial aspect, for example, in terms of our textile dye recycling technology, adapting to alternative textile dyes that will be incorporated in these circular supply-chains. The goal is to address the environmental impact associated with manufacturing whilst supporting innovation**

- DyeRecycle

## INTERVIEW WITH JASON HALLETT

We interviewed Jason Hallett, Professor of Sustainable Chemical Technology within the Department of Chemical Engineering at Imperial College London, to gain insights into chemical circularity and its impact on sustainability in textile and apparel dyeing.

Refer to the bio in **Appendix 4**.

**Q. Why do you believe the current textile dyeing stage needs to be targeted from an environmental perspective?**

A. The most glaring issue is water usage, but there are other subtle, yet impactful problems. Textile dyeing consumes large amounts of energy, contributing to a high carbon footprint in textile manufacturing. Sustainable dyeing is crucial to lower this energy footprint, reduce the environmental burden of dye manufacturing, and address the toxicity of dyes and fibres. **Recycling dyes is preferable to avoid releasing harmful chemicals into the environment.**

**Q. Why is sustainable chemistry important in the textile dyeing stage?**

A. Sustainable chemistry aims to use resources at a rate equal to their replenishment, minimising environmental impact. In textile manufacturing, the industry is currently unsustainable, with vast resources invested in production and minimal recycling. Sustainable chemistry focuses on making the products themselves more environmentally friendly, reducing the need for disruptive changes in consumer behaviour. It complements bulk reuse and recycle approaches, providing a holistic solution to make textiles more sustainable. **Sustainable chemistry in textile dyeing aims to reduce dye manufacturing and use alternatives to conventional dyes or minimise the reliance on fossil fuel materials. It’s about making the dyeing process itself more sustainable**, for example with considerations for natural dyes. However, the sustainability of natural dyes remains an open question, as historical practices like using snail shells demonstrate their environmental harm.

“

**Recycling dyes is preferable to avoid releasing harmful chemicals into the environment**

**Q. You mentioned that chemicals currently go through a linear lifetime. What's the impact of that chemical process being linear instead of circular? Why do you think that in the textile dyeing stage, chemical circularity is important?**

A. We are predominantly using fossil fuels as source material for dyes, depleting this non-renewable resource, which brings with it immense environmental burdens. **Implementing circularity strategies at the end of life of a textile dye reduces the need to manufacture new dyes.** The second aspect is the longevity of chemicals compared to garments, since chemicals have a much longer lifetime. **Adding circularity ensures the chemicals embedded in textiles are in continued use, reducing pollution from continuous manufacturing.** Ultimately, it lessens the environmental impact of the whole dyeing process.

**Q. Could you elaborate on what you envision as more sustainable alternatives in the colouration stage of textile dyeing?**

A. From a recycling standpoint, my research team remains agnostic about specific chemicals, because we focus on the actual recycling of those dyes. **If more sustainable dyes become prevalent in waste fabrics, our recycling processes would naturally adapt to incorporate these alternatives.** The real challenge lies in transforming the entire chemical manufacturing process into a sustainable one, which emphasises the fact that the focus shouldn't solely be on dyes. The existing chemical industry wasn't even originally designed with the primary goal of producing dyes, **so it's imperative to address the broader sustainability of chemical production to reduce environmental impact.**

**Q. Moving beyond the production of chemicals and going into recycling, can you shed light on how the decolouration of fibres influences the efficiency of fibre-to-fibre recycling?**

A. Decolouring fibres primarily impacts the consumer-facing aspect of the recycled product, allowing to offer more alternatives when it comes to the colour shades of the recycled fibres. Usually, when melting mixed textile waste, colours tend to amalgamate, restricting recycled fibres to specific shades of colours that depend upon the colours of the textile waste input. The removal of colour in the recycling process becomes a critical factor in making the recycled fibres into a consistent product that can later be dyed to match the shades of virgin fibres. While the act of colouring itself doesn't necessarily damage the synthetic fibres, it does limit the application of specific colours to recycled materials, which poses challenges in terms of recycled material variety for consumers.

## Officina+39

**Year founded:** 2009

**Location:** Piedmont, Italy

**Founding team:** Venier Andrea (Managing Director)

**Business size:** Small sized (10-49 employees)

**Website:** www.officina39.com

### ABOUT

Officina+39 has 30years of expertise in textile research and chemical applications and offers a range of chemical specialties, dyestuffs and pigments.

The company's flagship product is Recycrom, a complete range of pigment powders from 100% recycled used clothing, fibrous material and textile scraps and obtained through a state-of-the-art upcycling process. The technology has evolved to offer brands sustainable colouring solutions through Recycrom Ready to Dye, featuring a range of 15 standard stock-ready colours.

### HOW IT WORKS

Officina39 has developed a technology to transform pre- and post-consumer textile waste (recycling used clothing, fibrous material and textile scraps) into coloured powder. This led to the Recycrom range.

Recycrom can be applied on cotton, viscose, Tencel, wool, linen, polyamide plus other natural fibres and blends (with limitation on polyester).

It can be applied in:

- Exhausting dyeing by garment dyeing
- Dipping by garment dyeing
- Spray by garment dyeing
- Screen printing by garment and fabric dyeing
- Coating on fabric dyeing
- Fabric Dyeing (in progress).

### MARKET PRESENCE

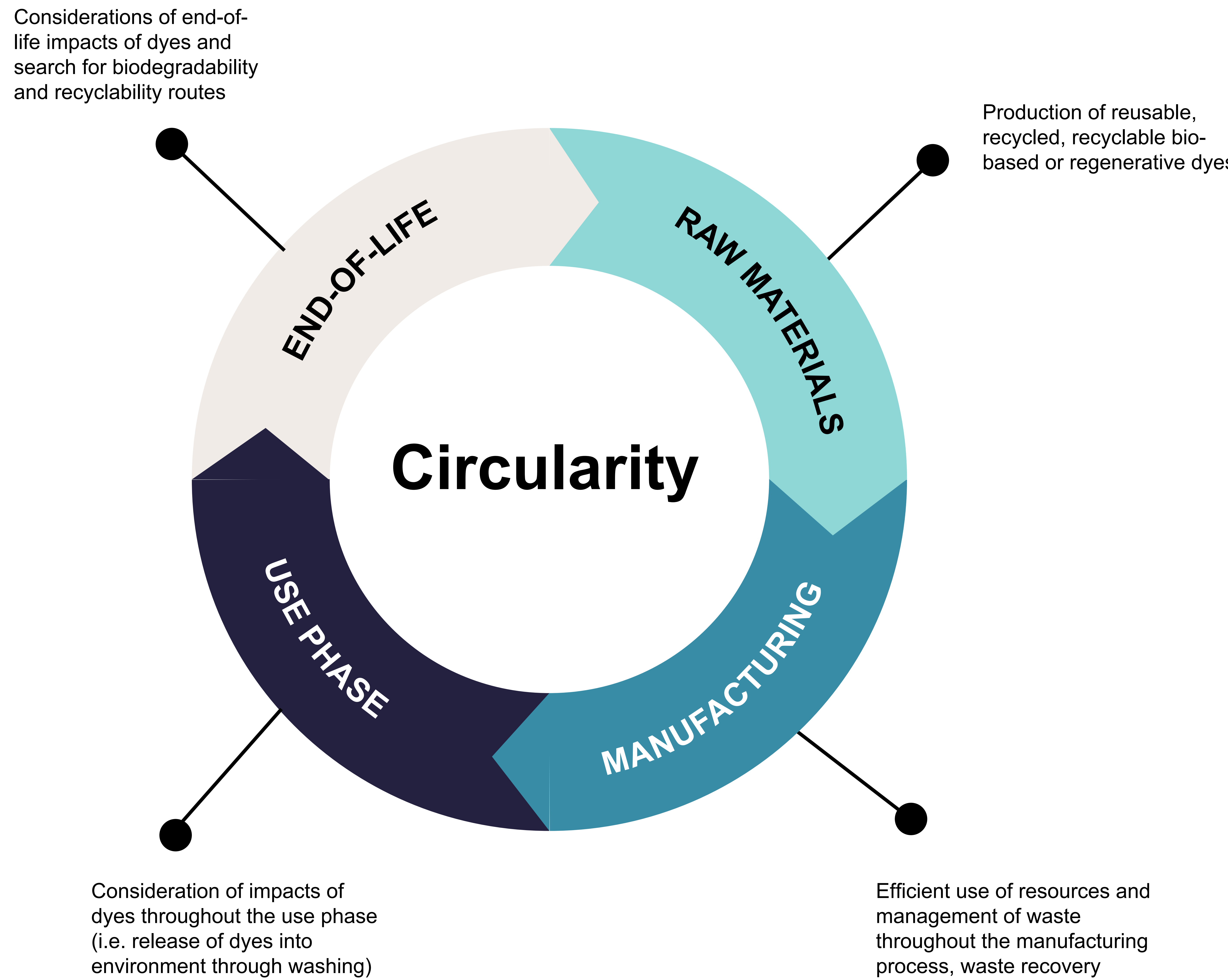
Recycrom started its first brand collaboration in 2018 for garment dyeing. Following that, the technology has evolved into Recycrom printing for fabric and garment and Recycrom GEL which is a waterless process. The company has collaborated with brands like Pangaia, Stella McCartney, Tommy Hilfiger and OVS.

Officina39 also offers brands the opportunity to collaborate on creating custom Recycrom Pure dyes using their own scraps and textile waste.

> **Engaging with end customers helps understand the market's true needs, preventing energy wasted on unsuitable technologies and focusing on practical and adaptable solutions**
>
> - Officina+39

# Circularity

The above sections of the report highlight the key areas of intervention to reach environmental impact reduction from raw material, to production, to end of life. This section of the report highlights the importance of considering circularity throughout the whole lifecycle of dyes (25):



## INTERVIEW WITH RICHARD BLACKBURN

We interviewed Richard Blackburn, Professor of Sustainable Materials at University of Leeds, whose research focus centres around the principles of sustainability and how these principles can be applied in the fields of material science, colouration technology and cosmetics (Refer to the bio in **Appendix 5**), in order to understand the importance of a wholistic and circular approach to environmental impact reduction in textile and apparel dyeing.

### Q. Why is it important to tackle textile and apparel colouration from a sustainability lens?

A. **I believe the key aspect is to look at textile dyeing from the perspective of circularity. Sustainability can mean various things, but what's increasingly vital is understanding the lifecycle of colourants. This involves their origins, manufacturing methods (whether from virgin petrochemicals or plant-based sources) and their environmental impact.** Simply being natural doesn't guarantee sustainability; poor agricultural practices can negate benefits.

Then there is application efficiency—minimising energy and water usage during dyeing processes is crucial but often overlooked in sustainability discussions, despite its economic relevance. The lifecycle impact might hinge more on energy and water savings than on the dyes themselves. Effective synthetic dyes can minimise wastewater and chemical auxiliaries, which highlights the point that sustainability isn't solely about the dyes but also their application and waste production.

Research into biodegradation of dyed fibres highlights concerns about slow degradation and potential toxic by-products. Some degradable fibres release dyes, which can persist in the environment and impact ecosystems. This is important as it challenges assumptions about the environmental benefits of biodegradation. Toxicology assessments throughout the lifecycle are thus essential.

Circularity is also about recovering and recycling dyes and this, in turn, could significantly enhance sustainability. Reusing dyes across product generations could reduce the need for new synthetics and make a much-needed future shift in dye innovation.

### Q. What are your thoughts on the future directions of sustainable colour and dye chemistry research in textile dyeing?

A. Some key aspects to consider would be waste and end-of-life products as they are valuable resources. Finding better ways to produce dyes such as cell-based production of natural dyes is important. We must also focus on the process, identifying where we can save energy and reuse water, which are significant issues in textile dyeing.

**Energy and water conservation can have a bigger impact than any dye innovation. These measures are crucial because most textile dyeing occurs in regions like South-east Asia, China and India, where energy is primarily coal-generated. Consequently, reducing energy reliance is more feasible than rapidly switching to green energy in major manufacturing countries.**

Plus, innovations in the dyeing process must be compatible with existing supply chains and practical for widespread adoption.

SC-$CO_2$ dyeing, for instance, requires expensive new machinery and skilled human resources which has hindered its success. **Sustainable innovations should work with minimal intervention in existing dye houses to be truly impactful. Scientific advancements are commendable, but practical implementation on a large scale is essential for real change.**

**Q. Any recommendations you have for the industry to switch to sustainable textile dyeing practices?**

A. **Anything that saves energy and water or minimises waste is beneficial. Instead of looking at waste as something to handle/ process, we should focus on using it. Same goes for textile dyes. How can we be smarter with textile waste and wastewater?** Instead of viewing it as something to dispose of, we can find ways to reuse it for different purposes, turning waste into value. This approach not only reduces waste but also makes economic sense.

> **Sustainable innovations should work with minimal intervention in existing dye houses to be truly impactful. Scientific advancements are commendable, but practical implementation on a large scale is essential for real change**

# Conclusion & recommendations

## Conclusion & recommendations

It is pivotal for the textile and apparel manufacturing sector to embrace green transformation. The dyeing stage, particularly, presents significant opportunities for improvement in the environmental impact areas of energy, water and chemicals.

However, the direction of travel is not easy, and there are inherent complexities to navigate. First, a transition to greener dyeing capacity requires cleaner production in the industrial processes involved in textile and apparel dyeing. Whilst throughout the years improvements have been made in the restriction of toxic chemicals used in production, there are still possibilities to progress in energy and water conservation. In fact, energy and water conservation practices can have a bigger impact than any dye innovation.

From an energy perspective, coal is still heavily used in manufacturing countries to generate electricity and for thermal heating, which are essential steps for the dyeing and finishing stages. A transition towards cleaner energy sources is a fundamental step. Scope 3 emissions should therefore be prioritised in the decarbonisation strategies of the textile and apparel sector. Moreover, improving the overall efficiency of boilers and generators serving the entire factory and invest in new machinery can significantly reduce the impact across all machines and processes. It is key not to divert the attention from the unresolved fundamental issues of the textile and apparel wet processing stage.

Whilst the innovative landscape of textile and apparel dyeing has been incubating for the past decade, it is still messy. The impacts of the dyeing stage are distributed across different environmental impact areas and stages, and there is therefore not one solution.

Innovations in technology are flourishing, whether contributing to energy and water conservation or both, sometimes even making the textile and apparel dyeing process water free. There are even developments happening exploring the use of nano-technology for textile and apparel dyeing. However, many of the new technological developments cannot be plugged in easily into existing supply chains and industrial facilities, making the economic investment needed for this transition very high. It is essential that these new technologies can be integrated with minimal intervention into existing manufacturing facilities, to scale.

When it comes to colour, innovations in synthetic biology, biotech, bio-engineering, sustainable chemistry, blue chemistry and beyond, are revolutionising the way colours have been traditionally produced, moving away from natural and synthetic dyes solely. New colours could lead to the elimination of the high level of toxicity of current dyes. However, many of the innovations in colouration and pigment do not lead to the same material properties and options (i.e. colour gamut) as conventional dyes and their development is still at low TRL levels. Also, it is important to consider the auxiliary chemicals and other components used in the process that are added to reach the necessary properties (i.e. dyeing performance, colour fastness) in order to classify a dyed product as sustainable.

Finally, the recycling of dyes at the end of life is an area of critical importance and it has, for the most part, been underexplored. The amount of textiles ending up incinerated or in landfill are progressively increasing, and with that, the dyes that are released into the environment, without having reached their end-of-life. Recycling dyes might even eventually facilitate the recycling of textiles, for example, extracting the dyestuffs prior to the fibre-to-fibre chemical recycling process. It is therefore essential to consider the whole lifecycle of the colourant.

It is crucial for textile and apparel manufacturers, brands, retailers, and innovators to collaboratively adopt strategic approaches that prioritise sustainability in the dyeing stage. By securing investments in sustainable technologies, establishing long-term commercial relationships, and collaborating with innovators, these stakeholders can drive significant advancements in the industry. Implementing these strategies within existing industrial frameworks and products and conducting pilot programs will ensure that new technologies and colour innovations are both practical and effective, ultimately leading to a greener future for textile and apparel dyeing.

# Appendix

## Appendix 1: Research Methodology

Below is an outline of the approaches used to capture contemporary expertise and best practices in sustainable textile and apparel dyeing:

**PRIMARY RESEARCH**

- In-depth interviews with industry experts to gain insights into the history of textile and apparel dyeing as well as challenges, innovations and opportunities in the landscape.
- Field Visit to Pincroft, one of Europe's largest commission dyers and textile finishers with 130 years of experience, featuring fully integrated textile processing and finishing operations, expert staff, state-of-the-art machinery and excellent testing facilities. The UKFT team visited the Pincroft facility in Lancashire, UK, where they observed the dyeing processes and sustainable methods implemented. The team also interviewed the Pincroft team to gain deeper insights into their operations, innovative practices, challenges and recommendations for dyeing mills aiming for sustainability.
- Developed and circulated a questionnaire template to innovations (in sustainable textile and apparel dyeing) identified from desk research. The questionnaire helped gather information on these innovations, including the products they offer, their applications and how they contribute to sustainability.

**SECONDARY RESEARCH**

- Reviewed existing literature, industry reports and case studies on textile and apparel dyeing innovations, best practices and case studies.
- Explored UKFT network and desk-based research to identify innovations (companies, start-ups) in sustainable textile and apparel dyeing. The emphasis here was on resource-efficient processes.

**COLLABORATION WITH MANUFACTURING TECHNOLOGY CENTRE (MTC)**

- Partnered with MTC to foster the gap between academic research and industry practices when it comes to textile and apparel dyeing. For this, MTC conducted desk-based research and identified novel technologies developed in the last 10 years for the dyeing stage that contribute to reducing environmental impact.

MTC explored these technologies and highlighted their advantages compared to conventional dyeing techniques and processes based on the information available in the public domain. This section of the report intends to provide clarity and clear understanding of these technologies.

- The desk-based study of novel textile dyeing technologies was focused only on the latest developments more specifically in the last 10 years with claims of environmental benefits. Although the search was limited to the information available in the public domain, multiple credible sources were used to explore, compile, structure, analyse, down-select and present the vast amount of data in the most usable format
- Information collected targeted eco-friendly textile and fabric dyeing technologies which offer energy savings, water conservation and claims to reduce pollution due to excessive use of chemicals in traditional dyeing processes. The search included companies in textile and apparel manufacturing, dyeing experts, professionals associated with the fashion industry, and certifications and standards which can lead to relevant technologies.

## Appendix 2: About Phil Patterson

Phil Patterson is the Managing Director of **Colour Connections Textile Consultancy** which provides advice, information and training on dyeing, printing, finishing, colour management, restricted substances management and sustainability to all parts of the textile supply chain from industry through to retail. He has long experience in textile dyeing, including a decade as the Dyeing, Printing and Finishing Manager at M&S. Phil has led eco-efficiency of dyehouses for the UK government and World Bank. He is on the Apparel Impact Institute Climate Solution Portfolio advisory council, a founder member of the AFIRM Group and chairs the ZDHC MRSL and wastewater councils. Also, he co-founded the RITE (Reducing the Impact of Textiles on the Environment) Group to reduce the environmental impact of textiles.

## Appendix 3: About Ruth Lloyd

Ruth Lloyd is a textile design-led researcher and PhD candidate at Central Saint Martins with the Living Systems Lab. Her research is in partnership with and funded by Colorifix in collaboration University of the Arts London. She develops practice-led research focused on the potential of microbial colourants for industrial textile printing, investigating how living colour systems present solutions and replacements to the global reliance on toxic petroleum-based colour and dye systems.

## Appendix 4: About Jason Hallett

Jason Hallett is the Professor of Sustainable Chemical Technology within the Department of Chemical Engineering at Imperial College London. His academic career has been dedicated to developing emerging sustainable technologies and translating them into commercial practice. His publication record has mainly focused on biorefining, and his group has been developing an ionic liquid biorefinery process, ionoSolv, toward commercial reality since 2014. He co-directs the UK's National Supergen Bioenergy Hub and holds a Royal Academy of Engineering Chair in Emerging Technologies. Jason has published over 160 papers with more than 30,000 citations and has secured over £40 million in research funding. He leads a team of 26 PhDs and postdocs (plus 15 Masters) students and collaborates with 30 researchers in spin-out companies.

## Appendix 5: About Richard Blackburn

Richard Blackburn is a Professor of Sustainable Materials at the University of Leeds. He researches sustainability in materials science, coloration technology, and cosmetics, focusing on textiles and natural dyes like anthocyanins. He co-founded Keracol Limited, a company that extracts and purifies active molecules from plants. He is a Liveryman of the Worshipful Company of Dyers of The City of London and has received numerous awards, including the Silver Medal and Fellowship of the Society of Dyers and Colourists. He also co-founded and was director of the RITE Group.

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# Glossary

| TERM | DEFINITION |
|---|---|
| Batch dyeing | In batch dyeing, a specified amount of fabric (the batch) is dyed in a single load. The fabric is immersed in a dye solution and the process continues until the desired color is achieved. |
| Bio-based dyes | Dyes derived from biological sources, such as plants, animals, or microorganisms, as opposed to synthetic dyes made from petrochemicals. |
| Biodegradability | The ability of a substance to be broken down naturally by microorganisms into non-toxic components over time. |
| Bioreactor | A vessel or device in which biological reactions, such as fermentation or enzyme processes, are carried out to produce or modify substances, including dyes. |
| Carcinogenic | A substance or agent that can cause cancer. |
| Certification | The process by which a product or process is verified to meet certain standards related to safety, quality, or environmental impact. |
| Chemical auxiliaries | Substances used in the dyeing process to enhance dye uptake, fixation, and overall efficiency. |
| Circularity | A system or process designed to be regenerative and sustainable, where materials are reused and recycled continuously, minimising waste. |
| Colour fastness | The resistance of a textile to losing its color when exposed to various conditions, such as washing, light, or rubbing. |
| Continuous dyeing | A method of dyeing where the fabric passes continuously through a series of dyeing steps. The fabric moves through dye baths, squeeze rollers and fixation units without stopping. |
| Decarbonisation | The reduction of carbon dioxide emissions in production, including textile production. |
| Drop-in replacement | A substitute that can be directly used in place of another product without requiring modifications to the existing system or process. |

| TERM | DEFINITION |
| --- | --- |
| Dye fixation | The process of ensuring that dye molecules are securely attached to the fibres of the fabric, improving colour fastness and reducing washout. |
| Eco-efficiency | The efficiency with which ecological resources are used to meet human needs, focusing on reducing environmental impact while maintaining economic value. |
| Electrochemical reduction | A chemical reaction induced by passing an electric current through a solution, often used in textile processing to alter dye properties or remove contaminants. |
| Energy efficient | The use of technology or processes that require less energy to perform the same function, thereby lowering overall energy consumption. |
| Exhaust dyeing | A dyeing process in which textiles are submerged in large vessels where the dye solution circulates around the material. |
| Foam dyeing | A technique that uses foam to apply dye to textiles. |
| Fibre-to-fibre chemical recycling | The process of chemically breaking down textiles into their original fibre components, which can then be reused to create new textiles. |
| Genetic engineering | The manipulation of an organism’s DNA to achieve desired traits, such as producing specific dye-producing enzymes in microorganisms. |
| Green chemistry | The design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances. |
| Green innovation | The development of new technologies or processes that have a reduced environmental impact compared to traditional methods. |
| Impregnation | The process of soaking textiles in a solution to ensure thorough saturation with dyes or other chemicals. |
| Modular manufacturing | A flexible production system where components are produced in separate modules, allowing for easy assembly and customisation. |
| Mutagenic | A substance or agent that can cause genetic mutations. |
| Nanotechnology | The manipulation of materials on an atomic or molecular scale, often used to enhance the properties of textiles, such as improving dye uptake or durability. |

| TERM | DEFINITION |
| --- | --- |
| Offshore production | The manufacturing of goods in a different country, typically to reduce costs for labour and production. |
| Petrochemistry | The branch of chemistry that deals with the transformation of crude oil and natural gas into useful products, including synthetic dyes. |
| Plasma technology | The use of ionized gas (plasma) to modify the surface properties of textiles, improving dye adhesion or imparting other desirable characteristics. |
| Plug-in solution | A ready-to-use solution or product that can be easily integrated into existing systems or processes. |
| Pre-reduced indigo | Indigo dye that has been chemically reduced to a soluble form, making it easier to apply to textiles. |
| Roap dyeing | A method where yarn is dyed in the form of a continuous rope, commonly used for dyeing denim. |
| Rotary printing | A method of printing patterns on textiles using a cylindrical roller or drum, allowing for continuous and efficient printing. |
| Screen printing | A technique where ink is pressed through a mesh screen onto the fabric to create designs, often used for detailed and multi-coloured prints. |
| Semi-batch | A process that combines elements of batch and continuous production, allowing for greater flexibility and efficiency. |
| Semi-continuous dyeing | A dyeing method that combines aspects of both batch and continuous processes, often involving multiple stages of processing. |
| Slasher dyeing | A method of dyeing warp yarns by passing them through a dye bath and then drying and sizing them in preparation for weaving. |
| Spray finishing | The application of finishing chemicals to textiles using a spray, allowing for precise and efficient treatment. |
| Standard | A set of criteria or guidelines established by an authority to ensure consistency and quality in products or processes. |
| Stenter pad | A machine used in textile finishing to stretch and set fabrics to the desired width and apply finishing chemicals. |

| TERM | DEFINITION |
|---|---|
| Supercritical $CO_2$ | Carbon dioxide that is in a state above its critical temperature and pressure, used as a solvent in dyeing processes to reduce water usage and environmental impact. |
| Supply chain | The entire network of entities involved in producing, handling, and distributing a product, from raw materials to final consumers. |
| Sustainability | The practice of meeting current needs without compromising the ability of future generations to meet their own needs, with a focus on environmental, social and economic factors. |
| Synthetic biology | The design and construction of new biological parts, devices, and systems, or the re-design of existing natural biological systems for useful purposes. |
| Synthetic dyes | Man-made dyes derived from chemical substances. |
| Toxic | A substance that can cause harm or adverse health effects to living organisms. |
| Virgin fibres | Fibres that are used for the first time in textile production, as opposed to recycled or reclaimed fibres. |

# Abbreviations

| TERM | DEFINITION |
|---|---|
| AFIRM | Apparel and Footwear International RSL Management |
| BOD | Biological Oxygen Demand |
| CapEx | Capital Expenditures |
| CMR | Carcinogenic, Mutagenic or Reproductive Toxicant |
| $CO_2$ | Carbon Dioxide |
| COD | Chemical Oxygen Demand |
| DNA | Deoxyribonucleic Acid |
| ECHA | European Chemicals Agency |
| EMS | Environmental Management System |
| EnMS | Energy Management System |
| ETP | Effluent Treatment Plant |
| FTR | First Time Right |
| GDP | Gross Domestic Product |

| TERM | DEFINITION |
|---|---|
| GHG | Greenhouse Gas |
| GOTS | Global Organic Textile Standard |
| GRS | Global Recycled Standard |
| HMI | Human-Machine Interface |
| IMCRC | Innovative Manufacturing Cooperative Research Centre |
| IPPC | Integrated Pollution Prevention and Control |
| ISO | International Organization for Standardization |
| KPI | Key Performance Indicator |
| LCA | Life Cycle Assessment |
| MRSL | Manufacturing Restricted Substances List |
| PCF | Product Carbon Footprint |
| PLC | Programmable Logic Controller |
| PM | Particulate Matter |

| TERM | DEFINITION |
|---|---|
| PPE | Personal Protective Equipment |
| PWM | Pulse-Width Modulation |
| R&D | Research and Development |
| REACH | Registration, Evaluation, Authorisation, and Restriction of Chemicals |
| RISE | Research Institute of Sweden |
| RSL | Restricted Substances List |
| SC-$CO_2$ | Supercritical Carbon Dioxide |
| STeP | Sustainable Textile Production |
| SVHC | Substances of Very High Concern |
| TRL | Technology Readiness Level |
| ZDHC | Zero Discharge of Hazardous Chemicals |

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