



Chemical Circularity in Fashion

BY PHIL PATTERSON, COLOUR CONNECTIONS CONSULTANCY LTD

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STUDY COMMISSIONED BY

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1. Report Summary

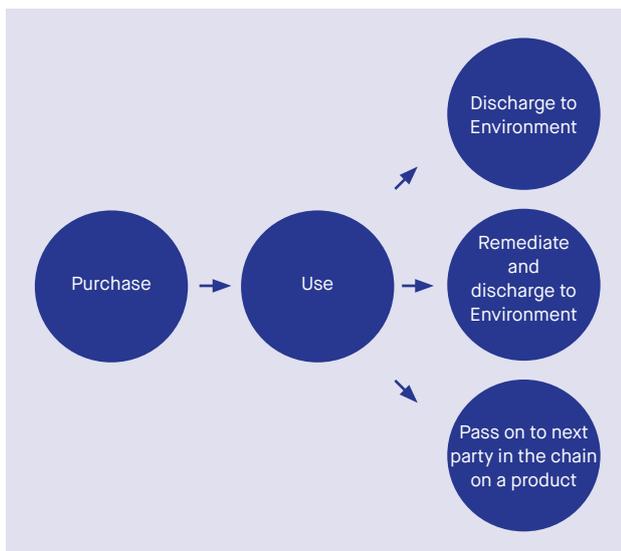
BACKGROUND

The fashion industry has to change its relationship with chemicals as a matter of urgency.

The way in which chemicals are currently used and disposed of makes textiles the second most polluting industry in the world. Furthermore, the extraction, production, transportation and remediation of those chemicals are a significant contributor to climate change.

As world fibre consumption passes 100 million tonnes per annum, the time has come to take a step back and challenge whether current, **single-use** models for chemicals used in the conversion of fibres to finished textile products should be allowed to continue.

Chemicals are used in yarn spinning, weaving, knitting and wet processing (e.g. dyeing, printing, finishing, laundry) and are typically used once only. After use in a particular process, they are either passed to the next actor in a supply chain on a product, removed and dumped into the environment, or partially remediated and dumped into the environment.



This can be described as a single-use **linear** model because there is usually no attempt to recycle or reuse the chemical prior to disposal.

This report is aimed at providing chemical suppliers and chemical users in the supply chain with recommendations and suggestions on how to move away from single-use linear models and increase the recycling and reuse of textile chemicals – referred to in the report as **non-linear** use models.

The recommendations and suggestions for change include a call for the wider use of existing good practice and the need for research and development. The intention is to highlight what **is** possible, what **should be** possible and what **could be** possible. This therefore raises many questions that will need to be addressed from both a technical and behavioural perspective.

In order to deliver significant change in the industry, there will have to be significant changes in ways of working, which may only be possible with technical changes in chemical formulations, processing methodology, machinery, infrastructure and logistics.

Inevitably, there will be some economic barriers to implementation, and some levers, in the form of incentives or controls, will be required to facilitate some changes.

It is therefore important that key stakeholders such as retail brands, policy makers, legislators and NGOs, which have a track record of driving change throughout the industry, understand the urgent need for radical change, understand what is possible and work collaboratively to enable non-linear use models to flourish.

It is envisaged that an advisory board of industry representatives and other key stakeholders will be formed to oversee the transitions from single-use linear models to chemical circularity.

The report provides a preliminary roadmap for the industry to move towards chemical circularity, and key concepts are presented in an accessible way that requires an elementary understanding of the fashion and textile industry. A very basic understanding of the chemical processes involved is helpful to the reader but not essential.

SUMMARY AND CONCLUSIONS

The report concludes that there are two key issues that must be addressed:

- Reduce net chemical consumption i.e. the total amount of chemicals used;
- Reduce chemical discharge to the environment.

There are two complementary approaches to achieving this:

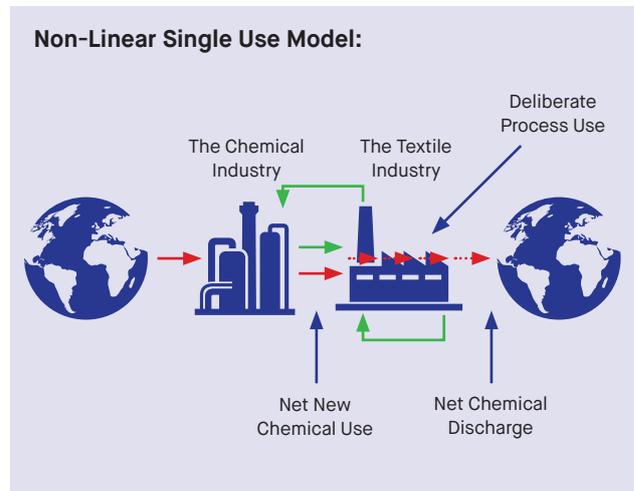
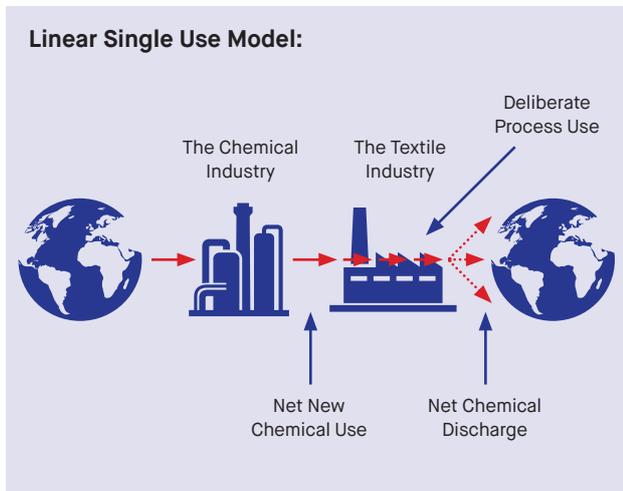
- Using lower amounts of chemicals by reducing the amounts deliberately applied in any given process;
- Increasing the amounts of chemicals that are reused and recycled by applying non-linear use models.

‘Chemical Leasing’ has been proposed as a potential solution to the problems caused by current chemical use models in the textile industry. On the face of it, chemical leasing is a slightly abstract concept where companies sell the **function of a chemical** rather than the volume of a chemical.

The report seeks to bring the abstract concept to life and provide an initial roadmap from the current single-use ‘linear’ model, where chemicals are viewed as waste-in-waiting, to non-linear use models, where chemicals are viewed as valuable resources that are reused, repurposed and recycled.

In the current single-use linear model, a relatively small number of chemical companies sell chemicals to a relatively large number of textile manufacturing facilities, which pass those chemicals down the production chain until they are removed and discharged to the environment.

When viewed on a macro scale, it can be seen, schematically, that reuse and recycling (as denoted by the green arrows) will reduce net chemical use and discharge to the environment:



It is understandable that many industry observers have called for extended supplier responsibilities – a situation where the chemical suppliers shoulder the responsibility for collection and disposal/remediation of the chemicals used in the textile industry.

This report argues that the chemical industry has a huge part to play in the way non-linear models are applied, but the key to catalysing radical, scalable change is to make the chemical **user** take responsibility for the chemicals they use and never pass on any unnecessary chemicals down the chain on a product unless absolutely necessary.

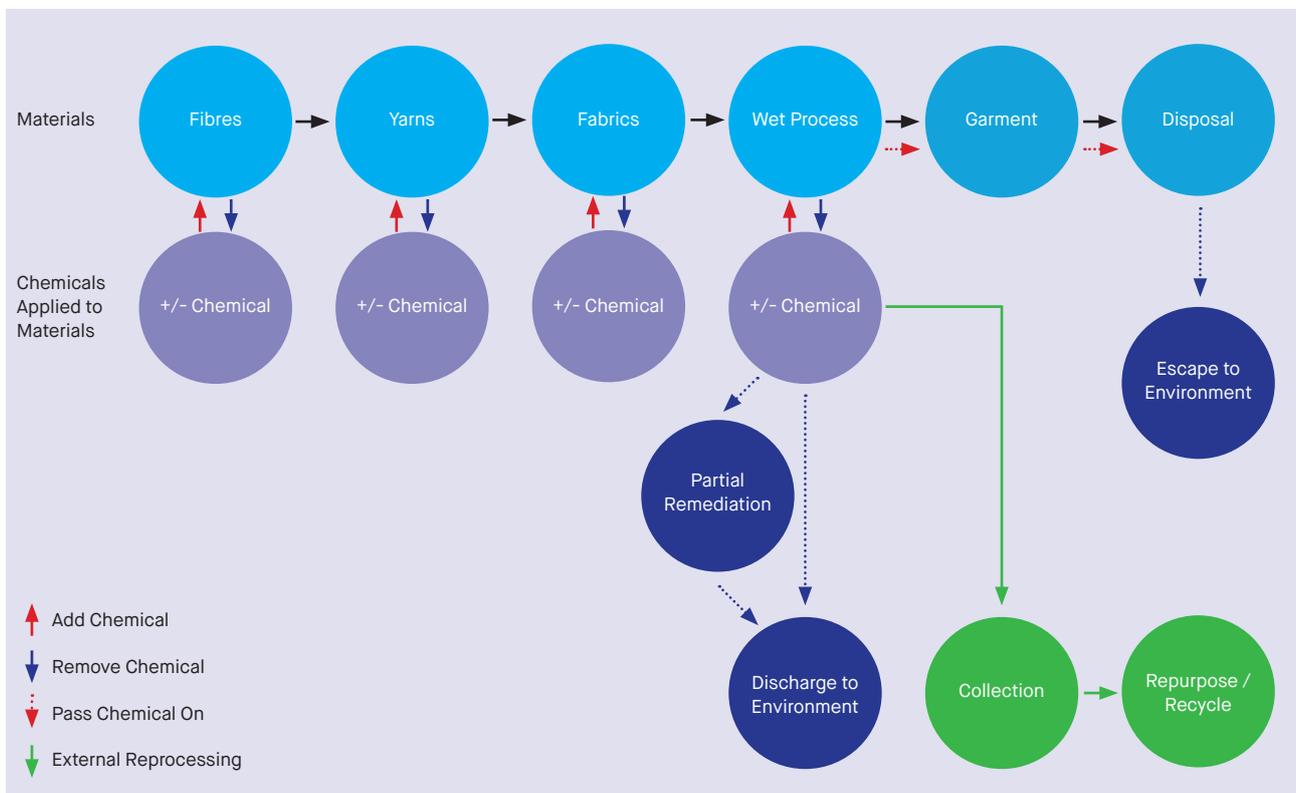
This Chemical User Responsibility Model (CURE Model) is easiest to explain by considering weaving as an example since it is a relatively simple process from a chemical perspective. Prior to weaving, a type of non-permanent ‘glue’ called weaving size is applied to yarns to protect them from damage during weaving. This chemical is almost always passed on to a dyer or printer on the woven fabric, and they have to remove it prior to dyeing or printing.

If all weavers were required to remove weaving size and send a clean fabric with no chemicals present to a dyer, what would the weaver do?

Would they use a non-recyclable size, such as starch, and build an expensive effluent treatment plant to remediate the effluent, or use a recyclable, soluble size, collect it and reuse it? The answer, hopefully, is fairly clear, and the CURE model would open the door for ‘size management’ companies to offer chemical leasing services.

When viewing non-linear use models on a sub-process level (with weaving included in the ‘fabrics’ box in the diagram below), it can be seen that moving responsibility to the user and pushing chemical management responsibility **up** the supply chain will reduce the amount of chemicals reaching wet processors, reduce the amounts of chemicals *they* have to use to remove upstream chemicals and thus reduce the amount being discharged to the environment.

Wet processors are currently held responsible for the remediation of all chemicals used in the supply chain. The CURE model would change this, and they would use significantly less chemicals in their processing. However, it is inconceivable that their use would drop to zero and some end-of-pipe collection by the chemical industry (indicated by the green arrows) may form part of the circular models of the future.



The diagram on the left hand page demonstrates a linear *material* flow with non-linear *chemical* use, but, interestingly, it is anticipated that a focus on chemical circularity will be an enabler of material circularity (fibre or polymer recycling). This is discussed in more detail in the main body of the report.

Despite single-use linear models dominating, there are already many excellent examples of non-linear use in the industry (including recycling of weaving size), and the report includes case studies that highlight the core concepts that make them possible and explores how they may be extended to wider parts of the industry.

In order to make non-linear chemical use models the norm, there will be a need for radical research and development. However, the chemical industry, textile machinery manufacturers and ancillary dispensing/control/engineering companies have an exceptional track record of problem solving. The main challenge will be for solutions to be rolled out at scale.

New non-linear usage models may also require a change in mindset for chemical restrictions, and the current trend of restricting input chemicals based on hazard may need to be reconsidered. The focus on chemical function may guide us towards the use of more effective, fully recyclable substances in zero exposure scenarios, and the report considers whether brands, industry groups and legislators need to rethink priorities.

It is likely that chemical companies' research archives hold tremendously effective chemicals that were never launched because they are unsuitable for dumping into the environment. However, in a post-dumping world, they may provide tremendous benefits.

What is abundantly clear is that, for non-linear use to happen at scale, there needs to be a significant improvement in chemical management in the downstream industry (spinning, knitting, weaving, wet processing), and this is potentially a huge opportunity for companies to provide expert chemical management services.

Where solutions are developed but there is a need for capital investment or significant disruption to day-to-day ways of working to roll them out at scale, there will inevitably be a need for levers to encourage adoption of non-linear use models.

As previously mentioned, good non-linear practice currently exists, but it is in the form of many small disparate processes. To promote the general approach, it is strongly recommended that they are pulled together under a simple, single coherent concept.

Throughout the report the term 'non-linear use' is used in preference to 'circularity' to give a *technically accurate* description of what is actually happening. However, for communication and promotional purposes, it is recommended that the simpler message of '**Chemical Circularity**' be used and promoted via a simple logo, similar to the way in which 'organic' or 'recycled' are currently badged and marketed.



It is suggested that brands could use simple messaging to **promote** good practice and that they **restrict** single-use linear models where viable non-linear use models already exist (such as the recovery and reuse of caustic soda in 'mercerisation', a common process to enhance dye uptake and lustre in cotton fabrics).

Ultimately brands and legislators could start to apply incentives and restrictions on the industry to reduce net chemical consumption and discharge. The report comes to the conclusion that an industry-wide adoption of zero liquid discharge, a situation where discharge of any liquid effluent is **prohibited**, could, and should, be considered in order to catalyse significant change in upstream use patterns.

The report offers a deliberately optimistic view of what is possible and what may be possible, but it is clear that there will be many barriers: some technological, but mainly behavioural and economic.

It is therefore proposed that, to take things forward, a senior advisory board of key industry stakeholders be created and placed within a highly influential industry organisation with a track record of driving change.

The advisory board would oversee the creation of a detailed roadmap, policies, standards, measurements and training to create, **from the outset**, a single vision of Chemical Circularity and what should be encouraged and discouraged.

The first and most important task of the group will be to get the industry as a whole to accept that the single-use, linear buy-use-dump model is neither sustainable nor morally defensible.

No one should be ashamed of that – it is the legacy of our forefathers and we are where we are. There is now a tremendous opportunity to make transformative changes and truly clean up our industry.

2. Introduction and Purpose of the Report

The fashion industry is huge, and the negative environmental impacts associated with the manufacture of products are also huge.

Slowly, parts of the fashion industry are beginning to accept that the current ways of working are not sustainable, and many initiatives are being started to reduce those negative impacts. Initiatives to reduce the negative impacts of product manufacturing can focus on reducing levels of consumption by end consumers, and thus the amounts produced, and/or reducing the negative impacts per unit produced.

The negative environmental impacts can be dissected into complex sub-criteria, but ultimately the key focus is on the depletion of natural resources, climate change via the emission of greenhouse gases and pollution.

Some environmental initiatives are based on avoidance of bad practice, some on the application of established good practice, some require detailed research to find a solution, and others require a change of mind-set or a different way of thinking in order to challenge normal modes of operation.

Fashion products cannot be manufactured without the use of chemicals, and over the past two decades there has been a movement, led by multi-brand groups such as Afirm, Zero Discharge of Hazardous Chemicals (ZDHC) and several regulatory bodies, to manage chemicals more responsibly.

In addition to the environmental impacts associated with the manufacture, use and disposal of chemicals in textile and leather processing, there are issues related to worker and consumer safety as a result of exposure to chemicals.

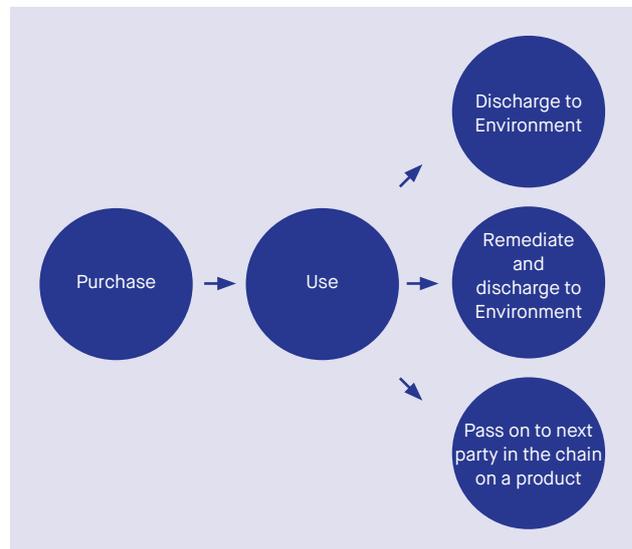
Recent efforts have therefore focused on managing the types of chemical input, to avoid harmful chemicals being used and avoid them being present in finished products or waste streams, and on the remediation of waste streams prior to discharge to the environment.

In essence, those efforts have been focused on **reducing the impacts of the standard way of working.**

This report supports those efforts but also challenges the entire relationship that the industry has with chemicals and whether the standard way of working should be changed.

Currently, most chemicals that are used in textile and leather processing are purchased, used and then either passed on to the next party in the supply chain on a product or partially remediated and discharged to the environment. Sadly, there are significant parts of the industry that discharge un-remediated chemicals into the environment.

It should also be noted that biodegradation of chemicals as they are remediated in effluent treatment plants releases greenhouse gases and contributes to global warming. Furthermore, biodegradation of chemicals in water courses (or anywhere in the environment) leads to global warming and the depletion of life-supporting oxygen.



Throughout this report, this type of single-use, ‘buy-use-discard’ or ‘buy-use-pass on’ approach to chemical use is referred to as a single-use **linear model**.

In order to reduce the amount of chemicals used in manufacturing and subsequently disposed of into the environment, we have to seek opportunities to use smaller amounts of chemicals in standard linear use models and also develop and roll out ‘non-linear’ use models.

'Non-linear' use models can involve a chemical being used multiple times before disposal/remediation or involve some level of recycling. Non-linear models can also involve diverting chemical waste away from disposal and using it as a valuable product, not necessarily in the same industry.

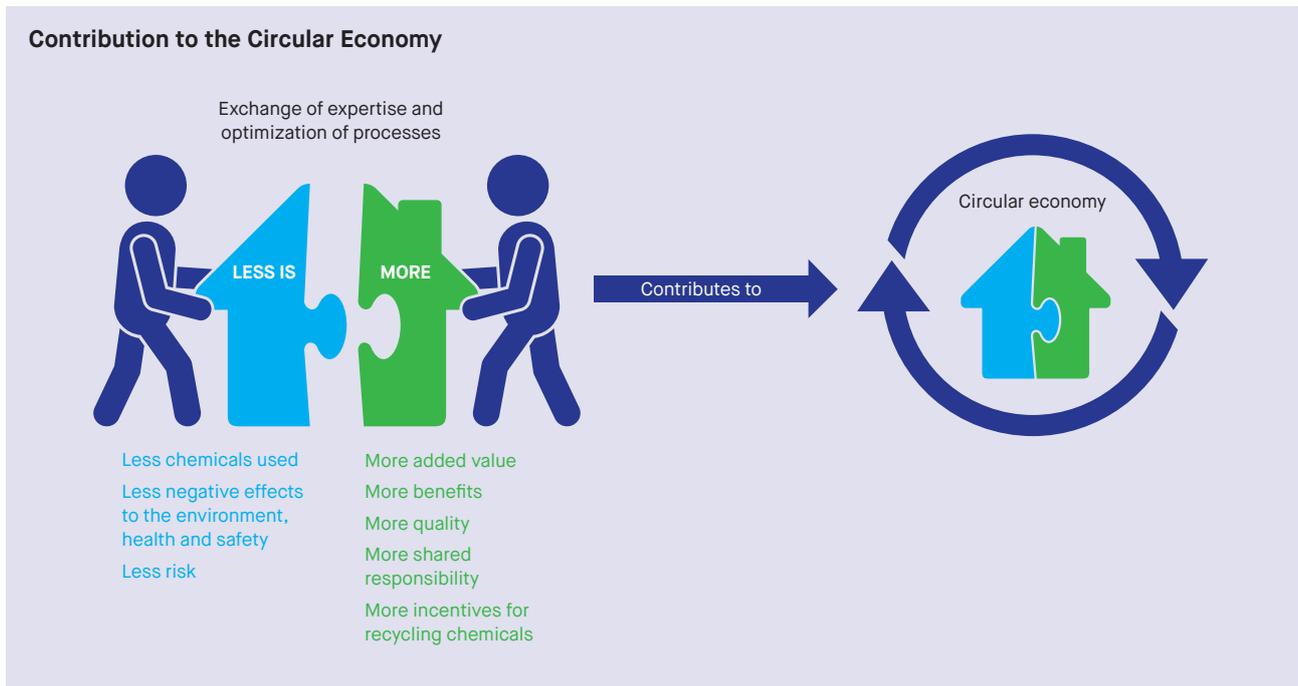
'Chemical Leasing' is an approach where the function of a chemical is the prime consideration and a company buys in chemical services rather than volumes of chemicals. An example would be where a company pays for machines to be cleaned rather than for the chemicals to clean the machines, with the supplier choosing the best chemicals for the job and using the minimum amount to do the job.

The precise definition of chemical leasing (e.g. by UNIDO) could potentially restrict the opportunities for implementing non-linear use models in the textile and leather industry, as it suggests that chemical leasing can only be applied to 'non-core' chemicals or chemicals that do **not** undergo reactions and that small companies are not ideally suited to the leasing model.

Since the textile and leather industry is largely comprised of thousands of small companies that are often directly using chemicals in core processes involving chemical reactions, there is a risk that adhering to a strict definition of chemical leasing could ignore opportunities for improving chemical management that are beneficial and, arguably, essential.

However, the chemical leasing model considers the **function provided by a chemical**, and this core concept can form the basis for a radically different way of looking at the industry's relationship with chemicals.

The aims and sentiments of chemical leasing are encapsulated in the following graphic taken from the UNIDO website. There are many opportunities to examine how the current chemical supplier-user relationship can be improved so that prioritising the **concept of chemical function** can lead to transformative change



It would be wrong to suggest that the concept of using lower amounts of more advanced/intelligent chemistry is not already being pioneered by leading textile and leather chemical manufacturers, but it would be correct to say that the use of more advanced chemistry still largely follows the single-use linear model.

The main purpose of this report is to highlight opportunities to change business models, ways of thinking and ways of working to reduce the net chemical consumption (the amount of chemicals used per unit of textile and leather production) and to reduce net discharge to the environment via:

- Less chemical use in standard processing
- More reuse and recycling of chemicals
- Genuine chemical leasing

In order to achieve significant progress, there has to be a change in behaviour with respect to how chemicals are viewed by all stakeholders in the textile supply chain, from single-use, disposable substances to valuable resources that should be used sparingly, reused or recycled where practicable and, as a last resort, discharged responsibly.

Therefore, in addition to practical suggestions on how to reduce net chemical consumption, there is an exploration of the regulatory and financial levers and incentives that can be used to promote and implement chemical leasing and improved chemical circularity, including the potential inclusion of chemical leasing and non-linear use models in existing industry certification schemes.

The inclusion of chemical leasing and non-linear use models in existing, respected certification schemes could provide a basis for the objective assessment of reduced 'net chemical consumption' that could drive, and ultimately embed, non-linear use patterns into the industry.

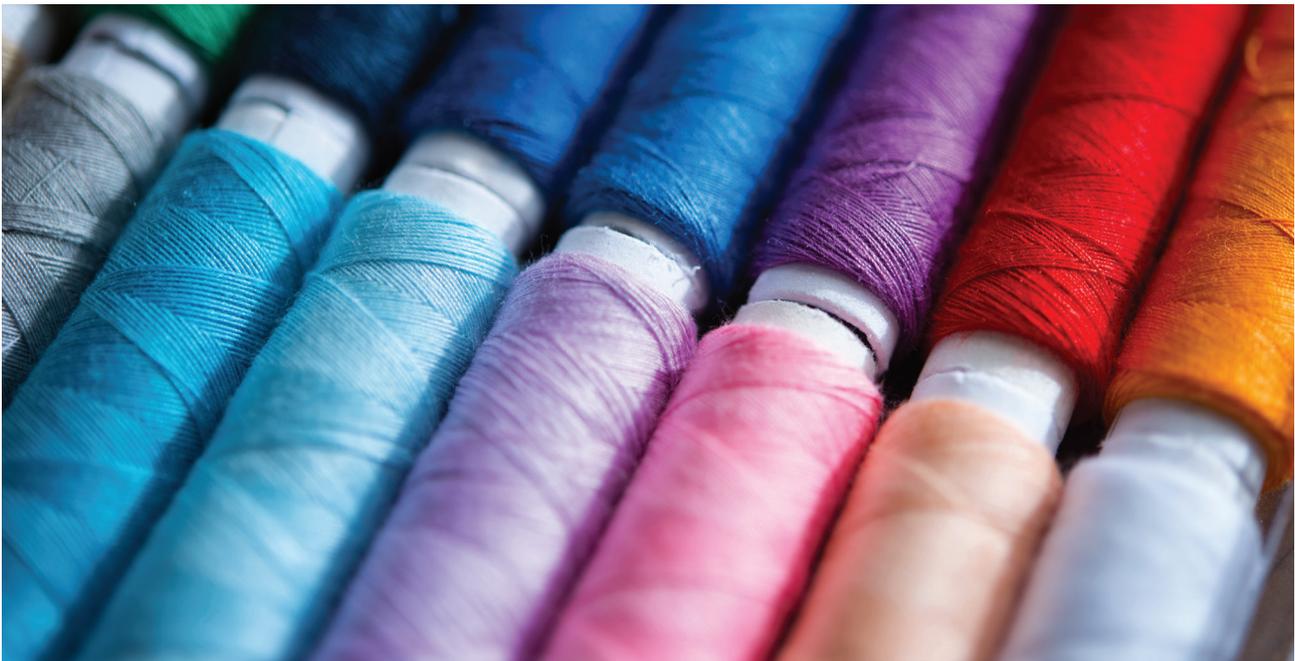
There are already pockets of excellence in the industry, and this report highlights several case studies where non-linear chemical use is in operation and how the approach benefits the environment and profitability of the organisations in question.

There is much talk about the circular economy in the fashion industry and in the manufacturing industry, and most of this is centred on the materials (fibres, polymers and so on) used.

The report seeks to emphasise current barriers to circularity in materials, underline where chemicals are seen as a challenge or a problem and highlight opportunities for chemical leasing or non-linear use patterns to become enablers of circularity.

Above all, the report aims to challenge readers to acknowledge that the way we have always worked with chemicals in the textile industry is fundamentally wrong.

Using chemicals just once, partially remediating them and putting them into the environment cannot be justified, and we should collectively find ways to stop this happening.



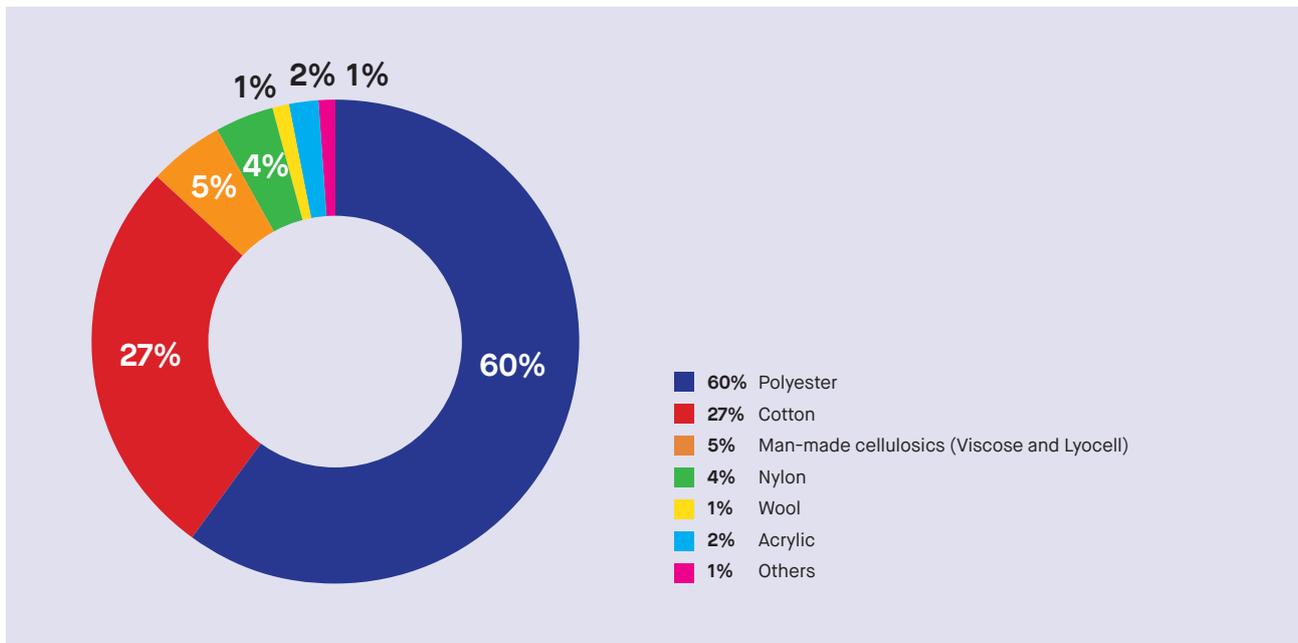
3. Background Information

In order to put the potential benefits of chemical leasing and non-linear chemical use models into some context, it is necessary to understand the scale of the industry and current chemical use patterns.

The majority of this report uses the textile industry as the main exemplar of current business models and opportunities for change. Leather is referenced and provides several examples of excellent practice and opportunities for improvement.

The world market for textile fibres is approximately 100 million tonnes per annum, with approximately 60% used in clothing and home textiles and the remaining 40% being used in technical textiles, medical textiles, automotive, safety and workwear, agricultural textiles and outdoor industries.

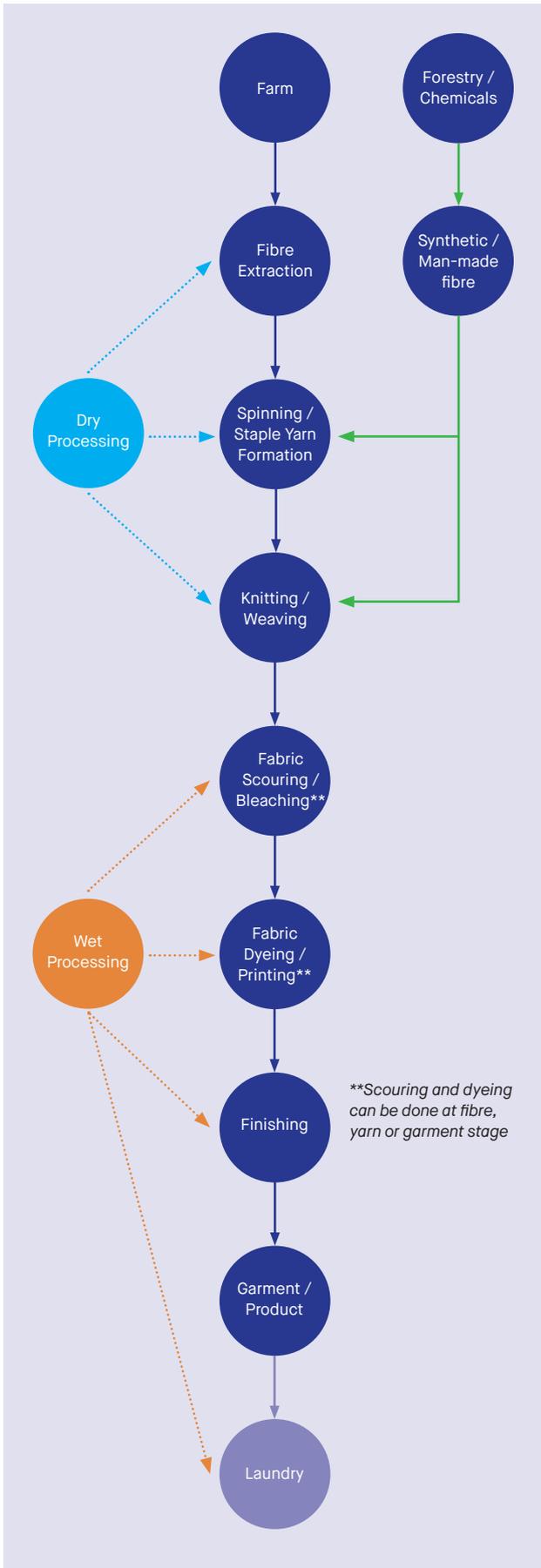
Of the 60 million tonnes that are used in home textiles and apparel ('the fashion industry') the percentage breakdown by fibre type is **approximately**:



Initiatives that can be applied to the major fibres or across multiple fibre types will have the greatest benefits. Nevertheless, those that are only applicable to, say, wool are still worth pursuing because 1% of the global fibre market is still a very large industry sector.

Textile processing is a multi-stage process which typically includes the following steps:

- Fibre harvesting (natural fibres) or fibre production (man-made or synthetic fibres)
- Yarn spinning – the conversion of fibres into yarns
 - synthetic fibres are often produced in continuous filament yarn form, or they can be chopped into shorter lengths and converted into yarns using cotton-type spinning processes
- Knitting or weaving to create a fabric
- Scouring – a wet process to remove chemicals from the surface of fibres/yarns/fabrics prior to dyeing
- Dyeing and/or printing – applying dyes or pigments to impart colour
- Finishing – applying physical surface treatments and/or chemicals to give the desired aesthetics or technical performance
- Garment or textile product manufacture
- Some garments are laundered prior to sale to create a worn look



Chemicals are used in upstream dry processing (spinning, knitting/weaving) and also in wet processing (dyeing, printing, finishing laundry).

The textile industry is global and, despite there being some major producing hubs in certain geographical locations, it is quite fragmented, with hundreds of thousands of farmers and factories involved in the production of fibres and their conversion into finished products.

This fragmentation of the textile supply base means that there are hundreds of thousands of factories using relatively small amounts of chemicals.

Note on specific product sectors:

There may be some chemical leasing and non-linear use initiatives that can be applied to a very large percentage of the textile industry, but there may be others that are limited to specific products or processes.

The product sub-sectors can be very large, and sub-sector specific initiatives can still deliver very significant benefits. For example, over a billion pairs of jeans are sold per annum. The denim industry operates a relatively standard production method across the entire industry, and it is served by around 500 dyeing mills. It is therefore an excellent candidate for adopting new ways of working.

LEATHER

The world market for leather is approximately 7 million tonnes. Approximately 84% is used in clothing footwear and home textiles.

With very few exceptions leather follows a relatively standard process route as it is converted from animal skins to useable leather:

- Removal of flesh and hair
- Tanning to cross link the skin and convert it to leather
- Dyeing to impart colour
- Fat-liquoring to improve softness and flexibility
- Finishing – applying chemicals to give the desired aesthetic and technical performance

The fact that a very consistent process is employed, using a small number of ‘core’ chemicals across most of the industry, makes leather a very interesting case study for leasing and non-linear use models. Indeed, some excellent examples of non-linear chemical use already exist.

4. Current Chemical Use

The chemicals used in textile processing can be viewed according to their function:

- Some are intended to stay on the finished product at point of sale, such as dyes, softeners, coatings and performance finishes;
- Some are referred to as process chemicals – they are intended to serve a purpose by being present on a substrate temporarily (e.g. weaving size) or in a processing bath (e.g. a fabric lubricant, to avoid creasing and abrasion marks). After they have served their purpose they are removed and typically discharged to the environment in effluent.

There is no such thing as a standard textile process. The table below gives a brief overview of **typical** chemical usage in typical, basic textile processes. The actual chemicals used for different fibres or to achieve different aesthetics will vary. The information below is provided to give an understanding of the step-by-step processing, where chemicals are added, where they are removed and their final fate.

PROCESS	CHEMICAL USE	FATE OF CHEMICALS
Synthetic Fibre Production	<p>Synthetic fibres are formed as continuous filament yarns as they are extruded. Yarns can be made from continuous filaments or the filaments can be cut into shorter lengths for forming into staple yarns.</p> <p>When the fibres are extruded, they are solidified and then coated with 'spin finish' to stop the fibres or yarns sticking to each other during storage and/or reduce friction and static in subsequent processing, such as knitting or beaming in preparation for weaving.</p> <p>Spin finish is a general term and covers lubricants, anti-static agents, emulsifiers and other additives.</p> <p>The amount added depends on the specific product in question (e.g. a texturised yarn may have higher amounts of finish applied) but on average around 1-2% is applied on weight of fibre.</p> <p>Polyester, nylon and acrylic have a combined market share of approximately 66%, and therefore an enormous amount of spin finish enters the effluent streams each year.</p>	<p>Spin finishes are normally washed off the fibres during wet processing, using detergents, and enter the wet processor's effluent treatment plant.</p> <p>Note: Monomers and oligomers may also be present in the yarns, and these come out during wet processing.</p>

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PROCESS	CHEMICAL USE	FATE OF CHEMICALS
Man-made Fibre Production	<p>Both viscose and lyocell are made from wood-based starting materials in a two-stage process.</p> <p>The first stage is to produce wood pulp from a source of cellulose. Viscose is produced from wood pulp using a multi-stage chemical process, and lyocell is produced from wood pulp using a simple solvent process where the solvent is recycled (wood pulp and viscose production requires an effluent treatment plant to remediate chemical waste).</p> <p>The fibres are produced as either continuous filament or staple fibres, and they are finished with spin finish as synthetic fibres.</p> <p>Around 1-2% is applied on weight of fibre.</p> <p>Viscose and lyocell have a market share of approximately 6%.</p> <p>Lenzing are the subject of a case study in section 6.c.ii which describes how they employ non-linear models to their viscose and lyocell production</p>	<p>Spin finishes are normally washed off the fibres during wet processing, using detergents, and enter the wet processor's effluent treatment plant.</p> <p>The fate of chemicals used in viscose and lyocell processing are described in section 6.c.ii.</p>
Natural Fibre Agriculture	<p>This report does not consider the use of agricultural chemicals per se, but it should be noted that these chemicals are generally applied in the field and not forcibly removed until scouring and bleaching at the wet processor.</p>	<p>Agrichemicals are normally washed off the fibres during wet processing, using detergents, and enter the wet processor's effluent treatment plant.</p>
Staple Fibre Spinning	<p>Cotton fibres are spun into yarns in their raw state (as they emerge from the field with oils, waxes, pectins and other natural substances present). Spin finish is applied to reduce friction in subsequent processing and is present at around 0.5 – 1.0% on weight of fibre.</p> <p>Cotton has a market share of approximately 27%, and therefore an enormous amount of spin finish enters the effluent streams each year.</p> <p>Synthetic staple fibres will have some spin finish present from their original manufacture but may have some additional finish added during spinning.</p>	<p>The natural substances on cotton fibre (which accounts for at least 4% of the raw fibre weight) and spin finishes on staple yarns are normally washed off the fibres during wet processing, using hot alkali and detergents, and enter the wet processor's effluent treatment plant.</p>
Knitting	<p>Knitting oil is used to lubricate machines, and this transfers onto the fabric.</p>	<p>Removed during fabric scouring and enters the wet processor's effluent stream.</p>
Weaving	<p>Weaving size is used to coat warp yarns to protect them during weaving. Weaving size is applied at the weaver and is applied at around 7.5 to 25% on weight of the warp yarn.</p> <p>Starch (derived from e.g. potatoes) is commonly used for cotton fabrics. Synthetic types such as PVA are more commonly used for synthetic fibres.</p>	<p>Size is removed during scouring and enters the wet processor's effluent stream. Without necessarily being judged as a 'harmful' chemical, it is a major contributor to effluent load and can cause severe oxygen depletion if discharged in an un-remediated state.</p>

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PROCESS	CHEMICAL USE	FATE OF CHEMICALS
<p>Scouring and Bleaching</p>	<p>Typically, detergents, bleaches (normally hydrogen peroxide), stabilisers, alkali, sequestering agents, dispersing agents, lubricants and enzymes are used to remove natural oils, waxes, pectins, etc, from natural fibres, size from woven fabrics, knitting oil from knitted fabrics and spin finishes from all fibres.</p> <p>The exact type and amount of chemicals employed depends on the fibre, yarn or fabric being processed and whether the substrate is scoured (either a white fibre or ultimately for a dull/dark colour) or bleached (a creamy fibre that has to be bleached to provide a white base for a bright colour).</p> <p>The purpose is to use chemicals to clean all upstream chemicals from the fibre to leave a clean fibre for dyeing or printing.</p> <p>The chemically aggressive scouring processes normally applied to cotton will generally chemically change the natural and synthetic chemicals although some will simply dissolve.</p>	<p>All chemicals that are used in the bleaching and scouring process plus all the upstream chemicals (applied and natural) enter the wet processor's effluent stream.</p> <p>The bleach/scour bath, particularly for cotton, has the highest effluent loading of any bath.</p>
<p>Pre-dye Preparation</p>	<p>There are some processes that are applied to certain fabrics prior to dyeing to enhance dye uptake or enhance product aesthetics, and these can involve large quantities of chemicals.</p> <p>Examples include mercerisation of cotton and weight reduction of polyester – these both use very high concentrations of caustic soda and require washing and neutralisation before subsequent processing.</p> <p>If there is no recycling of caustic soda, large quantities of acid are required in effluent treatment, forming large quantities of salts.</p>	<p>Unless there is recycling, all chemicals applied and removed from the base substrate will enter the wet processor's effluent stream</p>
<p>Dyeing</p>	<p>Dyes are applied to impart colour to fibres, yarns, fabrics or garments. The exact method depends on the fibre and dye type but involves pH control, sometimes chemicals to promote dye fixation and also sometimes lubricants, antioxidants, anti-reductants, anti-foams.</p> <p>Unfixed dyes must be removed from textile fibres to meet the stringent colour fastness requirements of brands.</p>	<p>Any unfixed dye (up to 30% of reactive dyes applied to cotton, typically <1% of disperse dyes applied to polyester) plus the chemicals used for dye fixation enter the wet processor's effluent stream.</p> <p>There is a disproportionate amount of concern over dyes in effluent because they are highly coloured at low concentrations. If present in discharged effluent they are normally more of a marker for more harmful, invisible chemicals than a nuisance themselves.</p>
<p>Dye Printing</p>	<p>Dyes are applied from a printing paste, which is a natural or synthetic thickener that contains the dyes and chemicals required to help the dyes fix to the fibres – such as pH control, humectants, anti-reductants, antioxidants.</p> <p>After printing, fabrics have to be fixed using steam, and then unfixed dye and the hardened print paste have to be removed.</p> <p>Excess print paste has to be dealt with and printing screens washed.</p>	<p>Unfixed dye, solidified thickener and fixation chemicals enter the effluent stream.</p> <p>With printing, there is invariably an excess of coloured print paste prepared, and this waste can either go into the effluent stream or be solidified and disposed of as solid waste.</p> <p>Print paste residues from printing screens are washed off and enter the effluent stream.</p>

CHEMICAL CIRCULARITY IN FASHION

PROCESS	CHEMICAL USE	FATE OF CHEMICALS
<p>Pigment Printing</p>	<p>Pigments are applied from a coloured ink/paste that is a polymeric binder with certain additives to aid flow/curing.</p> <p>They are dried and cured and normally sold in that state.</p> <p>Excess print paste has to be dealt with and printing screens washed.</p>	<p>The pigments and binder stay on the product and go to the final consumer.</p> <p>Additives may be washed out of the print during commercial or domestic laundry and enter effluent streams.</p> <p>Excess print paste and residues from print screens can enter effluent streams or be treated as solid waste.</p>
<p>Chemical Finishing</p>	<p>After fabrics have been dyed or printed it is normal for them to have a chemical finish applied. This can range from a very simple needle lubricant, that has no effect on the fabric other than making it easier to sew, through to thick polymer coatings that make fabrics unrecognisable as textiles. The most common chemical finishes are softeners to make fabrics feel nicer or technical performance finishes to make fabrics waterproof, flame retardant, non-iron, moisture wicking and so on.</p> <p>Most chemical finishes are applied by dipping the fabric in a bath of a chemical recipe (containing the active chemical plus pH control and so on) and then squeezing the fabric with a mangle prior to drying/curing.</p>	<p>Where finishes are applied by a pad mangle, there is always an excess of the chemical recipe prepared and, unless this contains very expensive chemicals, it tends to enter the effluent stream directly as 'waste'.</p> <p>Chemicals that are applied to products are either 'topical' (removed in the first couple of laundry washes) or 'durable' (they stay on the product for the lifetime of the product). Topical chemicals will go to municipal ETP's and chemicals used in durable finishes will stay on the product – and can have a negative impact on material recycling.</p>
<p>Industrial Laundry</p>	<p>An increasing number of garments undergo a laundry process prior to being placed on sale to give them a more casual or worn appearance.</p> <p>Processes vary from very mild detergent washes to very aggressive treatments using stones, bleaches and enzymes.</p> <p>Note: the most common industrial laundry process is for denim garments (see case study in section 6.c.ii).</p>	<p>Chemicals that are used in industrial laundry processes and any that are removed from garments enter the effluent stream.</p>
<p>Effluent Treatment</p>	<p>Effluent from a dyehouse, printworks or laundry typically enters a large collecting tank called a balancing tank. It reaches the average pH of the many different individual emissions from the wet processing unit and typically requires pH adjustment via the addition of acid or alkali.</p> <p>Most effluent treatment plants have an aerobic biological treatment process using microbes to digest organic molecules (both natural and synthetic) prior to discharge to the environment. This process significantly reduces the oxygen depletion potential of the effluent and is key to reducing environmental damage in the current linear use model. Oxygen is pumped into the treatment bath to keep the microbes healthy and also to chemically oxidise chemicals in the effluent. Although the chemicals in the effluent are 'food' for the microbes, it may be necessary to add additional nutrients (e.g. sources of nitrogen or phosphorous) to keep the microbial population healthy.</p>	<p>Unless the chemicals used in wet processing are particularly persistent, they will be partially or fully broken down into simpler (possibly ill-defined) species and will either leave the ETP in the effluent discharge, be absorbed by the microbes or be precipitated as solids during colour removal.</p> <p>During biodegradation greenhouse gases are released to the environment.</p> <p>Simple salts, used in large quantities in the reactive dyeing of cotton or created during neutralisation steps, pass through a standard treatment plant unchanged and can be problematic if discharged into fresh water such as rivers or lakes.</p> <p>Unfortunately, many effluent streams are not remediated at all and many are poorly remediated.</p>

PROCESS	CHEMICAL USE	FATE OF CHEMICALS
Effluent Treatment (continued)	<p>Colour has to be removed from effluent prior to discharge in most parts of the world, and this can be done by adding organic coagulants or inorganic coagulants such as ferrous lime. Occasionally chlorine-based bleach or ozone is used for colour removal.</p> <p>Anaerobic biological treatment is much less common but is considered to provide better remediation prior to discharge.</p> <p>See case study in section 6.c.ii on Zero Liquid Discharge.</p>	

AGGREGATE LEVELS OF CHEMICAL USE

PROCESS	APPROXIMATE AVERAGE CHEMICAL USE AS A PERCENTAGE OF SUBSTRATE WEIGHT
Spin finish	~1%
Weaving size	~7.5% to 25% applied to the warp threads of woven fabrics ~4%*
Scouring and bleaching	~3% (Average of 3g/l of additives at 10:1 liquor ratio)
Dyeing	~2% dyes ~3% dyeing auxiliaries
Wash off	~2% auxiliaries
Finishing	~1.5% chemical finish
Total	~16.5%

*Assume that woven fabrics account for 50% of all fabrics and warp threads make up 50% of fabric weight.

The amount of chemicals used varies depending on the fibre and process, but it is possible to make broad estimates for the average amount of chemicals used in dry processing, wet processing and finishing. This can provide a ball-park figure to highlight the overall magnitude of the challenge and the opportunities for improvement.

It is **estimated** that the total amount of chemicals used in the processing of 60 million tonnes of apparel and home textiles is **at least** 9,900,000 tonnes. With the exception of the dyes and finishes that stay on the product, the vast majority of the rest enters the effluent stream. A portion of this is partially remediated and discharged to the environment and a portion is discharged without treatment.

The amount is comprised of basic commodity chemicals and more complex man-made chemicals in formulations.

The intention is to demonstrate the order of magnitude of the problem rather than being an accurate calculation. The figure of around 10 million tonnes of chemicals is likely to be conservative. It is also an average: fibre such as cotton will have a disproportionately high chemical consumption compared to polyester.

Not included in this figure are some chemicals used in huge volumes in specific processes such as salt (reactive dyeing) and pumice stones (used in denim laundry).

It is recommended that a more detailed analysis of total industry chemical use be conducted as a follow up to this report.

Note: There are material losses throughout the textile chain which means that for every tonne of fibre produced, approximately 750 kg (source: Wrap UK) will be present in a finished product. Some of these losses are at early stages such as cotton ginning/spinning, where the waste may be sold and used as a useful product but have no further chemicals applied. Waste from garment making (typically 15% from fabric) may be sold and used for low grade end uses such as stuffing mattresses and toys, but these fabric off-cuts will have had chemicals applied to them.

CURRENT CHEMICAL USE IN LEATHER PROCESSING

Leather is a very chemically intensive process, but one that follows a relatively standard process.

The table below gives very brief overview of the chemicals used in typical chrome tanning processes and their fate.

PROCESS	CHEMICAL USE	FATE OF CHEMICALS
Salting	Salt is used to preserve skins to stop them rotting. This is removed by simple washing as the first stage of the leather making process. Salt recovery is possible.	Tannery effluent.
Fleshing	Flesh is removed from skins. This is a mechanical process with no chemical use.	Flesh is solid waste and should not enter effluent streams.
Liming	Alkali is used to swell the skins.	Tannery effluent.
De-liming	Chemicals, such as ammonium sulphate or ammonium chloride, are used to remove the alkali.	Tannery effluent (harmful gases can also be formed).
De-hairing	Chemicals, such as sodium sulphide, are applied that dissolve the hairs.	Hairs can be recovered and used or treated as solid waste. The dissolved parts of the hairs and the chemicals used to remove them enter the effluent stream (depending on the chemical used, harmful gases can be formed).
Pickling	Strong acids are used to lower the pH of the skins prior to tanning	Tannery effluent.
Tanning	Chromium salts are used to crosslink the skins and turn them into a leather. Excess chromium salts are washed out. Recovery and reuse of chromium salts is becoming more common. Less hazardous tanning agents are available, but these are not necessarily as effective or recyclable.	Tannery effluent.
Dyeing	The dyeing process is essentially the application of acid dyes to apply colour to the leather. However, it is actually a slightly more complex process involving retanning and sometimes the application of polymers/additives to enhance the appearance and softness of a leather.	Tannery effluent.
Post-dye Wash Off	Removal of excess chemicals from the dyeing process.	Tannery effluent.
Fat Liquoring	The application of chemicals into the leather matrix to provide softness and suppleness to the leather.	Tannery effluent.
Finishing	The application of coatings, polymers, polishes, waxes, etc. to the leather surface.	Air emissions and solid waste.

5. Current Business Models



MINDSET, COMMUNICATION AND RESPONSIBILITIES IN TEXTILE MANUFACTURING SUPPLY CHAINS

It should be noted that, in most current production processes, the chemical **use** occurs throughout the supply chain. However, almost all **discharges** to the environment occur during wet processing with, typically, a dyer or printer being forced to take responsibility for remediation and discharge of all the chemicals employed in the textile manufacturing chain. There are hundreds of thousands of farmers and factories involved in the textile industry, and a key consideration when evaluating the possibility of chemical leasing and non-linear chemical use models is the level of vertical integration in organisations.

In some instances, this can be full vertical integration from fibre cultivation/manufacture through to finished garments. However, even in these 'fully vertical' organisations, there are normally some sales of partially processed goods and some purchase of fibres, yarns and fabrics.

It is more common to have partial verticality, such as knitting and dyeing, or spinning and weaving, on the same production site or within the same organisation.

Where there is verticality, good communication throughout the chain is possible, and this can extend to discussions on chemicals. For example, a dyer can ask for information on the type of spinning oil used on a fibre or on the type of weaving size used on a fabric and, in some instances, even demand that a specific chemical type is used.

The reality is that, in almost all instances, the individual manager of a sub-process will use chemicals in a way that is best for *them*,* with little consideration for downstream processing, and leave the next processor in the chain to deal with their chemical inputs. This occurs until it reaches the wet processing stage where, typically, a dyer or printer has to remove and remediate the chemicals.

It is also very common to have single-function, non-vertical factories that carry out only one process, such as just dyeing or just printing or just garment laundry.

There is sometimes a relationship between the non-vertical production facilities, but sometimes the steps in the production process are managed by middlemen, converters or agents that arrange for specific sub-processes to be carried out depending on price and availability of production capacity.

This common way of working virtually eliminates the opportunity for communication throughout the chain and virtually guarantees that chemicals are not used with downstream processing in mind.

**One notable exception to processors using chemicals that deliver the best results for them is where chemicals are illegal or restricted by retail brands or third-party certification schemes (such as ZDHC, Bluesign and Oekotex 100). These regulatory or voluntary levers have been proven to change industry behaviours in terms of chemical choice. It is conceivable that similar levers could influence the adoption of non-linear use models. This is discussed in detail in section 7.*

This complexity in the textile supply chain is often referenced by brands when they are challenged by stakeholders on environmental compliance and sustainability issues. However, the reality is that, for a given finished product, it is very easy to establish the production route if there is a willingness to do so.

Transparency of supply routes is an essential foundation for any sustainability initiative, including the promotion of non-linear chemical use models.

MANUFACTURE AND SUPPLY OF CHEMICALS

Ultimately, all chemicals are derived from crude oil, plants and mined or quarried minerals.

There are many, many farms, oil wells and quarries but relatively few chemical companies and, specifically, relatively few textile chemical **manufacturers**.

However, rather like the network of textile manufacturing factories have varying levels of vertical integration, there is a similar situation with dyes, pigments and textile (and leather) chemicals.

There are two types of chemicals used by the textile industry:

Commodity chemicals – such as acids, alkalis and salts

- These are normally supplied by local companies based in relatively close proximity to the factory where they are used

Synthetic chemicals – such as dyes, pigments, softeners, lubricants and performance finishes

- These are contained in complex **formulations*** and can be supplied by international chemical ‘manufacturers’ or by smaller local ‘formulators’

**Chemical formulations will contain a desired substance, such as a dye or a softener, and, often, benign diluents to standardise product strength. They may also include preservatives, emulsifying agents, pH controllers, viscosity control, antioxidants, anti-reductants and so forth to provide good shelf life, consistency and ease of use by the chemical user. This complexity has to be taken into account when considering recycling and reuse, especially when considering processes involving multiple formulations.*

There are some huge chemical companies with almost full vertical integration, from refinery through to a chemical formulation that is delivered to a dyehouse, and there are the traditional ‘textile chemical manufacturers’ that manufacture dyes, pigments, processing and finishing chemicals used by the textile industry.

These companies used to guard their secretly developed molecules very carefully, manufacture them in-house and sell them almost exclusively through their own sales channels, but now this approach only really applies to a selection of products. The reality is that the traditional international ‘manufacturers’ will now manufacture some of their own complex chemicals, they will outsource manufacturing of some complex chemicals to other chemical manufacturers under licence, and they will buy in some complex chemicals to include in their formulations.

Likewise, they will sell some of the chemicals they manufacture to their competitors and to smaller formulators.

In essence, there are ‘manufacturers’ who manufacture chemicals **and** create formulations, and there are ‘formulators’ who buy in chemicals and create formulations.

There are even instances where a formulation is purchased and simply relabelled.

Manufacturers and formulators should have an open dialogue with regard to the chemical content of formulations and their ingredients, and it is expected that chemical suppliers to the textile industry should have full* knowledge of all chemicals within a formulation.

Full disclosure of **all ingredients in a formulation to chemical users is incredibly rare. However, chemical manufacturers and formulators are increasingly willing to declare what is not there in order to demonstrate compliance with legal and brand requirements. There is an understandable desire **to protect intellectual property** and minimise the risk of patent breaches. However, in order to support non-linear use patterns, it may be necessary to get fuller information in future.*

The bigger, international textile chemical companies sell into multiple different countries via their own sales teams or via their appointed agents, who may represent more than one chemical company. They also usually have centralised expert technical support teams for specific industry sectors, who travel globally as required, and often general technical support teams in key producing countries.

The number of individual textile factories that a major international chemical company sells to, directly or via agents, may be in the many thousands, and while they may have very good, close relationships with some key accounts, it is impossible to have such deep relationships with all of them with current resources.

Smaller, local formulators will have fewer customers but smaller sales and support teams.

Although the logistical challenges of non-linear use models may prove to be very challenging, it has to be noted that chemical companies manage to **deliver** chemicals to all the thousands of chemical users in the supply base. That in itself is a huge logistical challenge and actually indicates that the logistics associated with non-linear use models may not be an insurmountable barrier.

WHO PAYS AND WHO GETS PAID?

Most users of chemicals in the textile industry pay for the chemicals they use. However, wet processors pay for chemicals they use, have to pay to dispose of the chemicals they use and have to pay to dispose of all of the chemicals used by upstream processors.

In general, the chemical supplier gets paid for the chemicals they supply and has no costs or responsibilities* with respect to disposal.

The standard textile chemical model also has elements of incentivisation encouraging the use of larger volumes of chemicals. The tactic of chemical suppliers offering rebates to users when consumption levels of a certain chemical product go beyond a certain volume is common. This can be viewed in two ways: (a) the user of the chemical is encouraged to use larger quantities of chemicals, or (b) the user of the chemical is encouraged to consolidate chemical inventories and use larger quantities of fewer chemicals.

The latter scenario could actually lead to lower stock holdings, lower levels of waste, less complexity and thus more opportunities for non-linear use models.

It is not surprising that there have been calls for the introduction of extended supplier responsibilities for chemical suppliers (where the suppliers are held responsible for dealing with the chemicals they sell after they have been used) to put an end to the situation where many, many small factories each dump a small percentage of the chemical manufacturer's large production volume into the environment across many, many locations.

Although this representation of the chemical industry and how it currently serves by the textile industry may seem harsh, it is fair to point out that there has been little challenge to the business model of how textile chemicals are supplied for well over a century, and to its great credit, the chemical industry does in fact embrace many non-linear chemical use examples in their own upstream activities.

**While it is fair to say that chemical suppliers do not have any responsibility for actual chemical disposal, it has to be recognised that responsible chemical companies:*

- Provide details of formulation content;
- Provide a good deal of information to users so that chemicals can be disposed of responsibly and provide specific data on biodegradability;
- Advise on optimal usage;
- Already focus on the cost of functionality not on the unit cost: the more innovative companies already differentiate on functionality, albeit with a single-use model.

The industry as a whole has made great strides in avoiding the use of chemicals that cannot be readily remediated using current common effluent treatment technologies. However, it is necessary to challenge whether that has actually been good progress or just a less bad version of a model that is fundamentally wrong.

CURRENT BUSINESS MODELS – WHAT MAKES A CHEMICAL OR FORMULATION 'GOOD'?

The model for chemical users is ordinarily a 'selfish model' where chemicals are used in a manner that benefits the user (and their profitability), with the next actor in the chain having to deal with what comes their way.

The main drivers that make a chemical buyer select a specific chemical or formulation (or that make a chemical or formulation 'good' in their eyes in the current single-use model) include:

Effectiveness at carrying out a process

- Those using chemicals want those chemicals to do an effective job.

Fear of failure

- Quite a lot of chemicals are included in processes as 'insurance chemicals' – to prevent something going wrong. A problem may occur occasionally and result in a very costly rejection of products, or even worse, an expensive financial claim from retail brands, such that insurance chemicals are almost always included.
- The chemicals themselves may be very clever and effective but are not necessarily needed. In the current cost model, where the cost of prevention is much less than the cost of failure, they are often employed. Therefore, the potentially unnecessary inclusion of anti-foams, anti-reductants, antioxidants, dispersants, anti-crease agents and so on is commonplace and completely understandable.

Cost

- Unit cost of purchase – in simple terms the cost per kilogram or per litre. This simple approach may not even consider the actual content of active ingredients and the levels of dilution of formulations.
- Cost of active ingredients – a slightly more sophisticated model that considers how much active ingredient is present in a formulation and what price is paid for that.
- In better organisations, the overall cost of processing is considered, and in general they will be assessing the relative costs of chemicals, water and energy. Where water and energy are expensive it is more common to see the application of more advanced, intelligent chemistry that can help reduce water and energy use.

Compliance with chemical legislation and standards (brand standards)

- Increasing chemical legislation has led to increased fragmentation of legislation, which in turn has led to increased brand-led, unified standards that specify the permitted/restricted chemicals in inputs, on finished product and in effluent.
 - This means, for example, that cost-effective and highly effective detergents such as APEO's are no longer acceptable, nor are cost-effective pigments based on lead and cadmium.
- Chemical restrictions largely originate from the evaluation of chemical hazards and do not always factor in dose (how much harmful chemical is actually there) and likely exposure.
 - The opportunity to use highly effective but harmful chemicals in no exposure or no discharge scenarios is currently limited.
- Many intelligent thinkers challenge hazard-only approaches to chemical restrictions, but it has to be recognised that downstream users (especially wet processors) have a poor track record of protecting workers from exposure, and this does actually lend weight to hazard-based approaches.
- In addition to restrictions on specific chemicals, legislation and brand requirements promote the avoidance of all chemicals with a range of negative properties (e.g. carcinogen, mutagen, reproductive toxin etc).

Ease of remediation

- This essentially promotes the use of chemicals that are readily biodegradable in an effluent treatment plant.
- The single-use model predicates that chemicals will have to be remediated, and responsible wet processors will factor this into their buying choices as it is they who will be carrying out the remediation.
- The ease of remediation of chemicals used in upstream dry processing may not be given much consideration by those that use them, although the avoidance of chemicals that are banned or restricted is becoming the norm.

Financial incentives (discounts, paybacks)

- It is unrealistic to suggest that any chemical user will use chemicals that are fundamentally unsuited for a particular end use simply in order to increase consumption to a point where it triggers a discounted unit cost or a financial rebate. However, these models are out there and do not discourage over-use.

Inventory management (minimising stock units or individual products)

- Chemicals in an inventory tie up cash, and a chemical user may choose to have a smaller number of dyes or chemicals in their inventory. This may result in compromises and the use of some chemicals that do a fit-for-purpose job rather than optimising the effectiveness of all chemicals in all processes.

CURRENT BUSINESS MODELS – BRINGING NEW CHEMICALS TO MARKET

There is a widely held view that 'green chemistry' will revolutionise the chemical industry and in particular the textile industry.

The hope is that existing 'synthetic chemistry', which is viewed as being problematic, will be replaced by safer, more benign chemicals and that those chemicals may be derived from natural, renewable resources.

This utopian view is laudable, but 'green chemistry' isn't actually well defined and there are some challenges:

Not all safer alternatives are equally effective

- If larger volumes of safer chemicals are required to make products of the same quality and durability, the levels of cumulative damage may be higher than using standard chemicals (for example, the carbon footprint of manufacture, transport, remediation and greenhouse gases released during remediation).
- If safer chemicals are used to make products that are not as durable as those made with existing chemistry, higher volumes of chemicals with higher levels of cumulative damage may be used over time.

Bringing new chemicals to market is incredibly difficult, time-consuming and expensive

- This is the 'elephant in the room' during chemical discussions. The days of enormous research and development budgets and teams of thousands of chemists have gone, and the number of genuinely new textile dyes and chemicals coming to market is smaller than ever.
 - The cost of research and development is expensive relative to the price that can be commanded (most textile formulations cost between \$4 and \$15 per kilogram with very few being more expensive). Dye and pharmaceutical research are very similar from a chemistry perspective, but a new drug can command several thousand dollars per kilogram.

- The first synthetic dyes, created in the 19th century, were incredibly expensive, and much of the wealth of the existing European chemical companies was based on this early pioneering research.
- To protect consumers, workers and the environment, the regulatory barriers are understandably high – and the costs of registration are significant relative to the price that can be commanded for a chemical product. The cost of conducting all the necessary eco-toxicological testing can be higher than the registration costs.
- The cost of patent protection can be very expensive, and with the globalisation of manufacture and use, patents have to be taken out in multiple territories to protect patent rights.
- Analytical techniques have never been so good or widely available. This means that, even in the absence of production information, a counterfeiter can elucidate the molecular structure of a new chemical very quickly and thus copy it.

New chemistry will still come to market, but we cannot assume new chemistry will offer all the solutions to our current problems.

New chemistry may be part of the solution, but there has to be an acceptance that new ways of working with existing chemicals will need to form the major part of non-linear use model initiatives in the short term.

CURRENT BUSINESS MODELS – WHAT DRIVES THE BEHAVIOUR THAT PERPETUATES THE HIGH NET CONSUMPTION, SINGLE-USE LINEAR MODEL?

Legacy

- The textile industry operated with a buy-use-dump model for centuries, and the imposition of pollution controls moved the industry towards a buy-use-partially remediate-dump model.
- The industry does what it did, with a slight modification. Changing fundamental behaviours that have developed over centuries will take time, effort and levers.

Profits

- Chemical buyers, chemical sellers and retail brands are generally focused on maximising profits and that means making a product that is fit for purpose for the lowest possible cost.
- The model relies on all chemicals being remediated by a wet processor, and by that stage, there is a complex mixture of chemicals in the effluent stream.

This means only one actor in the chain needs to build infrastructure for dealing with chemicals.

- Cost of downgrades vs cost of chemicals. As mentioned in the previous section, some chemicals are deliberately used to protect profits.

Brands

- Brands have a huge influence over behaviours in their supply chains and they can demand that certain practices are avoided or pursued. Quality, aesthetics and cost are key factors, but an increasing number are demanding that environmental/sustainability criteria are met.
- Many brands have chemical management programmes, but these tend to be based on avoidance of harmful chemicals on finished products. The subject of chemical inputs and the content of effluent discharge is gaining traction and wet processors are being asked to demonstrate compliance by leading brands.
- Whilst brands don't necessarily support the single-use linear model, their standards and expectations are built with that model in mind. Their standards are based on the avoidance of specific chemicals and concentration targets rather than reduced net consumption and discharge.

Governments

- Governments have the somewhat challenging task of introducing legislation to avoid bad practice and promoting good practice.
- Most governments have legislation to avoid the worst excesses of pollution (hence the common practice of partial remediation of effluent), and an increasing number have legislation to avoid the most harmful chemical inputs.
- Rather like brand standards, legislation tends to assume the current model will happen and seeks to make it less bad.
- Currently legislation does little to restrict volumes of chemicals used or promote reuse or recycling.
- One notable exception is Zero Liquid Discharge, and this is discussed in detail in section 6.

Use of current infrastructure in factories vs capital investment

- It is no surprise, after over a century and a half of the single-use linear model and over half a century of pollution legislation based on partial remediation, that the industry is largely geared up from a hardware perspective to cope with that model. The lack of machinery, hardware and human resources to support non-linear use models is not a surprise.

Brand/Supplier relationships and supply base stability

- Brands have a history of moving garment production to countries where the cost of labour is lower so that they can improve margins and profits. Initially, the assembly factories will import materials (textiles, leather, etc.) to those countries to support this production, but eventually they will hope to be able to source materials of the desired standard from local sources. This movement of production causes nervousness in textile supply chains, and the perceived lack of stability can hinder investment in new technology. Many factory owners are constantly fearful that they may lose orders to cheaper nations and therefore have the attitude that 'investments' could actually be a waste of money.
- Many brands have little knowledge or control of their supply routes in terms of textile manufacturing and wet processing: the sourcing of materials is delegated to their vendors (referred to as vendor-sourced materials), and details of fibre, yarn fabric and wet processing are not necessarily required.

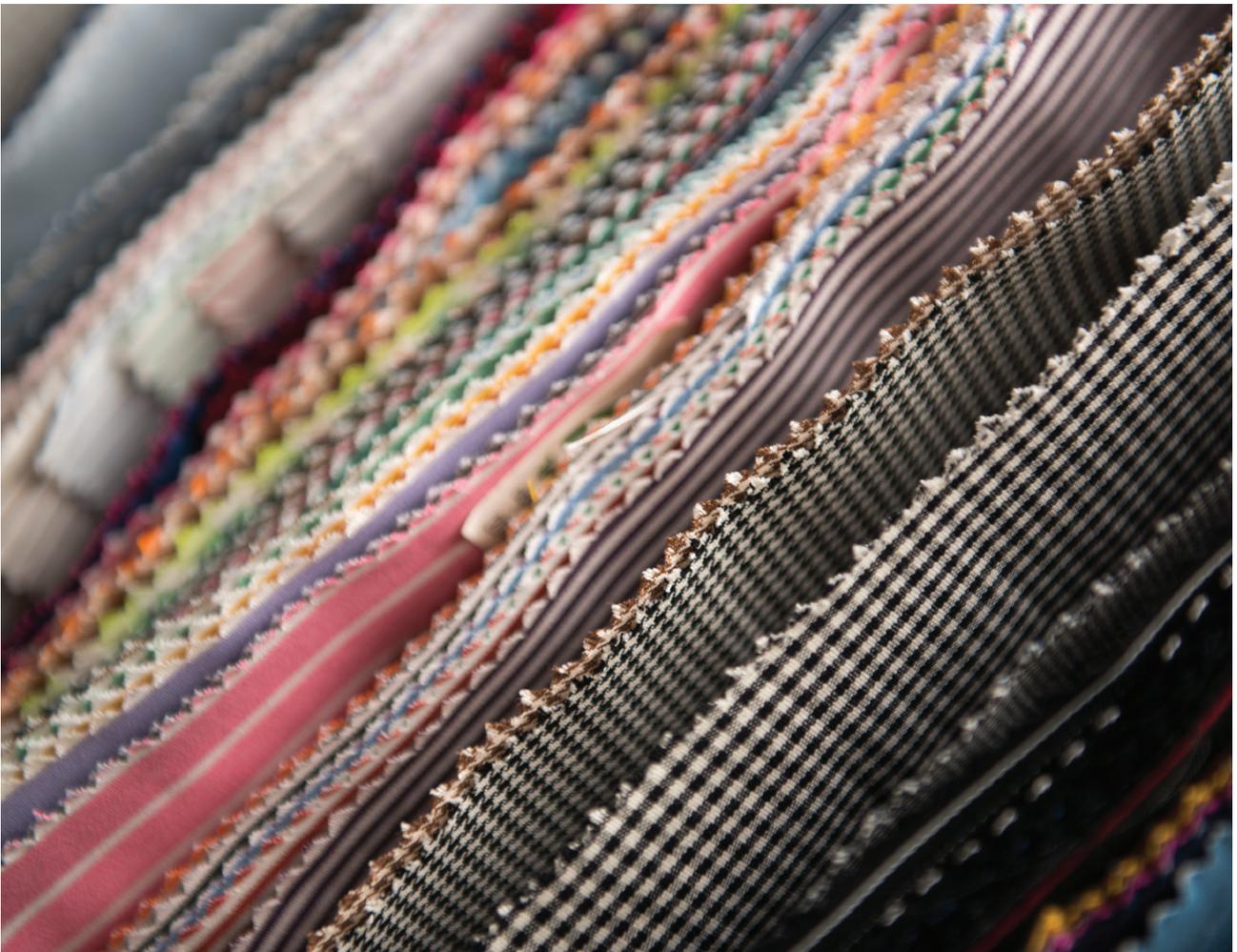
- Where brands do have full traceability, and particularly where the brand specifies the wet processor and other parts in the supply route, there is a greater level of trust, longevity of relationship and appetite for capital investment.

Fragmented supply chains with no extended supplier responsibilities

- As mentioned in the previous section, the network of factories involved in textile manufacture is extensive and complex. Currently, there are no extended chemical supplier responsibilities, and those at the end of the linear chain (the wet processors) have no real option but to carry on with the partial remediation and dumping.

Chemical management practices

- The industry is built on the assumption that the chemical manufacturers are chemical 'managers' and that the chemicals users are just that: users, with no ability to manage chemicals in anything like a sophisticated manner.



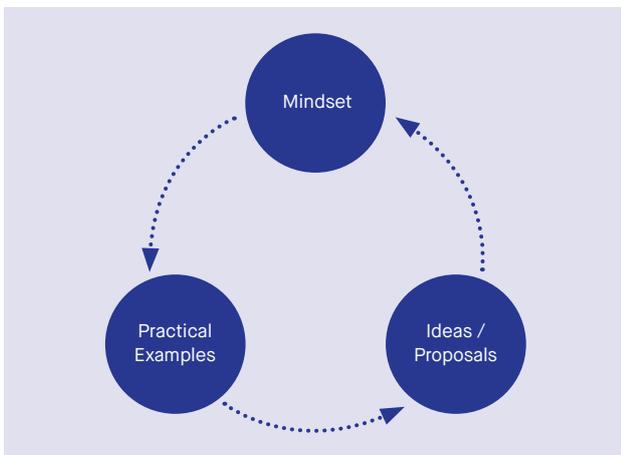
6. Making Non-linear Chemical Use Happen

6.A THE CHANGE IN MINDSET REQUIRED TO MAKE NON-LINEAR CHEMICAL USE HAPPEN

CHANGING THE RELATIONSHIP WITH CHEMICALS:

Moving away from single-use linear models and promoting non-linear use models requires a change of mindset. To start to change the mindset, there have to be practical, tangible, implementable non-linear options available.

Once the mindset changes from one of chemicals as waste-in-waiting to chemicals as a resource, the talent in the industry will seek further opportunities to make non-linear and circular chemical use happen.



This section contains thoughts on how philosophies of chemical use should be changed and where technological changes may be required. It also contains case studies that we can use to learn about non-linear use, which we can then apply to other areas of the industry.

The suggestions, proposals and thoughts are presented with a **positive** view of:

- What is already being done
- What could be done
- What could possibly be done

It assumes someone in the industry **can** design and build equipment and machinery to support non-linear use models and does not get too hung up on the cost and hassle of introducing it (although those barriers must be recognised).

It assumes that chemical suppliers, currently selling chemicals, **can** adapt to be chemical management companies rather than getting hung up on the organisational changes required to adapt.

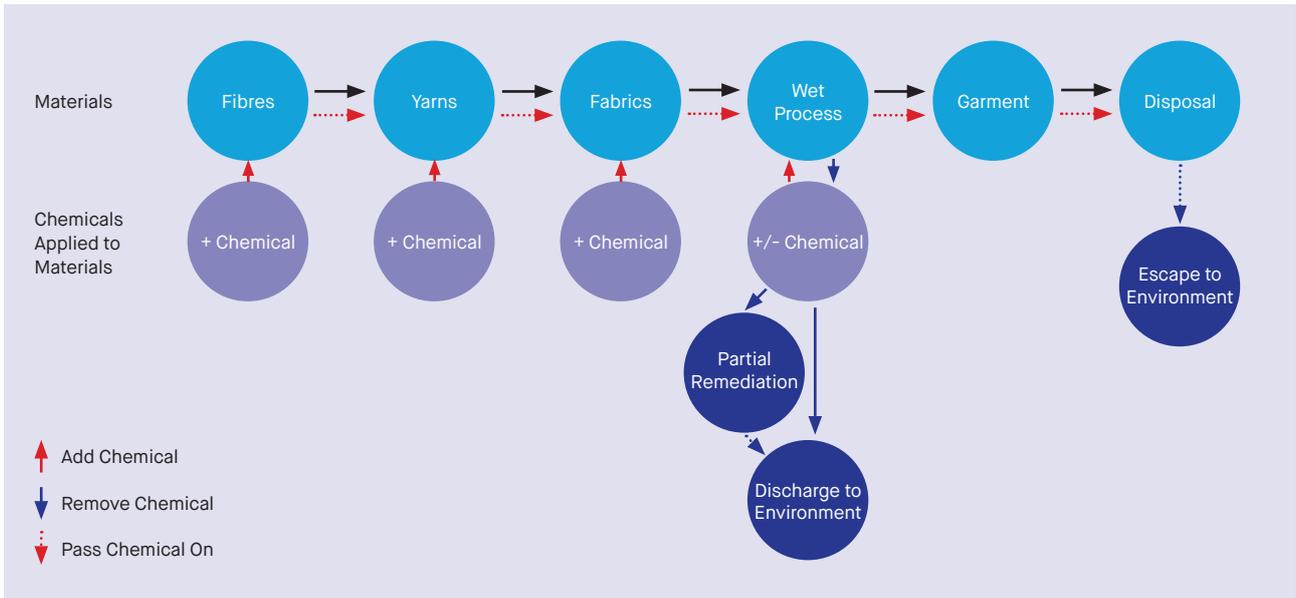
And it assumes that people will be open minded enough to recognise that what is done now is unsustainable and that, in the future, the somewhat binary view of chemicals, as either a useful entity or waste, will be replaced by more circular thinking where all chemicals have value.

For over a century, it has been seen as morally acceptable for a chemical user to use chemicals for their own purposes and then either pass them on to the next actor in the chain or dump them in the environment.

This has to change.

The first step in any change programme is getting those involved in the industry to accept that there is either a problem or an opportunity. This should be done in a sensible way without denouncing those that are currently using the linear model and complying with current pollution standards. Those that are discharging effluent that does not meet regulatory standards, or those that turn a blind eye to the problem, should be denounced.

The collective industry approach should be “we recognise that the way we are working with chemicals is not sustainable or defensible, and we will work together to find ways to reduce the net use and net discharges to the environment”



6.B CHEMICAL USER RESPONSIBILITY (CURE) MODEL

The current situation with chemical use can be demonstrated by the above schematic diagram.

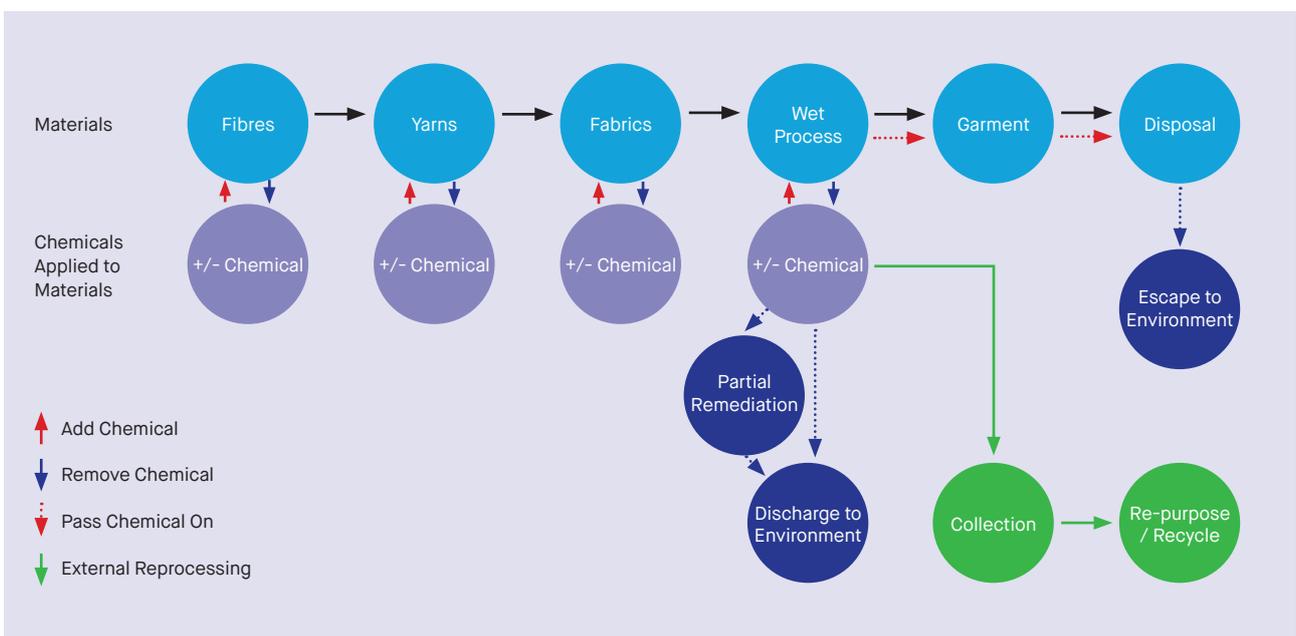
There are some calls for extended supplier responsibilities, but it would be wrong to place all the responsibility for chemical management with just one actor in the supply chain.

It is proposed that the concept of '**Chemical User Responsibility**' (CURE) is applied to break the single-use linear model.

In very simple terms, CURE means that all chemical users become responsible for the chemicals they use at the location they are used.

The concept requires that, unless there is a clear, irrefutable NEED for a chemical to be present on a partially processed or fully processed product, it should be free from any unnecessary chemicals as it is passed on to the next actor in the chain.

The CURE model can be demonstrated by the following schematic diagram. This example shows full reuse or recycling of chemicals in upstream processes and a combination of in-house reuse/recycling, remediation and external reuse/recycling at the wet processor.



The example above accepts that there may still be some discharge to the environment at wet processing but that this should be drastically reduced compared to the standard model.

Of course, a chemical user may wish to focus on their core business (which may be knitting and weaving, for example) and outsource the handling of chemicals in their facility to a chemical management company. This is where chemical leasing by an external company becomes a real possibility.

WEAVING AS AN EXAMPLE OF CURE

The simplest way to explain how the concept of CURE works is by using weaving size as an example.

If weavers were made to take responsibility for the size they applied, using the CURE model, they would be obliged to remove the weaving size before passing on de-sized fabric to the next actor in the chain – normally a dyer or printer.

Faced with the choice of building a fully functioning effluent treatment plant, a (simpler) size recovery plant or employing a contractor to remove and repurpose the size for reuse, they would most likely opt for one of the latter two options, which would be a perfect fit for chemical leasing.

There are a small number of instances where weaving size is recycled but this represents a tiny fraction of woven fabrics and is currently only viewed as being possible in a facility where there is verticality from weaving through to wet processing.

Some brands and standards actually promote the use of biodegradable starch size over the use of recyclable PVA size because of the lower biodegradability of the latter. Some recognised schemes, such as GOTS, encourage the use of starch (which is chemically changed during removal) over recyclable size, but do permit recyclable synthetic size if more than 80% of it is recycled.

The removal and reuse of size at the weaver would dramatically reduce the net chemical use at the weaver. It would also dramatically reduce the amount of chemicals used by a wet processor to remove the size and dramatically reduce the amount of chemicals going into the environment.

6.C.I OPPORTUNITIES TO REDUCE NET CHEMICAL CONSUMPTION AND DISCHARGE IN TEXTILE MANUFACTURING – GENERAL CONSIDERATIONS

The following section considers different parts of the textile manufacturing chain, highlights existing good practice and considers what could be technically possible with a can-do attitude and the CURE model in place.

The aim is to stimulate thought and challenge the many different actors in the industry to consider what could be possible.

Before looking at specific opportunities in specific areas of the industry, there are number of general points to consider. In the following section, the general points are illustrated with real life examples, but the more detailed recommendations and suggestions are provided in section 6.c.ii.

WHAT MAKES A CHEMICAL ‘GOOD’ IN A POST-LINEAR WORLD?

Currently a ‘good’ textile chemical is cost-effective, technically effective, easy to handle, safe and easy to remediate.

The current model assumes that it acceptable for the chemical industry to use very harmful chemicals in very tightly controlled conditions to make textile chemicals. However, it also assumes that users of their products cannot be trusted to employ the same levels of control, and they therefore have to be provided with more benign chemical formulations.

Chemical leasing and non-linear use models do not presume users are non-experts.

Of course, safer chemistry is preferable to less safe chemistry, but chemical leasing services could be provided by experts who use incredibly hazardous, incredibly effective chemicals in a very safe manner in enclosed systems. The focus would be on the function of the chemical and not on the ‘what ifs’ associated with poor handling and irresponsible disposal.

The following factors could and should be a consideration for non-linear use models.

Ease of recycling

- Persistence compared with biodegradability. Persistence is normally considered as being a terrible property because we assume there will be leaks to the environment. But what if fully enclosed, zero-discharge systems were employed? Are there easily recyclable chemicals with great functionality that are currently not used because of their persistence?
- Simplicity of formulation over stability or shelf life. As mentioned earlier in the report, chemical formulations can contain multiple chemicals to aid stability and shelf life. Would simpler formulations with a shorter shelf life be easier to recycle?

Is 'water-based' the future?

- Most current single-use linear models are based on a requirement that all other chemicals, with the exception of dyes, pigments and chemical finishes that are passed on to the final customer, have to be removed using water-based washing processes.
- Organic solvents have got a bad reputation, primarily because poorly contained hazardous solvents can cause severe harm to workers and the environment. However, if managed by experts, solvents offer great potential in terms of the removal and reuse of chemicals.

Are chemical hazards over-prioritised?

- If there were a closed loop chemical leasing and recycling system with no leakage and no residues on product, the current restrictions on chemical inputs imposed by Manufacturing Restricted Substance Lists (MRSLS) in particular might need to be reviewed and chemicals that are currently considered as 'upstream use only' (in the chemical industry) might need to be reconsidered for use in downstream facilities.

Using the same chemical for multiple processes

- Is there an opportunity for universal chemicals or universal formulations? Currently the selfish user model dictates, for example, that a weaver will use the best size for weaving. But could a semi-solid detergent be used as weaving size? (In other words, could a fabric be 'self-cleaning' when immersed in water?)
 - This approach is not necessarily a circular approach but one that reduces net chemical consumption.

- Are there chemicals that operate as both dyebath lubricants and antioxidants or detergents and anti-redeposition aids? This concept suggests that simpler processing baths could be used and reused/recycled more easily than complex, multi-formulation process baths.

Process Bath Stability/Reuse

- Can chemical formulations and recipes be engineered so that process baths can be used several times? For example, could bleaching and scouring baths be monitored to see when they reach saturation of contaminants? Synthetic knit goods have relatively low levels of chemicals on their fibre surface compared to cotton, yet in the majority of cases, the scouring baths are still only used once before being dumped.
- It will be necessary to better understand which chemicals in a process bath remain unchanged in a process and which are chemically reacted.
- Note: Continuous, counter-flow wash ranges inherently reuse wash baths and their use in place of more wasteful batch processing is established. Mechanical and engineering solutions will compliment chemical solutions.

IS PERFECTION THE ENEMY OF THE GOOD?

Wet processors are trained to do things 'properly', and it is normal to see processes broken down into a series of sequential sub-steps that are, ordinarily, each carried out in fresh process baths.

Wet processors are generally trained to fully remove all chemicals from a substrate (usually by using chemicals) before applying the next set of chemicals, often with changes in pH and neutralisation steps. This results in more chemical use than if processes were combined.

For example, it is common to scour a fabric using detergents, pH control, sequestrants, dispersants and so on to remove spinning oil, knitting oil, weaving size and natural impurities. It is then standard practice to fully wash the fabric to remove all traces of those chemicals before proceeding to the dyeing stage.

For many years, dye companies have offered combined scour/dye processes where unwanted chemicals are removed from the fibre surface and dyes applied simultaneously. These processes certainly save water, energy and chemicals but are viewed by users as risky and 'low quality'.

The main risk is a failure to meet the very stringent colour matching requirements of brands, which can result in the rejection of a batch and serious financial consequences. Dyers are prepared to spend a little more money and use more chemicals, energy and water rather than risk a large financial sanction.

Standards for colour matching have become stricter in recent years, with objective science-based colour decision-making often being replaced by visual checks where any deviation from a standard is regarded as failure. This contributes to increased net chemical use.

Similarly, the expectations for colour uniformity within a dye batch are very stringent and result in the use of super-conservative, sequential process baths.

There is an argument to say that, if we recalibrated colour and uniformity standards to be more in line with fit-for-purpose and less in line with perfection, there may be more of an incentive to deviate from the norm, and the use of combined process baths or even the reuse of certain process baths may become more prevalent.

Reusing and topping up certain process baths (scouring baths and even bleach baths) with reactive chemicals such as dyes or bleaches would essentially reuse non-reacting chemicals such as fabric lubricants.

It should be noted that combined process baths would reduce net chemical use compared to sequential baths in the single-use linear model, but the increased chemical complexity may make reuse and recycling of chemicals less easy.

Careful analysis would be required to work out an appropriate pathway.

WASTE AS A PRODUCT/WASTE AS A USEFUL RESOURCE

Lanolin is a very interesting substance, and we can learn a lot about non-linear use models from it.

Raw wool is so greasy and dirty that, unlike cotton, it has to be cleaned before any further processing. Lanolin is extracted from raw wool during the scouring process, recovered, purified and used in a whole host of cosmetics and pharmaceuticals.

A 'problem' chemical for a wool spinner or dyer becomes a valuable product for a different industry. Lanolin can account for between 5% and 25% of the weight of raw wool. The quantities of 'waste' are therefore high relative to the original crop.

Not only is the use of 'waste' from wool noteworthy, but the business model also deserves mention.

Individual dyers or wool yarn spinners do not scour wool. Wool is scoured, and has been for centuries, by wool scourers who offer a dedicated service in centralised locations. Essentially, this is the CURE model or chemical leasing in action.

If everyone in manufacturing chains actively looked for potential uses for their chemical waste, and thought about concentrating it rather than having enormous volumes of diluted effluent, solutions would almost certainly emerge.

THE RELATIONSHIP BETWEEN MATERIALS AND CHEMICAL CIRCULARITY

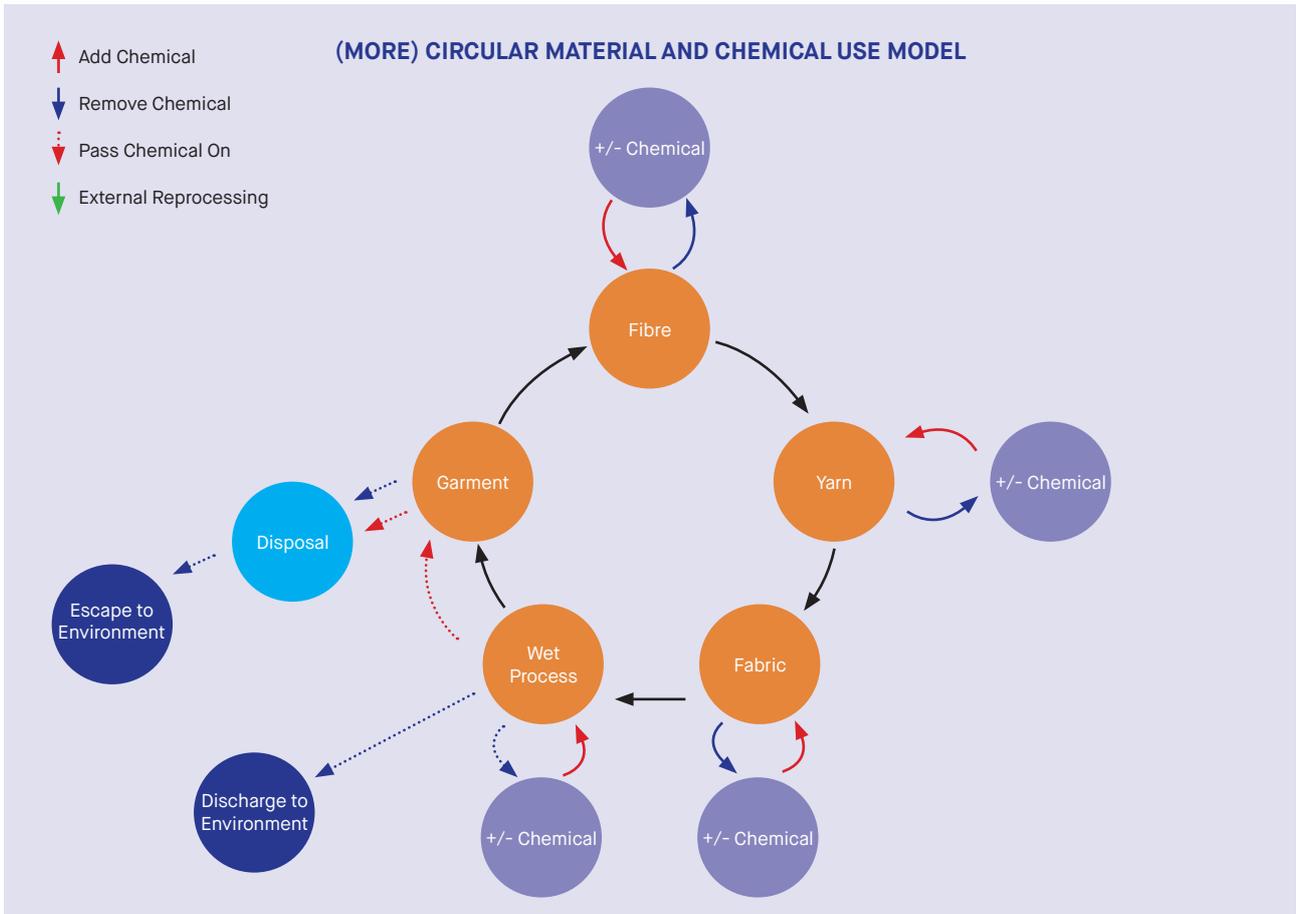
When evaluating the concept of chemical leasing within a circular materials economy, a user of chemicals should ask themselves several questions:

"How does my behaviour with respect to chemicals affect the next person in the chain?"

"Do the chemicals I pass on create unfair chemical management or remediation responsibilities?"

"Do the chemicals I pass on affect material circularity?" (this may be very significant for wet processors and where performance finishes are applied)

The graphic on the right-hand page shows both the concept of CURE and how it links in with the circular materials economy. It is expected that a CURE model would enhance rather than inhibit the circular materials economy.



Colorants are currently chemicals that are passed on to the consumer as a necessity, and they are generally viewed as a significant problem in the context of the circular materials economy (this is why recycled polyester is made from clear plastic bottles: the pigments in clothing are viewed as problematic).

There are other examples where durable chemicals are applied to deliver specific technical performance (e.g. water repellency, non-iron, wrinkle-free) and where the chemicals have a negative impact on circularity.

Chemical leasing, with chemical user responsibilities (where the user only passes chemicals down the chain where absolutely necessary), would also place responsibility on the user to clearly identify which chemicals are passed down the chain.

This could allow non-recyclable materials to be easily identified – thus making recycling simpler – or, at some stage in the future, performance chemicals could be identified, removed and reused by leasing companies, possibly using unique techniques (for example, the chemicals may be durable to normal customer use patterns but removed by a special solvent or other specific technique). After removal of the finish, the fibres may be extracted and used in a circular materials model and the chemical repurposed and reused.

Currently, colour is viewed as a problem in the circular economy, but there is a good case for recycling coloured materials. Detailed examples are provided below.

6.C.II OPPORTUNITIES TO REDUCE NET CHEMICAL CONSUMPTION AND DISCHARGE IN TEXTILE MANUFACTURING – CASE STUDIES AND SPECIFIC OPPORTUNITIES

CASE STUDIES

The main focus of this report is on opportunities for non-linear use models. However, the following section also considers some opportunities to reduce the quantities of chemicals deliberately used in standard processing.

Chemical leasing and the concept on non-linear chemical use models may seem slightly abstract to some observers but some excellent examples exist where chemicals and materials are reused or recycled, where waste is viewed as a valuable resource or by-product, and where chemical use is minimised and discharges to the environment eliminated.

Therefore, this is not a new subject but one where good practice, and the core elements of that good practice, needs to be applied more widely and deeply throughout the industry.

The purpose of the following, very brief, case studies and examples is not to provide in-depth technical and chemical reviews of specific processes but to look at the technology, business models and mindset of the chemical users in these scenarios and what makes these non-linear use models happen in an industry dominated by linear use models.

EXAMPLE/CASE STUDY:	OIL REFINERIES
WHAT ARE THE MAIN LEARNINGS OR OPPORTUNITIES?	CHEMICALS ARE VIEWED AS A RESOURCE AND NOT WASTE
DETAILS AND SIGNIFICANT POINTS:	
<p>An oil refinery takes a complex mixture of chemicals in the form of crude oil and separates it out into constituent chemicals for use as fuel or as feedstocks for the chemical industry.</p> <p>Although a refinery is essentially a linear model where unrefined products come in and separated chemicals go out, the key aspect to note is that the refinery tries to maximise the useable, valuable, saleable outputs from the chemical inputs.</p> <p>Refineries are often linked to chemical reaction facilities where separated chemicals are reacted to form useful building blocks for more complex chemistry, as demanded by the textile and other industries.</p> <p>It should be noted that refineries receive large deliveries of crude oil from a limited number of oil wells. Crude oil has a complex, but fairly consistent composition.</p> <p>There is very little waste from a refinery, with even the most unsophisticated or least well characterised chemicals (tar, bitumen) having obvious end uses and therefore obvious value.</p>	
WHAT LEARNINGS FROM OIL REFINERIES CAN BE APPLIED TO THE WIDER TEXTILE INDUSTRY? WHAT SPECIFIC OPPORTUNITIES SHOULD BE FURTHER EXPLORED?	
<p>In textile processing there is a general acceptance that, with the exception of dyes, pigments and performance finishes, all incoming chemicals are waste-in-waiting and that the requirement to remediate waste streams are a drain on profitability.</p> <p>Is there a possibility that textile waste streams (currently, primarily at a wet processor) could be considered as a source of useful chemicals?</p> <p>Mixed Streams:</p> <p>The chemicals in the effluent stream are often sophisticated chemicals, and time and money has been spent making them from simple building blocks. For many wet processing facilities, the balanced effluent has similarities with crude oil in that it is a complex mixture with fairly consistent composition.</p> <p>The following questions and thoughts are based on a linear model (not CURE) with end of pipe processing.</p> <p>Firstly, it should be established whether separation and use of expensively manufactured complex chemicals is technically possible (for example, can lubricants or unfixed dyes that have remained chemically unchanged be extracted from effluent?).</p>	

WHAT LEARNINGS FROM OIL REFINERIES CAN BE APPLIED TO THE WIDER TEXTILE INDUSTRY? WHAT SPECIFIC OPPORTUNITIES SHOULD BE FURTHER EXPLORED? (CONTINUED)

Secondly, if separation is technically possible, it should be established whether the collection of balanced effluent can be managed from a logistical perspective – locally at a mill, at hubs within processing zones or at regional centres.

If we ever reached a situation where zero discharge to the environment (see later case study) and chemical recycling were mandated, could this catalyse the creation of chemical reprocessing hubs in the areas with intensive wet processing?

Can the effluent stream be concentrated locally and the extracted water reused in processing?

If complex chemicals in mixed waste streams cannot be recovered and reused, can they be broken down into usable building blocks for use by the chemical industry?

If chemicals cannot be recovered or broken down into usable chemicals, is it better to filter out chemicals and deal with solid/semi-solid waste rather than using partial remediation and discharge) (Maybe there could be shared take-back schemes for the chemical industry?)

If chemicals have to be remediated and discharged, can they be remediated in such a way that useful biogas is created and used as fuel, rather than the current situation of greenhouse gas emissions from standard effluent treatment and further biodegradation in the environment?

Segregated Streams:

Using the CURE model, it is conceivable that a typical wet processor would not have to remediate weaving size, spinning oils, cotton waxes/pectins or the chemicals currently used to remove them. Using fewer processes to just apply dyes or chemical finishes may result in much less complex waste streams that can be reused locally or less complex waste streams that the chemical industry can more easily separate and reuse.

EXAMPLE/CASE STUDY:	LOW MINIMUM ORDER QUANTITY DOPE DYE
WHAT ARE THE MAIN LEARNINGS OR OPPORTUNITIES?	ELIMINATION OF UNNECESSARY, CHEMICALLY INTENSIVE PROCESSES BY CONSOLIDATING PROCESSES UPSTREAM
DETAILS AND SIGNIFICANT POINTS:	

Dope is the viscous liquid from which man-made or synthetic fibres are extruded. Dope dye is an established process whereby colours (mainly pigments) are introduced into a polymer solution or melt before the fibres are spun, resulting in coloured fibres being extruded. This means that no dyeing process is required in downstream processing, and it reduces the water, chemical and energy use enormously. It also means that there is no effluent relating to dyeing processes and no need for specific colour removal from effluent.

Dope dyeing (or variations such as gel-dyeing for acrylic) can be applied, in theory, to any man-made or synthetic fibre. It cannot be applied to cotton, wool or other natural fibres since there is no ‘dope’ to dye.

The main problem with dope dye is that it has always been seen as a ‘dirty’ process carried out in ‘clean’ factories. Fibre manufacturing factories are always geared up to produce white fibres and the contamination of pipes and machinery with coloured pigments is problematic (the use of titanium dioxide as a white dulling agent is common).

Dope dye has therefore been the subject of very large minimum order quantities (MOQs) – around 10 tonnes – and this has limited its use to blacks and large volume use areas such as fibres being used for uniforms.

Dope dye finds little use in fashion because the order sizes in fashion are relatively low, and for dope dye to be seen as viable, colour decisions have to be made early in a fashion buying process – before fibres are spun – which goes against the trend of fast fashion, where colour decisions are made as late as possible. Even black dope dye is ignored, sometimes because it is “the wrong black”.

ColorMatrix have created a late injection system where polyester dope is coloured just before it exits a spinneret. This means that colour contamination is limited to a very small part of the spinning system that is fed with colourless dope. MOQs are as low as 10 kg and this opens up the possibility for use in fashion provided that colour decisions can be made early and that slight differences in colour of pigmented fibres compared with colour standards (produced by dyes) are acceptable.

Similarly, We Are Spin Dye is a start-up enterprise that is aiming to create standalone dope dyehouses where polyester chips are used in a dope dye process to make smaller lots in tailored colours for the fashion industry.

DETAILS AND SIGNIFICANT POINTS: (CONTINUED)

The cost of conventional dope dye is one factor that puts off buyers. The cost should be lower than conventional dyeing as it is inherently a much cheaper process, but the highly increased costs of bespoke colours and perceived MOQs mean dope dye is probably not even considered for 99% of orders placed by brands or garment vendors.

Low MOQ dope dye should challenge these views.

WHAT LEARNINGS FROM LOW MOQ DOPE DYE CAN BE APPLIED TO THE WIDER TEXTILE INDUSTRY? WHAT SPECIFIC OPPORTUNITIES SHOULD BE FURTHER EXPLORED?

It can be argued that dope dyeing should be the dyeing method of choice for the industry: it is much lower impact than conventional dyeing, and the technical performance of the pigmented fibres is much better than that of dyed fibres (in terms of colour fastness, etc.).

The textile industry is quite conservative in many respects and a large-scale move away from conventional dyeing has not happened, despite the known benefits.

There is a great opportunity to create an industry 'brand' for dope dye, rather like there is an industry brand for organic or recycled.

If the benefits of dope dye were more routinely understood and marketed, retail brands may start to demand it and start to build full ranges from it.

If restrictions on chemical use, water use, effluent loading and so on were introduced, dope dye could be a very useful solution. With regulatory levers, examples of the widespread use of low MOQ dope dye in fashion ranges and marketing of the benefits, dope dye fibres should become part of the mainstream landscape.

EXAMPLE/CASE STUDY:	LENZING FIBRES, AUSTRIA - VISCOSE
WHAT ARE THE MAIN LEARNINGS OR OPPORTUNITIES?	WASTE AS A RESOURCE, ZERO DISCHARGE MINDSET FROM A PREVIOUSLY POLLUTING INDUSTRY, PARTNERSHIPS WITH OTHER INDUSTRIES TO SELL OR USE 'WASTE'. SAFE CHEMICALS CAN CAUSE SERIOUS DAMAGE.

DETAILS AND SIGNIFICANT POINTS:

The viscose fibre industry has, historically, been viewed as extremely damaging as a whole. There has been extensive use of timber from unmanaged forests, and the two-stage production process, consisting of wood pulp manufacture followed by viscose fibre production, has often led to serious pollution incidents to the point where the very existence of viscose fibres has been questioned.

Indeed, several decades ago, some manufacturers themselves questioned whether viscose production could be made cleaner and less damaging, and they embarked on research projects that ultimately resulted in the creation of lyocell, a fibre with much lower environmental impacts (see next case study).

Typically, a viscose process involved the creation of wood pulp, which involves stewing wood to remove lignin and hemicellulose to leave cellulose in the form of sheets (like rough paper). There are many variants of the pulping process, but it was not uncommon to convert the unwanted parts of the wood to water-soluble species and wash them away. Pulp effluent can be very high in terms of chemical loading, and historically this industry has caused major damage via the discharge of high concentrations of 'safe' chemicals.

The second stage involves the treatment of cellulose with sodium disulphide in a multi-step process that ultimately yields viscose fibre (cellulose) and sodium disulphide, hydrogen sulphide and sulphur. The process was incredibly dangerous for workers and polluting for air and water before more stringent controls were introduced.

The very stringent pollution controls forced a mindset change from the buy-use-dump of chemicals to a closed loop process, where some chemicals are continuously recovered and reused, other waste streams are used as fuel and others are treated as useful by-products that can be used in other industries.

At Lenzing, Austria, they have verticality from FSC managed timber supply through to viscose fibre production. They actually refer to their pulping process as a bio-refinery because they want every part of the wood to be useful.

DETAILS AND SIGNIFICANT POINTS (CONTINUED):

The pulping process sees 40% of the wood converted to wood pulp (the cellulose portion). The remainder is converted into useful chemicals such as acetic acid, furfural, sodium sulphate, soda ash and even wood xylose that is converted by a partner to make artificial sweeteners.

The bark from the tree and so-called ‘black liquor’ from the pulping process is used as fuel.

In the viscose process there is (almost) closed loop chemical recovery with reuse of key chemicals and recovery of sodium sulphate for sale to other industries.

A small amount of effluent discharge is treated before discharge to the environment.

Lenzing have also partnered with the local authority to take waste (which cannot be recycled) for use in their energy plant.

WHAT LEARNINGS FROM LOW LENZING VISCOSE PRODUCTION CAN BE APPLIED TO THE WIDER TEXTILE INDUSTRY? WHAT SPECIFIC OPPORTUNITIES SHOULD BE FURTHER EXPLORED?

The most important aspect here is for brands and legislators.

The imposition of strict legislation with regard to pollution challenged the linear buy-use-dump model. No longer permitted to simply dump (to air and water) chemicals that were not part of the desired output (viscose fibres), they were faced with a clean-up or close down choice.

There was a reappraisal of the total system, and this has resulted in a cleaner production process with lower net chemical use, lower discharges to the environment and a viable, profitable business selling by-products to other industries. The use of low-grade waste (bark, lignin, etc.) as fuel has also considerably reduced fuel bills and the reliance on fossil fuels.

The textile industry should see that tighter restrictions on the discharge of chemicals can actually be an enabler of new ways of working and thinking.

The concept of the bio-refinery for previously ‘unwanted’ chemicals in the wood could be applied to cotton. The percentage of natural ‘impurities’ is much lower on a weight basis than in wood, but the current volumes of cotton used in textiles are enormous compared to timber-based fibres.

Scouring of cotton close to its origin could provide very large quantities of useful chemicals and ensure a clean fibre was passed downstream, resulting in much lower net use of chemicals and discharges to the environment.

The concept of energy from waste is not new but is rarely seen in the textile industry. Provided emissions are managed, it is more sensible to burn waste (possibly waste chemicals) and capture useful energy than allowing/forcing it to biodegrade and contribute to climate change with no recovery of energy.

EXAMPLE/CASE STUDY:	LYOCELL/REFIBRA
WHAT ARE THE MAIN LEARNINGS OR OPPORTUNITIES?	THE USE OF WASTE AS A RESOURCE. THE USE OF RECYCLABLE SOLVENTS TO REDUCE NET CHEMICAL CONSUMPTION AND ELIMINATE EFFLUENT VIA THE REPLACEMENT OF AQUEOUS CHEMICAL PROCESSES. THE LINK BETWEEN CIRCULAR MATERIALS AND CIRCULAR CHEMICALS.

DETAILS AND SIGNIFICANT POINTS:

In addition to viscose, Lenzing produce lyocell fibre. The first stage of the production, pulping, is exactly the same as for viscose. However, the second stage is completely different and was invented at a time when the satisfactory clean-up of traditional viscose production was thought impractical.

Lyocell is made by simply dissolving wood pulp in a special solvent (N-methylmorpholine-N-oxide or NMMO) and extruding the fibres.

The solvent is completely recycled in a closed loop process and is often regarded (when coupled with Lenzing’s bio-refinery pulping of FSC certified timber) as the most sustainable textile fibre.

Refibra uses the lyocell technology to make new lyocell fibres from a combination of old cellulose garments (post-consumer waste) and pre-consumer waste, which is a combination of factory waste and off-cuts from garment factories.

The process can convert old, worn cotton into new lyocell.

DETAILS AND SIGNIFICANT POINTS (CONTINUED):

At present, the presence of dyes and colourants is a problem: they want to make white fibres and therefore the dyes have to be removed.

Refibra is now at a commercial scale and has the infrastructure and backing of a large fibre company.

Using a similar mindset, but striking out as an independent start-up, Worn Again are using solvent-based fibre recycling for a number of different fibre types, even being able to recycle blends. Key to their success is an understanding of what chemicals are present, or could be present, in textile waste streams. Currently, they have to cope with what comes their way, but as these approaches to support the circular materials economy develop in scale, they may be able to start to dictate what chemicals are present in textile products at point of sale.

WHAT LEARNINGS FROM LYOCELL/REFIBRA CAN BE APPLIED TO THE WIDER TEXTILE INDUSTRY? WHAT SPECIFIC OPPORTUNITIES SHOULD BE FURTHER EXPLORED?

Dope dyeing using pigments has very clear environmental benefits and dramatically reduced chemical consumption in wet processing since no dyeing stage is required: the fibres are coloured as they are formed.

The current scale of the Refibra process necessitates the removal of colour, but there is a possibility that in future dope-dyed waste streams (viscose and potentially lyocell) could be segregated into different colours and coloured fibres produced.

If dope-dyed coloured waste streams were accurately measured, there could be an option to mix e.g. red, blue, yellow streams to make a palette of colours. This would not result in 'endless' recycling but would contribute to the circular material economy via non-linear use models for both the polymer and the colours.

If pigments were used for dope dye lyocell/Refibra (or indeed any other dope-dyed fibre), they could be removed, filtered and separated and reused.

The key learning from lyocell and Refibra is the replacement of an aqueous (previously) buy-use-dump fibre manufacturing model to a circular use model with no effluent. This is achieved by the use of fully recyclable solvents. There are many processes that are currently carried out in aqueous processes that could conceivably be carried out using solvents in closed systems (see case study on solvent scouring).

EXAMPLE/CASE STUDY:	RECYCLED POLYESTER
WHAT ARE THE MAIN LEARNINGS OR OPPORTUNITIES?	WASTE AS A RESOURCE OF MATERIALS AND AS A SOURCE OF BUILDING BLOCKS. DISPARATE WASTE CAN BE CONSOLIDATED INTO A SMALL NUMBER OF PROCESSING CENTRES. MARKETING A SIMPLE MESSAGE WORKS AND CREATES DEMAND.

DETAILS AND SIGNIFICANT POINTS:

Recycled polyester is one of the most successful innovations in the sustainable textiles arena, to the point that many brands would have consumers believe that the unit of input to clothing is now 'the plastic bottle'.

Recycled polyester is made from clear plastic bottles because there is little contamination by chemicals or colour and there is a ready supply of discarded, single-use bottles.

There are two type of recycled fibre: one that is melted and extruded and one that is depolymerised into starting building blocks and then repolymerised. Neither method is free from energy inputs, and the inputs associated with transport and cleaning have to be factored in, but overall it is widely agreed that recycled polyester has a lower impact than virgin polyester.

One of the reasons for its success is that the fibre company does all the work and the downstream industry carries on as normal – there is no hard work for knitters, weavers, dyers or printers, no changes to everyday processing and brands simply specify the fibre type, pay a premium compared with virgin fibre and then market it.

The investment required for bottle cleaning and depolymerisation is large, but this is carried out in only a few locations, so reasonable levels of scale and therefore efficiency can be achieved.

It is noteworthy that the collection of bottles from billions of global users is an enormous logistical challenge and one that has been successfully achieved.

WHAT LEARNINGS FROM RECYCLED POLYESTER CAN BE APPLIED TO THE WIDER TEXTILE INDUSTRY? WHAT SPECIFIC OPPORTUNITIES SHOULD BE FURTHER EXPLORED?

One of the key learnings is simple messaging.

For downstream textile processing, what could be marketable? Could we see a situation where lower impact processes are neatly wrapped up by marketeers, sold to end consumers, and sought and promoted by large retail brands?

Could Zero Discharge facilities be promoted in the same way that 'organic' and 'recycled' are? Could weaver-designed fabrics become mandated? Could farm-scoured cotton or bio-refinery-scoured cotton challenge organic or BCI?

The potential for the promotion of non-linear use models is discussed in detail section 7.

From an organisational and logistical perspective, the collection, consolidation and transportation of bottles to reprocessing hubs is interesting. Because they have a value (to the fibre company and to retail brands), this seemingly incredibly difficult task just gets done. Obviously, bottles are polyester only – a single polymer with fairly consistent composition.

Could/would this type of logistical operation be done for mixed dyehouse effluent? Could/would this type of logistical operation be done for simpler, segregated waste streams?

The number of dyehouses in the world is much smaller than the number of litter bins in the world!

EXAMPLE/CASE STUDY:	DENIM
WHAT ARE THE MAIN LEARNINGS OR OPPORTUNITIES?	DENIM USES RELATIVELY STANDARD PROCESS, APPLIED ACROSS ALL FACTORIES INDUSTRY. PRACTICAL CHANGES COULD BE WIDELY IMPLEMENTED RESULTING IN LARGE BENEFITS.
DETAILS AND SIGNIFICANT POINTS:	

From an environmental perspective, denim is whole series of contradictions.

Yarns are spun from raw cotton and undergo a fairly cursory scouring process as they are passed through hot alkaline baths prior to dyeing.

Indigo dye is applied to warp yarns on continuous dyeing machines from reused, topped-up dyebaths, which are only periodically completely drained and replenished. This conserves water, chemicals and energy and is a model that does lend itself to chemical leasing. The dyebaths are very simple and contain dye, alkali and reducing agents and, in order to keep the dye soluble, an excess of chemicals is often used.

However, when the dyebaths are drained – usually because contamination from cotton (waxes, pectins, etc.) has become too high or there is an inability to achieve high pH because of buffering effects – the amount of dye and chemical that goes to waste is significant.

The yarns are always dyed to a very dark blue colour, irrespective of the final desired shade, and are sometimes tinted with sulphur dyes. After dyeing, the dyed yarns are coated with weaving size, fabrics are woven and then garments are made from either loomstate or de-sized fabric.

There are various trends in terms of localised abrasion, tinting, ripping and so on, and these tend to be applied to unlaundered garments (although not always).

There are examples of lower impact localised effects, such as the use of lasers to replace chemically intensive and potentially dangerous processes (for example, potassium permanganate spray).

The garments then undergo washing and bleaching processes in an industrial laundry to achieve the desired shade, which can vary from very dark blue to almost white. Very large amounts of dye are washed off, sometimes with the aid of abrasives such as pumice stones, and the laundry effluent has a very high chemical loading.

Ozone bleaching is becoming more popular and is potentially an alternative to chemically intensive bleaching processes. However, at the time of writing, it is rarely used for genuine indigo bleaching, despite being marketed as a legitimate alternative. Concerns over the toxicity of ozone dictate that very tight controls on workplace exposure must be in place.

WHAT SPECIFIC OPPORTUNITIES SHOULD BE FURTHER EXPLORED? WHAT LEARNINGS FROM DENIM CAN BE APPLIED TO THE WIDER TEXTILE INDUSTRY?

The basic method for dyeing uses caustic soda, powdered indigo dye and hydros as a reducing agent. Indigo is soluble when reduced in alkali medium, and the dyebath has to reach a certain pH level and reduction potential to keep the dye dissolved. Caustic soda and hydros are cheap, commodity chemicals and are often used to excess “to keep the dye dissolved”. However, salts are formed, and these impair solubility and mean that dyebaths have to be dropped and replenished. The amount of salt going into effluent treatment plants, and thus into the environment, is very high (standard effluent treatment does not remediate salt).

The use of pre-reduced indigo dye (sold as a liquid in reduced form) reduces the amount of hydros required and thus reduces the salt formation and keeps dyebaths viable for longer.

Clever reducing agents (e.g. Sera Con C-RDA from DyStar®) can be used to replace hydros and further reduce salt formation, keeping dyebaths viable for longer and reducing the amount of salts formed and discharged to the environment.

Indigo is a commodity dye and inexpensive compared to most other dyes. However, it is generally present in dyehouse effluent on its own and is therefore recoverable (some sulphur bottom applications may have small amounts of sulphur dyes in the first indigo dyebath).

There are some pilot projects to recover indigo, but this practice is not widespread.

There are only approximately 500 denim dyers globally, so the reuse of indigo from dyebaths should not pose a huge logistical challenge. There are many, many more denim laundries than indigo dyers, and the denim laundry process removes very large quantities of indigo from the surface of fabrics. This almost always goes into effluent and is either discharged to the environment or becomes part of a solid waste stream. Similar to the dyehouse situation, this dye could be recovered and reused.

Denim is often bleached to lighter colours using chlorine-based bleach, and in this process, some dye is physically removed and some permanently destroyed. The strong oxidative bleaching destroys the dye molecule, making it non-recoverable.

The whole denim dye-laundry process should be challenged. A process where 100 units of dye are applied and up to 95 of them (in the paler shades) are subsequently removed to deliberately leave traces of dark patches in puckered seams should be questioned.

The denim business is huge and is based on the use of one dye molecule. The lack of complexity makes it an ideal industry for non-linear use models.

If the cost and purity of recovered indigo could be aligned with the cost of virgin indigo and promoted with a simple message, the build-it-up-to-knock-it-down dyeing method could be easier to justify.

Spanish denim technology providers Jeanologia have developed a zero-discharge module for denim laundries. The full scope of this approach, including dye recovery should be explored.

If cotton fibres were scoured prior to yarn spinning, in line with the Chemical User Responsibility Model, the levels of contamination in dyebaths could be reduced and, coupled with the use of reducing agents that form less salt, the lifetime of the baths could be extended.

The use of pre-reduced indigo and specific low salt-forming reducing agents is becoming more popular in the dyeing phase, and other non-denim dyeing processes could learn from this. Many standard processes have neutralisation steps, and these are often poorly controlled with over-dosing of acids and alkali, resulting in salt formation.

The denim industry should look at methods to build up colour to achieve the desired pale and medium shades rather than bleaching down from a dark base. In the absence of dye recovery, the current 95% dye wastage in pale shades, with attendant water, energy, chemical and effluent impacts cannot be defended. The use of localised dye resists and dye ‘attractants’ or inkjet printing could be employed.

Indigo could be recovered from waste denim – whether post-consumer or pre-consumer waste – either by using solvents or other means of extraction.

The lack of chemical complexity and indigo recovery from waste would also make take-back schemes by denim brands relatively straightforward.

WHAT SPECIFIC OPPORTUNITIES SHOULD BE FURTHER EXPLORED? WHAT LEARNINGS FROM DENIM CAN BE APPLIED TO THE WIDER TEXTILE INDUSTRY? (CONTINUED)

Dye could be extracted and used, and the fibres recycled, either mechanically or via a chemical process such as Worn Again or Refibra.

Indigo is made using aniline as a starting material, and residual aniline is present in crude indigo powder. As questions start to be asked about the aniline content of indigo, there may be a push to reduce levels, which in turn is likely to cause prices to rise. Currently indigo is very cheap, but an increase in price (possibly due to regulatory or brand pressure) will make recovery and recycling far more attractive. If recycled indigo was cheaper and promotable, it would happen.

EXAMPLE/CASE STUDY:

LEATHER – CHROME RECYCLING ([HTTP://LIFE-SHOEBAT.EU/EN/SEARCH-TOOLS/TANNERY-BATS/ITEM/TANNERY-29-EN](http://life-shoebat.eu/en/search-tools/tannery-bats/item/tannery-29-en))

WHAT ARE THE MAIN LEARNINGS OR OPPORTUNITIES?

WASTE FROM AN AQUEOUS PROCESS AS A RESOURCE. THE USE OF A 'HARMFUL' BUT RECYCLABLE CHEMICAL IN PREFERENCE TO A MORE BENIGN CHEMICAL THAT IS MORE SUITED TO A LINEAR USE MODEL. A CENTRALISED HUB FOR WASTE RECOVERY/CHEMICAL RECYCLING. LEGISLATION CATALYSING INNOVATION.

DETAILS AND SIGNIFICANT POINTS:

The leather industry is viewed as a dirty, chemically intensive, polluting industry and, in many areas of the world, that is true.

However, there are increasing numbers of tanneries working to higher standards (such as those promoted by the excellent leather Working Group or LWG), and these tend to have very stringent controls on chemical discharges from facilities.

Almost all leather used in the fashion industry is chrome-tanned leather. Chrome tanning involves the use of water-soluble chromium salts to crosslink animal skins to turn them into useful leather.

The effluent from the chrome tanning process contains quite high levels residual chrome salts and, in many areas of the world, it is no longer permitted to discharge them to the environment.

Recycling of chrome can be carried out at an individual tannery or in a central chrome recovery unit. Central facilities serving multiple tanneries are operational in Europe. Individual facilities discharge to a central chrome recovery plant, and the chrome salts are collected, divided and reused by the tanneries. Up to one third of the chrome intake for the tanneries comes from recovered chrome. The chrome recovery plant is essentially a great example of a non-linear use model with external contractors collecting waste, repurposing it and selling 'new' recovered chemicals back to the tanneries.

WHAT LEARNINGS FROM CHROME RECYCLING CAN BE APPLIED TO THE WIDER TEXTILE INDUSTRY? WHAT SPECIFIC OPPORTUNITIES SHOULD BE FURTHER EXPLORED?

The chrome recycling facilities serve the dual purpose of reducing discharges and reducing costs of production in the tanneries.

There are many examples in the textile industry of wet processing hubs with many factories sharing central effluent treatment plants (CETPs).

The infrastructure for collecting effluent from multiple facilities is not uncommon and therefore consideration should be given to whether they should evolve to become chemical recycling centres – maybe with segregated effluents coming in, maybe with clear restrictions on chemicals that can and cannot be used by the factories whose effluent they currently treat.

The leather industry has looked at using less harmful tanning agents, and aldehydes find popularity in some areas, notably the automotive industry. However, they are not recoverable nor recyclable.

Circular models require chemicals to be recoverable from waste streams, and there may be occasions where a less safe but recoverable chemical is a better all-round choice than a 'greener' or 'safer' option.

In some parts of Turkey, wet processors are being forced to send their effluent to CETPs (over distances of several kilometres) despite having on-site facilities, because the remediation in the CETP is better than it currently is on site.

Although this seems draconian, it does highlight what is possible logistically with regulatory levers. If the CETPs evolve to become chemical recycling centres or partial recycling centres and their use is made mandatory, this would be progress for the industry.

EXAMPLE/CASE STUDY:	MERCERISATION/LIQUID AMMONIA
WHAT ARE THE MAIN LEARNINGS OR OPPORTUNITIES?	THE USE OF RECYCLED CHEMICALS TO TRANSFORM TEXTILES WITH NO CHEMICAL ADD-ON
DETAILS AND SIGNIFICANT POINTS:	
<p>Solvents and solutions have the ability to swell certain textile fibres and permanently change the cross-sectional shape, surface characteristics and therefore their aesthetics and performance.</p> <p>A common example is mercerisation, which uses very strong caustic soda to make elliptical cotton fibres rounder and smoother and makes a cotton fabric more lustrous and more receptive to dye.</p> <p>After application, the strong alkali is washed away leaving no chemical residue but producing a permanent change to the fibre properties.</p> <p>The use of a chemical that does not have to stay on the fibre to modify its aesthetics and performance is attractive in that there are no concerns with consumer safety or legal issues. The concept also fits well with the CURE model.</p> <p>If the caustic soda is simply washed off, removed and sent to an effluent treatment plant, it will need to be neutralised by an acid, forming salt as part of this process. Such processes therefore have a significant environmental impact.</p> <p>It is therefore not uncommon for factories to have caustic recovery plants to recover and reuse the caustic soda.</p> <p>A similar process is carried out using sophisticated, fully closed machinery and liquid ammonia (liquefied gas at very low temperature). After application, the ammonia evaporates and is recycled leaving dry fabric with altered properties and aesthetics. Cotton fabrics are more lustrous and also have some resistance to permanent creasing.</p> <p>Liquid ammonia processing requires refrigeration units and very stringent engineering controls to avoid dangerous releases of ammonia gas.</p> <p>Normally these levels of control for chemical containment are only seen in the upstream chemical manufacturing industry.</p>	
WHAT LEARNINGS FROM 'CHEMICAL-FREE' CHEMICAL FINISHING CAN BE APPLIED TO THE WIDER TEXTILE INDUSTRY? WHAT SPECIFIC OPPORTUNITIES SHOULD BE FURTHER EXPLORED?	
<p>The ability to carry out processes with full chemical recycling is clearly beneficial and has a large positive impact on net chemical use.</p> <p>With a common process such as mercerisation, the difference in net chemical consumption between a linear and circular process is very significant.</p> <p>It should be debated whether 'circular mercerisation' should be marketable and/or whether linear mercerisation should be discouraged/banned.</p> <p>Liquid ammonia processing challenges the industry stereotype that wet processors cannot be trusted to handle hazardous chemicals in a professional manner.</p> <p>The machinery has to be built to very high specifications, and safety is engineered into the process.</p> <p>'Chemical-free' chemical processing challenges the popular concept of the MRSL – the sensible concept that you should control chemical inputs in order to control chemical outputs. MRSL thinking generally permits hazardous substances to be used in upstream chemical manufacturing, where levels of exposure control are assumed to be adequate, but restricts their use in downstream processing, the assumption being that some of the chemical will remain on the substrate, that some will enter the environment and that workers will inevitably be exposed.</p> <p>By moving upstream levels of containment and exposure control into downstream facilities, we could permit the use of more hazardous, more effective and more easily recyclable substances.</p>	

EXAMPLE/CASE STUDY:	CONTINUOUS SOLVENT SCOURING
WHAT ARE THE MAIN LEARNINGS OR OPPORTUNITIES?	USE OF RECYCLABLE SOLVENTS. POTENTIAL RECYCLING/USE OF CHEMICAL REMOVED IN THE SCOURING PROCESS
DETAILS AND SIGNIFICANT POINTS:	
<p>Continuous solvent scouring is a process that has been applied to synthetic knitted fabrics prior to heat setting for some time. Its use is proven but is not commonplace.</p> <p>The main area of use is in the removal of knitting and spinning oils from synthetic fabrics, and it is very well suited to a chemical leasing or non-linear use model.</p> <p>The solvent used is normally perchloroethylene. This solvent has come under scrutiny because of its hazard profile, and it is the most common solvent used in commercial dry cleaning. Exposure of workers to perchloroethylene in poorly managed dry-cleaning facilities is a concern, and concerns over the solvent choice have limited the roll out in textile facilities.</p> <p>In industrial continuous solvent scouring, the solvent is completely recycled: the contaminated solvent is recovered and reused and the oils are separated out. Currently the oils are generally seen as waste and are disposed of according to local regulations.</p> <p>Continuous solvent scouring is sometimes used to improve the colour fastness of polyester and polyester/elastane blends.</p> <p>The disperse dyes used to dye polyester are not soluble in water. It is therefore typical, after a polyester dyeing, to carry out a process called reduction clearing using caustic soda and hydros. This requires water, energy and chemicals and contributes to effluent loading. Solvent scouring can be used as an alternative with no net chemical use.</p> <p>Solvents are typically recovered using distillation, but more energy efficient alternatives using filtration are becoming available in the commercial cleaning sector.</p>	
WHAT LEARNINGS FROM SOLVENT SCOURING CAN BE APPLIED TO THE WIDER TEXTILE INDUSTRY? WHAT SPECIFIC OPPORTUNITIES SHOULD BE FURTHER EXPLORED?	
<p>There is no reason why chemicals that are removed from fabrics could not be separated and recycled if the required logistics, infrastructure and mindset were in place.</p> <p>Continuous solvent scouring is available in the textile processing industry, but batchwise processing is not available. There is merit in examining where closed loop solvent-based processes could be used in place of current aqueous processes.</p> <p>Supercritical CO₂ has been used for dyeing polyester but has not taken off at scale because the cost of the highly pressurised equipment is prohibitive. The use of other solvents at atmospheric pressures could be employed if the necessary controls were in place.</p> <p>Solvent scouring, using a range of solvents in both continuous and batchwise processing, could revolutionise the textile industry and net chemical consumption – the use of solvents in an industry founded on open vessels and poor exposure control seems far-fetched because of some obvious dangers (worker exposure, air emissions, etc.). However, closed systems with excellent engineering controls are worthy of fuller investigation. Different solvents at different parts of the textile manufacturing chain should be considered.</p> <p>Now that ultrafiltration, nanofiltration and reverse osmosis are becoming more widely available, robust and cost-effective consideration could be given to using water as the ‘solvent’. Rather than viewing the filtration of effluent as water filtration, it could be viewed as both water and chemical recycling. Chemicals can be collected rather than being sent to an ETP.</p>	

EXAMPLE/CASE STUDY:	LANOLIN
WHAT ARE THE MAIN LEARNINGS OR OPPORTUNITIES?	WASTE AS A RESOURCE. USING HUBS FOR PROCESSING MATERIALS FROM MULTIPLE REMOTE LOCATIONS
DETAILS AND SIGNIFICANT POINTS:	
<p>The wool industry is ancient and the use of ‘waste’ on wool fibres as useful products is a carry-over from old-fashioned thriftiness rather than relating to the new topic of sustainability.</p> <p>Wool in its raw state contains around 5-25% of grease and other materials. These are removed and purified to produce lanolin that is used in the cosmetics and pharmaceutical industries. Other components of the wool ‘waste’ have been used historically to make chemicals such as potash.</p> <p>Because of their high percentage content, these substances have to be removed in order for the wool fibre to be further processed.</p> <p>Lanolin itself is a very complex chemical mixture, and there are some concerns over contamination by agrochemicals such as sheep dip, but the composition of the substances on raw wool is relatively consistent.</p> <p>Rather than individual farmers scouring their own fleeces, the industry developed to have dedicated wool scourers who provide cleaned wool for sale to spinners.</p> <p>There may be levels of verticality in the industry, but wool scouring, where the waste becomes a useful product and clean fibre with no unnecessary chemicals present is passed down the chain, is a useful reference point for chemical leasing and non-linear models.</p>	
WHAT LEARNINGS FROM WOOL SCOURING CAN BE APPLIED TO THE WIDER TEXTILE INDUSTRY? WHAT SPECIFIC OPPORTUNITIES SHOULD BE FURTHER EXPLORED?	
<p>Wool has approximately 1% market share, but cotton has around 27%.</p> <p>The natural oils, waxes, pectins and so on that make up approximately 4% of raw cotton could be a valuable chemical resource. If they were removed at source – or in hubs – the chemicals could be available in large quantities, and clean fibre could be passed down the chain, vastly reducing the chemical use downstream. It may be possible to use recyclable solvents to remove the natural substances from cotton and have the cotton scouring processor as a zero-effluent facility.</p> <p>Could ‘field scoured cotton’ be marketable in the same way that ‘organic’ or ‘recycled’ is marketed?</p> <p>There may be other smaller scale or even niche fibres, such as linen or nettle, which have much higher amounts of pectins and other ‘waste’ present, that become more attractive.</p> <p>Currently there is a requirement for retting, where the natural substance that hold the fibres together in a stem are broken down by microbiological action to release the fibres before spinning. The substances are currently seen as problematic, but if they were viewed as a valuable resource, possibly removed via solvents, this may change the way they are processed.</p>	

EXAMPLE/CASE STUDY:	PRATO WOOL RECYCLING INDUSTRY
WHAT ARE THE MAIN LEARNINGS OR OPPORTUNITIES?	WASTE AS A RESOURCE. CONSOLIDATION OF MATERIALS FROM MULTIPLE REMOTE LOCATIONS. RECYCLING OF COLOUR TO ELIMINATE WET PROCESSING. VIEWING COLOUR AS A BENEFIT IN THE CIRCULAR ECONOMY.
DETAILS AND SIGNIFICANT POINTS:	
<p>Prato in Italy is well known for its wool industry and, specifically, for its recycled wool industry.</p> <p>Knitwear garments are collected throughout Europe (and possibly beyond) and transported to Prato, where they are segregated into colours, washed, teased apart into constituent fibres that are then blended and re-spun. Depending on the requirements of the new final product, it may be necessary to use a carrier fibre to give the recycled wool yarn greater strength.</p> <p>There are two types of fibre removal from garments: a dry process, which is aggressive and produces shorter fibres, and a wet process, which is gentler and preserves more of the original fibre length.</p> <p>The yarns are woven or knitted and may or may not require topping up with colour to meet a customer’s colour palette.</p> <p>Wool has a small market share in the fashion market but there is still enough product recycled to make a viable business that recycles materials and the dyes. As a result, there is much less use of dyes and colourants in the second production process.</p> <p>There is a downgrade of quality compared to virgin yarns because of the reduced fibre length of the recycled fibres, but the products are still fit for purpose – although it is unlikely that they would survive a further mechanical recycling process.</p>	
WHAT LEARNINGS FROM THE PRATO WOOL RECYCLING INDUSTRY CAN BE APPLIED TO THE WIDER TEXTILE INDUSTRY? WHAT SPECIFIC OPPORTUNITIES SHOULD BE FURTHER EXPLORED?	
<p>Other fibre types could be mechanically recovered from fabrics, segregated into different colours and used to produce certain fit-for-purpose products.</p> <p>Recycled cotton is a challenge because after recycling the fibres are quite short and the yarns produced are not of good quality. However, it could work for certain fibre types.</p> <p>The main area of interest in Prato is the ability to collect large amounts of garments such that they can be segregated into colours. The aim is to recycle the dyes within the fibre and view it as a valuable resource rather than as a problem.</p> <p>This may be of interest to Refibra, Worn Again or other chemical recycling initiatives that currently see colour as a problem but may, after reaching a certain scale, see colour, as a benefit.</p> <p>Work has been conducted at The University of Leeds to examine whether ‘imperceptible fibre blending’ can be used to create a full palette of colours. The concept is that if you mixed red, yellow and blue fibres together in a yarn to achieve multiple colours they may look acceptable from a distance but would look like a melange yarn. If you had an inventory of maybe 30 or 50 stock colours, different colours could be achieved with good solidity. This could work for recycled yarns and, potentially, fast response dope dye.</p>	

<p>EXAMPLE/CASE STUDY:</p>	<p>ZERO LIQUID DISCHARGE (ZLD)</p>
<p>WHAT ARE THE MAIN LEARNINGS OR OPPORTUNITIES?</p>	<p>PLACING DRACONIAN RESTRICTIONS ON OUTPUTS SHIFTS THE FOCUS TO INPUTS AND CATALYSES INNOVATION. WATER IS VIEWED AS A VALUABLE COMMODITY. USING LESS WATER MEANS USING LESS CHEMICALS. THE COST OF REMOVING CHEMICALS FROM EFFLUENT STREAMS PROMOTES REDUCED CHEMICAL USAGE. MAKING INDUSTRY PAY A FAIR PRICE FOR WATER HAS ENORMOUS ENVIRONMENTAL ADVANTAGES BEYOND SIMPLE WATER CONSUMPTION.</p>
<p>DETAILS AND SIGNIFICANT POINTS:</p>	
<p>Zero Liquid Discharge is a situation where there is no discharge of any effluent, treated or otherwise, outside the boundary wall of a wet processor.</p> <p>Initially introduced in parts of India where rivers were becoming too polluted, it is a model that could, and maybe should, become the industry norm.</p> <p>Normally ZLD is mandated by a local authority, but a few mills are seeing how it promotes a virtuous circle of less water use, less net chemical use, less net energy use and therefore lower costs and lower environmental inputs.</p> <p>The mandate for ZLD is normally accompanied by a requirement to pay a fair (high) price for incoming water.</p> <p>ZLD forces factories to recycle water: water recycling is the only way that they can remove pollutants from their effluent streams and turn it into solid waste, which is currently collected by licensed contractors.</p> <p>The factories that were forced to operate as ZLD facilities were almost exclusively weft knit cotton dyers with jet dyeing machines. Their effluent contained a lot of unreacted reactive dye, salt and natural substances that were removed from cotton. Their response to the ZLD mandate was to build water recycling facilities and position them after their standard effluent treatment plants. These recycling facilities were based on reverse osmosis (which gave approximately 75% fresh recycled water from the effluent) and very energy intensive evaporators to reclaim as much of the remaining 25% as possible. After evaporation thick slurry remains and is dried and disposed of as solid waste.</p> <p>Overall net water consumption dropped by a staggering 90% (the only losses being due to evaporation during processing). Initially, however, gross water use remained the same, resulting in almost a doubling of energy use, with water recycling requiring approximately the same amount of energy as the dyehouse facility itself.</p> <p>Over the years, dyers in ZLD facilities have realised that by cutting gross water use (the amount used in processing) they can dramatically reduce the cost of recycling – because there is less to recycle. They have also realised that cutting gross water use automatically reduces chemical use – because most chemicals are used in grams per litre (g/l) quantities, and fewer litres = fewer grams.</p> <p>Additionally, they have realised that deliberately reducing the amounts of chemicals used on a g/l basis makes water recycling more efficient and cheaper.</p> <p>Advances in water processing, with reverse osmosis being used in multiple banks and being augmented by nano- and ultrafiltration, means that the amount of water being passed to the energy intensive evaporators in the better facilities is now as low as 7% and gross water consumption in world class facilities can be as low as 40 to 50 l/kg.</p> <p>Originally, dyers were faced with augmenting existing factories, but new investments in salt-free reactive dyeing equipment, such as cold pad batch, are further improving the situation.</p> <p>There is an environmental cost to water recycling – energy is required, but overall ZLD has developed to a stage where it could reasonably be demanded by any government or brand.</p> <p>ZLD reduces ground and surface water depletion, eliminates water-based pollution, gross water use and energy use in processing, and it stimulates innovation. If the solid waste currently generated could be used as a valuable resource, it should almost be demanded. It would be irresponsible not to do so.</p>	

WHAT LEARNINGS FROM ZERO LIQUID DISCHARGE CAN BE APPLIED TO THE WIDER TEXTILE INDUSTRY? WHAT SPECIFIC OPPORTUNITIES SHOULD BE FURTHER EXPLORED?

Salt-free reactive dyeing is key to lower cost water recycling in reactive dyeing facilities.

Cold-pad-batch dyeing is salt-free and there are some other developments available, such as a patented salt-free reactive dyeing method developed at The University of Leeds.

Governments and brands could mandate ZLD for all dyehouses, and this would force innovation that promotes reduced chemical use and circularity. If the CURE model were applied, the waste streams would be much less chemically loaded than normal dyehouse effluent and recycling would be much easier and cheaper.

Currently, ZLD water recycling always comes after a standard biological effluent treatment process, in order to try to break down chemicals that could foul up reverse osmosis membranes. As filtration technology improves and effluent streams get less complex, simple filtration with the collection and reuse of chemicals could make water recycling easier and cheaper.

The purpose of this report is to seek ways to reduce net chemical consumption and net discharge to the environment. ZLD almost solves the issue of discharge to the environment and also acts as a very forceful lever to stimulate initiatives to reduce net chemical consumption. The cost of water and cost of mandatory water recycling forces change.

SUMMARY OF POTENTIAL OPPORTUNITIES FOR IMPROVEMENT AT EACH STAGE OF THE PROCESS

The examples and case studies mention some possible opportunities for the implementation of non-linear use models.

The table below summarises some recommendations and suggested opportunities for reduced net chemical use and reduced net discharge on a sub-process by sub-process basis for a typical textile manufacturing process.

These are provided to initiate a discussion on non-linear use models, and it is anticipated that experts from different areas of the industry will add, review and refine these in due course.

It should also be understood that if more is done to promote circular chemical use in upstream processes, it will result in fewer chemicals being used in downstream processes. Therefore, suggestions for end of pipe recycling and repurposing may not actually be required if upstream initiatives are successful and nothing exits the pipe.

PROCESS	OPPORTUNITIES FOR REDUCED USE AND NON-LINEAR USE MODELS
<p>Synthetic Fibre Production</p>	<p>Reduced Use:</p> <p>It is conceivable that 'lubrication of fibre' could be a service that is provided under a chemical leasing arrangement. Yarn/fibre is typically sold by the kilogram and the weight of the lubricant will not be discounted. Moving to sales by dry/clean weight would encourage spinning oil/lubricant use to be minimised.</p> <p>Spin finishes are generally applied to assist with subsequent processing, notably knitting or preparation for weaving. A main component in many formulations is a lubricant to reduce friction as a yarn goes over (potentially many) guiders, rollers and slots and so forth. The one-off purchase of low friction guiders may reduce or eliminate the need for spin finish. It is worth noting that the friction of PTFE is less than a tenth of that of steel.</p> <p>Non-linear Use Models:</p> <p>There are some self-emulsifying spin finishes available, and these do not require the use of additional detergent for them to be removed during wet processing.</p> <p>If spin finishes 'have' to be present in knitting and weaving, they can be removed by solvent scouring after a fabric has been created using a technique that allows for recycling of the solvent and collection of the spin finish. This may permit the simple reuse of spin finish if it is not contaminated with other chemicals used in knitting and weaving. Spin finish could be removed as the first stage of a sizing operation and recovered in an uncontaminated state. With some form of machinery modification, spin finishes could be removed on entry to knitting machines.</p>

CHEMICAL CIRCULARITY IN FASHION

PROCESS	OPPORTUNITIES FOR REDUCED USE AND NON-LINEAR USE MODELS
<p>Man-made Fibre Production</p>	<p>Reduced Use: Same as synthetic fibre production.</p>
<p>Natural Fibre Agriculture</p>	<p>Reduced Use: The well-established organic fibre choice provides options for no chemical use, and BCI cotton provides options for reduced chemical use.</p> <p>Non-linear Use Models: There are some self-emulsifying spin finishes available, and these do not require the use of additional detergent for them to be removed during wet processing.</p> <p>It is beyond the scope of this report to consider agrochemicals, but there is merit in considering whether they can be removed from fibres at source and reused (it should be noted that agrochemicals are generally applied to a field and only a tiny fraction is present on fibres). There is also a theoretical possibility that a 'dual/multi-purpose' chemical could be used – for example, an agrochemical that acts as a spin finish.</p> <p>Natural substances could be removed from cotton at source and collected. This would provide a potentially useful supply of useful chemicals and provide clean fibre to the downstream industry, reducing chemical use and discharges to effluent. (See case study on lanolin.)</p>
<p>Staple Fibre Spinning</p>	<p>Reduced Use: See synthetic fibre production.</p> <p>Non-linear Use Models: See synthetic fibre production</p>
<p>Knitting</p>	<p>Non-linear Use Models: Self-emulsifying oils can eliminate the need to use detergents in downstream scouring (only applicable on synthetics and man-made fibres and only applicable where spin finish is also self-emulsifying).</p> <p>The amount of knitting oil that is present on knitted goods is small and the amount that could be recovered would need to be established, but applying the CURE model to knitters and using solvent scouring to recover solvents and oils would mean dyers could avoid scouring and go straight into a dyeing process for certain dye/fibre combinations, saving time, energy, chemicals and effluent loading.</p> <p>Machine lubrication is a candidate for genuine chemical leasing.</p>
<p>Weaving</p>	<p>Reduced Use: Is size always needed? From a weaving efficiency and weaving damage (at current weaving speeds) perspective there will be strong arguments against it, but can we weave with no size? Would size-less weaving be marketable?</p> <p>Non-linear Use Models: Recycling weaving size is possible and is occasionally practised. Widespread adoption of this practice and promotion of weaver-sized fabrics would be of great benefit in terms of reduced net chemical consumption and reduced chemical discharge.</p>

PROCESS	OPPORTUNITIES FOR REDUCED USE AND NON-LINEAR USE MODELS
<p>Wet Processing (in general)</p>	<p>Reduced Use:</p> <p>Most chemicals are used on a g/l basis. The reduction of liquor ratio (the ratio of water to substrate) in any active process bath will reduce the litres and therefore the grams used.</p> <p>Where machinery design precludes the option to reduce liquor ratio, investment in newer, lower liquor ratio machinery should be encouraged.</p> <p>Many chemicals are included for 'insurance'. Studies should be conducted to establish which can be removed and where concentrations can be reduced.</p>
<p>Scouring and Bleaching</p>	<p>Reduced Use:</p> <p>Self-emulsifying knitting oils and spin finishes can reduce detergent use.</p> <p>For cotton, the use of enzyme-based scouring processes reduces chemical and energy consumption.</p> <p>Lower liquor ratio processing.</p> <p>Scour/dye combined processes generally result in reduced net chemical use.</p> <p>Any upstream initiatives to remove oils, finishes, and size – plus natural impurities – will reduce chemical use and even render the process unnecessary.</p> <p>Non-linear Use Models:</p> <p>Non-linear Use Models:</p> <p>A study of which chemicals in the scour/bleach process bath are reacted or consumed (e.g. hydrogen peroxide) and which remain unchanged (potentially lubricants) could lead to some bath reuse via topping up.</p> <p>The scour/bleach bath for fibres such as cotton has an extremely high effluent loading and, even if new models are not applied to chemical use, there is a strong argument for segregating the effluent streams to examine whether they can be used for 'biogas' generation in a modified effluent treatment process or filtered to recover some chemicals.</p> <p>Continuous bleaching and scouring of fabrics, using modern counter-flow machines, tends to be more efficient than batchwise processing. The design of these machines includes the inherent reuse of process baths, and they therefore use less water and chemicals.</p> <p>Solvent scouring using recyclable solvents can be employed to remove chemicals from fibres, yarns and fabrics and permit recycling and reuse.</p> <p>Scouring and Bleaching is one of the most chemically intensive processes in terms of both chemicals applied and chemicals removed and should be a key focus.</p>
<p>Pre-dye Preparation</p>	<p>Non-linear Use Models:</p> <p>Liquid ammonia.</p> <p>Mercerisation with caustic recovery (see case study).</p> <p>Can anything be done to recover caustic from polyester weight reduction? (This may also help with reducing the amount of antimony entering the effluent stream.)</p>

PROCESS	OPPORTUNITIES FOR REDUCED USE AND NON-LINEAR USE MODELS
<p>Dyeing</p>	<p>Reduced Use:</p> <p>The most chemically intensive dyeing process is the reactive dyeing of cotton. The use of salt-free dyeing processes or low salt reactive dyes reduces salt use and discharge, and the use of high fixation dyes reduces the amount in effluent streams and the amount of chemicals required to remove colour.</p> <p>Non-linear Use Models:</p> <p>Most dyes stay on the fibre and go through to the end consumer. The amount used is determined by the colours chosen by designers and buyers.</p> <p>Fully exhausted dyebaths, where the dyes have been transferred to a fibre but the fixation chemicals are present, could in some circumstances be topped up and reused. If upstream initiatives were employed to remove oils, spin finish, size and natural impurities, this would be eminently feasible for high fixation dyeings such as polyester, acrylic and nylon. Denim dyeing ranges use dyebaths that are topped up (see case study).</p> <p>The most common source of unfixed dyes in effluent is reactive dyes from cotton dyeing but these are hydrolysed (chemically changed) during the process and are no longer reactive. They could potentially be used as lower fastness direct dyes for less demanding end uses.</p> <p>Dyes are an obstacle to the circular economy for materials – at the current scale. Material recyclers currently struggle with coloured materials, hence the use of clear plastic bottles for recycled polyester, but in future it may be possible to recycle materials in colour groups and reuse the dyes or pigments.</p> <p>The most obvious opportunity for altering the industry business models would be a radical shift to dope dyeing for man-made and synthetic fibres (see case study on dope dyeing).</p> <p>A circular materials model could go hand in hand with the recycling and reuse of dyes or pigments (see case study on the Prato wool industry).</p>
<p>Dye Printing</p>	<p>Reduced Use:</p> <p>Better matching of paste quantities to fabric quantities minimises waste.</p> <p>Inkjet printing creates colours via optical illusions (different coloured dots are placed so close together as to be indistinguishable) and enables millions of colours to be created from a small number of stock colours, thus reducing waste.</p> <p>The use of water atomisers on entry to steamers can reduce the level of humectants in print pastes (including potentially damaging urea).</p>
<p>Pigment Printing</p>	<p>Reduced Use:</p> <p>Better matching of paste quantities to fabric quantities minimises waste – as per dye printing.</p> <p>Inkjet printing creates colours via optical illusions (different coloured dots are placed so close together as to be indistinguishable) and enables millions of colours to be created from a small number of stock colours, thus reducing waste.</p>
<p>Chemical Finishing</p>	<p>Reduced Use:</p> <p>Better matching of chemical finish quantities prepared relative to fabric quantities minimises waste.</p> <p>Single-sided application of finishes via coating or kiss-roll should be considered where two-sided effects are not required.</p> <p>Physical finishing (such as brushing, sueding and so on) can replace some chemicals.</p> <p>Plasma can be used to apply much smaller quantities of chemical to substrates – it is yet to become mainstream.</p> <p>Some chemical treatments, such as the use of liquid ammonia (fully recycled) and mercerising (with caustic recovery), can be used to modify the aesthetics of fibres without fixing chemicals to the fibre surface (see case study).</p>

PROCESS	OPPORTUNITIES FOR REDUCED USE AND NON-LINEAR USE MODELS
<p>Chemical Finishing (continued)</p>	<p>Reduced Use:</p> <p>The use of techniques to modify textile surfaces by physical means, temporary application of chemicals or exposure to other agents (such as electrical fields or radiation) has to be further explored, especially with the growth in the circular materials economy.</p> <p>Non-linear Use Models:</p> <p>Pad liquors can be pumped into storage tanks for future use. It has to be questioned whether there is ever any excuse, with the exception of machine cleaning, for finishing chemicals applied by pad mangles to enter effluent streams.</p>
<p>Industrial Laundry</p>	<p>Reduced Use:</p> <p>See general wet processing, scouring and dyeing.</p> <p>See denim case study.</p> <p>Ozone can be used to reduce chemicals in denim bleaching.</p> <p>Lasers can be used to reduce chemicals used in localised denim bleaching.</p> <p>Physical abrasives can be used to reduce chemicals used in localised denim bleaching.</p> <p>Non-linear Use Models:</p> <p>See general wet processing, scouring and dyeing.</p> <p>See denim case study for comments on indigo recycling.</p> <p>Abrasives such as pumice cannot be recycled as they are no longer useful for abrasion in powder form, but the pumice powder should be recovered and not allowed into the environment and other uses should be evaluated.</p>
<p>Effluent Treatment</p>	<p>Reduced Use:</p> <p>Very simply, the use of lower amounts of chemicals in wet processing reduces the amount of chemicals in effluent streams. It also reduces the amount of chemicals added at the ETP required to treat the effluent.</p> <p>Any upstream initiatives will reduce chemical use in wet processing and therefore chemical use in the ETP.</p> <p>The use of ozone for the decolourisation of effluent results in reduced chemical use, and organic flocculants result in less chemical use than crude ferrous lime..</p> <p>Non-linear Use Models:</p> <p>See case study on ZLD.</p> <p>It is convention to treat effluent prior to discharge. This is entirely because a linear use model that accepts that some pollution is acceptable pervades the industry and, to some extent, society. Rather than partially treating effluent with aerobic digestion, there are other options to consider:</p> <ul style="list-style-type: none"> • Filtration (standard, ultra-, nano-) so that all chemicals can be taken out of effluent for reuse, reprocessing and so on • Used as fuel • Stored/disposed of as solid waste (potentially reducing greenhouse gas emissions) • Concentrated and biodegraded in a manner that generates useful biogas <p>Currently, mixed effluent streams are balanced/mixed as that is the most convenient way to prepare effluent for biological treatment. Streaming effluent depending on content/concentration may allow for reuse of some streams and for different, tailored remediation methods for others.</p>

6.D CHALLENGES TO THE IMPLEMENTATION OF NON-LINEAR USE MODELS AND LEVERS TO FACILITATE ADOPTION

Some of the examples in section 6.c.ii may be easy to implement, have very low barriers to their introduction, and are almost in the 'no-brainer' category. Others, however, may need levers to be pulled, incentives to be given or restrictions placed on existing linear models in order to make them more mainstream.

It could be argued that things such as the use of dope-dyed fibres, low liquor dyeing machines, enzymatic bleaching of cotton and high fixation reactive dyes should be in the no-brainer category as far as the reduced deliberate use of chemicals is concerned.

Likewise, the recycling of caustic soda in mercerising, the use of self-emulsifying spin finishes and solvent scouring for synthetic fabrics should be easy to roll out across the industry.

However, for some proposals there are many potential barriers and things to consider:

Can models be developed that make reduced net chemical usage more profitable for the existing chemical industry?

Will they adapt by selling lower volumes of more innovative chemicals or will they adapt to have a mixed portfolio of sales of virgin chemicals and repurposed/recycled chemicals?

Can models be developed that result in the emergence of innovative chemical leasing companies that challenge the current chemical companies?

These questions will require detailed analysis by the chemical industry.

Will a CURE model see innovative new technologies emerge that are so good that certain technologies become almost obsolete? Rather like digital photography killed off silver halide films, could we see solvent scouring and dope dye take over from aqueous processing and the use of dyes as the preferred colouring matters? If solvent scouring of recyclable weaving size at the weaver becomes the norm, it is inevitable that sales of detergents and additives for scouring processes will drop off. This would be a good thing for the planet but not for a detergent company.

Can we expect to see brands promote non-linear use models within their sustainability programmes?

Can we expect governments and brands to mandate behaviours that forbid the use of single-use linear models?

The answer to the last question is key and, in order for governments to consider making such mandates, they must be sure that viable non-linear alternatives are available.

CHALLENGES AND OPPORTUNITIES FOR THE CHEMICAL INDUSTRY

The main question to address is how do you get buy-in for business models based on selling lower volumes of chemicals from chemical companies that make their money based on selling higher volumes of chemicals?

The good news is that the better chemical companies already do this to some extent via promoting innovative new chemicals and formulations. However, the concept of take-back, on-site repurposing or the use of mixed dyehouse effluent as a chemical resource would need to be embraced by them or by new entrants into the market.

Logistical problems associated with the number of individual chemical users may be cited as an obstacle to take-back or chemical repurposing.

This argument has limited credibility from a purely logistical standpoint, as they manage to deliver chemicals to these factories. However, significant investment in talented resources (more highly trained than delivery drivers) may be required if on-site or regional repurposing were to be carried out.

The logistics for non-linear use models may actually already be in place to a large extent. It is more a case of how the chemicals are viewed, used and disposed of/recycled that has to be considered.

In some respects, the chemical companies may even reach a situation where they sell more chemicals. Would they actually need to sell 'less' if they were reusing and recycling? In some instances, it may even be better to use higher concentrations to aid functionality while reducing net consumption via non-linear use models.

The chemical industry will be a key player if non-linear use models are to become mainstream, and its research, development and know-how will be critical in making increased circularity possible.

CHALLENGES AND OPPORTUNITIES FOR CHEMICAL USERS

For chemical users, chemicals are a cost. They have to be bought and ultimately remediated. They enable products to be made and, in many cases, they prevent problems from occurring.

Chemical users do not define themselves as ‘chemical users’; they are spinners, knitters, weavers, dyers and printers.

Their job is to spin, knit, weave, dye and print, and they make their money by doing just that, as they have for centuries. The split in profits in textiles is heavily weighted to retail brands, with manufacturers making much lower profit margins. They must therefore focus on the daily routine of making things.

This breeds conservatism, and the industry is generally risk averse and change averse. In addition, the amount of time and effort spent on research and development is relatively low – even though the opportunities for improvements in efficiency are very significant.

Chemical users will have to think long and hard about how much effort and how much capital investment they can put into initiatives to use lower amounts of relatively cheap chemicals. Using lower amounts should be quite simple and easy to implement, but the financial cost of new equipment or engineering projects associated with reuse and recycling, coupled with the disruption to day-to-day manufacturing, may be a challenge.

This is why external providers of chemical solutions may be a better model. The reduced disruption aspect may push the industry to look for external solutions and open up chemical leasing as something more mainstream.

This is why the CURE model is proposed. If users are forced to take responsibility for the chemicals they use, they will have a stark choice to make: upskill or outsource.

CHALLENGES AND OPPORTUNITIES FOR MACHINERY MANUFACTURERS

Progress in textiles in terms of efficiency has largely been due to machinery manufacturers, with support from the chemical industry.

For example, in the past 40 or 50 years, the liquor ratios of dyeing machines (the ratio of water to substrate) have come down from 40:1 to around 5:1, and the speed of spinning, knitting and weaving has more than doubled. This would not have been possible without developments in chemistry and chemical formulations to support these more intensive processes.

They key aspect to understand when it comes to any new push, such as non-linear use models, is that the industry is conservative. They do, however, renew machines periodically when investment in the latest technology becomes a ‘no-brainer’. When the pay-back time associated with reduced water, energy and chemical consumption becomes so short as to be impossible to ignore, the industry invests.

Part of the non-linear use model story will undoubtedly be from pioneering machine builders who, supported by the chemical industry, will create machines with in-built engineering for reuse, recycling and repurposing.

The desire by leading machinery and chemical companies to be one step ahead of their competitors will lead to change, but that change will only happen in a big way if the economic drivers for the industry are compelling.

PROMOTION OF NON-LINEAR MODELS AND INCLUSION IN INDUSTRY SCHEMES

In order to propose how non-linear uses may be rolled out throughout the industry, it is important to look at how other chemical related issues are managed and how their roll-out has been conducted.

Currently, most brands manage chemicals on their products via Restricted Substances Lists (RSLs), and a growing number are implementing restrictions on the chemical inputs used to manufacture their products (MRSLs).

There are also guidelines on the content of wastewater discharges, and these guidelines are based on basic legal requirements and the analysis of chemicals listed on MRSLs. The most commonly referenced wastewater guideline is that of ZDHC.

The MRSL and wastewater guidelines are important in terms of managing the worst excesses of the current linear model, but they do accept a linear model is in place.

For any issue, there is general progression towards the introduction of controls that avoid the worst behaviours or incentivise better behaviours:

Guidance

- Drawing up good and bad practice related to the issue

Promotion/Marketing

- Promoting good practice that rewards industry with extra orders, in-store marketing, etc.

Standards/Expectations

- Compliance with the standards for a particular area of interest may be requested but policed in a light touch manner, with non-compliance being the subject of action plans and co-operative working

Enforceable standards

- Standards may be actively policed with demonstration of compliance mandatory before contracts are signed and serious consequences for non-compliance
- The standards may demand good practice and/or forbid bad practice

Legislation may also be passed in certain countries to support an initiative by promoting good practice and/or restricting bad practice.

Over the past two decades the industry, brands and legislators have made very good progress with respect to reducing the amount of harmful chemicals on product at point of sale, and this is because there are standards and legislation that are actively policed.

Chemical inputs and wastewater remain a work in progress.

Although legal standards for conventional wastewater parameters exist in most areas of the world, the policing by brands and governments is very patchy with non-compliance being tolerated. Zero liquid discharge is easier to police and, where it is mandated, it is more actively policed.

MRSL management is a newer stream of work, and early signs are encouraging with industry schemes such as the ZDHC MRSL being viewed as the de facto standard that the industry is striving to meet.

Some industry schemes related to the selection of chemicals in textiles and the content of effluent discharge (such as Afirm, ZDHC, Oekotex and Bluesign) are becoming increasingly influential, and such schemes could be a very important part of a chemical circularity approach.

Other areas of promotable good practice are visible and growing. For example:

Recycled polyester is common and well promoted, recycled nylon is emerging and, as noted elsewhere in the report, recycled wool and cotton are available. Recycled fibres are seen as 'better', but standard fibres are still available and are not banned or necessarily seen as 'bad'.

Organic cotton and BCI cotton are very common. These are seen as 'better', but conventional cotton is still available and is not banned per se. Nevertheless, some brands are now pushing for only organic or BCI cotton in their ranges.

Responsible down standards and responsible wool standards are becoming more popular. These relate to animal welfare but are notable because they are basically a certification that certain processes and systems have been conducted within certain boundaries of acceptability. It is getting to a stage where failure to get these certifications is being seen as 'bad'.

HOW COULD CHEMICAL LEASING AND NON-LINEAR USE MODELS BE PROMOTED?

At this stage it is too early to make a definitive recommendation for the promotion and roll-out of chemical leasing and non-linear use models. It is clear, however, that simple messages work.

There are many competing and complementary chemical management schemes in existence. Although they tend to share the same sentiments, the lack of alignment causes difficulties. It took a long time for Afirm to create a single unified RSL, and even now, brands and other schemes have differences. The ZDHC group faces challenges with industry alignment despite the concept being relatively new with relatively little deviation from a core list of substances.

Therefore, while it would be very beneficial for all existing schemes to promote the concepts of non-linear use models, care should be taken to avoid the creation of competing scoring systems or criteria.

As detailed in this document, despite the overwhelming prevalence of linear buy-use-dump use models, there are already many good examples of non-linear chemical use. This is really helpful in providing examples of business models, changed mindset and technical detail to the public, governments and brands, who may not understand the complexity or benefits of those pockets of excellence.

Because textile processing is a multi-stage process and there is an almost infinite combination of processes, it is impossible to define what the perfect scenario is or what a product made entirely by non-linear chemical use models looks like. It is likely that perfection will never exist and there will always be leakage from closed loops, but where non-linear use models lead to reduced net chemical consumption and reduced discharges of chemicals to the environment, it should be recognised.

Throughout the report the term ‘non-linear use’ is used in preference to ‘circularity’ to give a *technically accurate* description of what is actually happening. It is, however, recommended that, for communication and promotional purposes, the simpler message of ‘**Chemical Circularity**’ is used and promoted using a simple logo in a similar way to ‘organic’ or ‘recycled’:

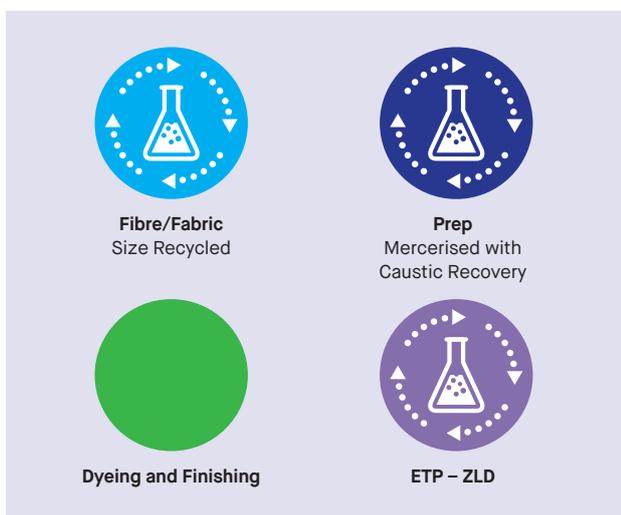


The logo could highlight/reward non-linear chemical use in textile processing and there could be product-based marketing to promote good practice. If used wisely, this could provide pull-through to market and encourage the use of Chemical Circularity/non-linear use models in industry.

A simple graphic of this kind could indicate where non-linear use patterns have been used; it would be the equivalent of the recycled symbol for materials. It could potentially carry a score or a colour grading to denote the level of non-linearity/circularity/leasing. The details or criteria that must be met to achieve the label, grading systems and so on will need to be established. (The Textile Exchange is becoming recognised for its work in recycling certifications, and its input would be invaluable.)

For a product, you could possibly introduce a label that covered different parts of the textile production chain, for example, fabric production, preparation, dyeing and finishing, and chemical remediation (ETP).

If you had a theoretical woven cotton fabric that was de-sized at the weaver with size recycling, mercerised in a facility with caustic recovery and dyed normally at a factory with zero liquid discharge, the label could possibly look like this:



The logical first stage for introducing such a scheme would be to draw up guidance documents. Information from this report may be helpful in that regard.

Chemical leasing and non-linear use models are not yet recognised as a single concept. This provides the opportunity to create a single, unified approach from the start.

Agreement should be sought on which non-linear sub-processes should be mandated, which can be promoted at point of sale, and on which single-use linear model processes should be banned or phased out.

Stakeholders may be able to work together to create a scoring or grading system for products, processes and facilities.

This may result in buying choices based on non-linear chemical use and even a critical failure scenario where some linear use model processes are forbidden.

LEVERS

If chemical leasing and non-linear use does not occur organically – because of either financial or behavioural barriers – levers may need to be introduced to encourage or mandate its use.

If this were necessary, the questions would be what levers, introduced by whom and how?

Incentives or requirements for lower water use are beginning to creep into some enlightened brands’ buying processes, and these tend to have the knock-on benefit of lower energy and chemical use (since many chemicals are used on a g/l basis).

This is not common, and detailed verification of factory water consumption remains an expert job, but it demonstrates the direction of travel: better brands are demanding more responsible ways of working from their suppliers and are prepared to invest in expertise to verify supplier performance.

Ultimately, the easiest and most impactful way to reduce net chemical consumption and discharge to the environment is via reduced water consumption – because, as mentioned previously, most chemicals are used on a g/l basis. And the best way to reduce water consumption is by charging a sensible price for industrial water use.

Provision of free water for the wet processing industry is something collective governments should address, as it is a massive contributor to net chemical use, net discharges to the environment and climate change (energy required to treat, heat and remediate).

Regulatory levers do work. Where water is expensive or there are super-strict (and actively policed) discharge limits, you will find that water consumption, and therefore net chemical consumption, is reduced.

Water charges, water caps and active pollution management have to be a big part of the solution.

In Europe the Mogdon formula is often used to set discharge limits. This is a complex mathematical algorithm that considers a number of basic effluent parameters to work out the cost of water treatment by a central or municipal facility.

$$\text{Trade Effluent Charge} = R + [(V + Bv) \text{ or } M] + B(Ot/Os) + S(St/Ss)^7$$

VARIABLE	DESCRIPTION
R	This is the charge for receiving the effluent, given per cubic metre.
V	The charge for primary treatment, per cubic metre.
Bv	An additional charge if the wastewater needs to be treated biologically.
M	Extra charges per cubic metre if the water is discharged into the ocean.
B	Charge depending on the biological oxidation of sewage.
Ot/Os	Chemical oxygen demand measurements.
S	Charge for getting rid of primary sewage sludge, per kilogram.
St/Ss	Measurement of total suspended solids in the effluent, measured per litre.

The key factor is that it considers volume and content – it does not allow lower charges for those who try to dilute their effluent to comply with certain standards. It is not inconceivable that a similar formula could be introduced for textile effluent in such a way that chemical content is also considered. It would be complex, but if effluent treatment was centralised rather than carried out on-site at the wet processor (as is becoming the case in areas of Turkey as described in the case study in 6.c.ii), it could be possible to use water charges as a lever to reduce net chemical consumption.

Policing actual chemical consumption on a facility by facility basis would be incredibly challenging without extremely intrusive monitoring. However, some financial levers could possibly work.

ZLD (see case study) is potentially a ‘self-regulating’ system. ZLD mandates the recycling of all water and permits no liquid discharge. Originally, where this was

mandated, water recycling facilities were bolted onto standard dyehouses with standard effluent treatment facilities, but over time the relationship between the dyer and the water recycler has developed and there is now a keen focus on reduced gross water use and reduced chemical use in order to reduce the cost of the ZLD process.

Mandatory ZLD and expensive water – in line with the core concept of this report that it is not acceptable to use, partially remediate and dump chemicals – would force the industry to find the easiest and cheapest way to recycle water. That means a solution using the lowest possible amount of chemicals would be sought that may involve simple filtration (ultrafiltration and nanofiltration) to recover and reuse chemicals.

Even if ZLD were not mandatory, governments could offer other financial incentives for ZLD facilities. These would need careful consideration because there are arguments for and against subsidies.

Brands can choose to mandate or incentivise whatever they wish, and they have the tools to market products and explain the benefits compared to standard practice.

For example, there is no reason why they could not market products that are dyed in ZLD factories (provided energy use is below an agreed cap and solid waste is dealt with in an appropriate manner) or are produced using “field-scoured cotton” or “weaver-scoured fabric” or “zero net chemical use” or any other chemical circularity initiative.

History tells us that if a lower impact textile product is marketed and promoted, it will get made – and the industry will find ways to make it as efficiently as possible. Not all products or processes will get rolled out at scale, but the mere fact that Chemical Circularity products are present in the market will highlight the problems with chemical over-use and discharge to the environment, and new solutions to alleviate the problem will emerge.

Brands have an excellent track record of promoting new lower impact products and processes, and while they want to sell specific types of products, the industry will want to make them – provided they can make them at a profit.

The likelihood is that there will be a combination of gradual industry progress and brand incentivisation to set non-linear use models on their way, and in many respects, this will be built on the foundation of existing good practice.

Ultimately, unless there is a compelling economic argument for the industry to make changes, brand incentives and restrictions and government regulation will be required to make non-linear use mainstream.

7. Next Steps - Recommendations for Transformative Change

The concept of chemical leasing in textile processing, a complex multi-stage operation with many chemicals and chemical reactions at its core, is initially quite abstract and highbrow.

The first stage is to make the concept real, tangible and accessible to the industry by focusing on the desired outcomes and providing examples and suggestions of how those may be achieved.

The concept has the power to transform the way we think about chemicals and our relationships with them.

At some time in the future chemical leasing/non-linear use models may be regarded as the concept that transformed the industry and the environment for the better.

Initially, it is necessary to mobilise change and, in order to catalyse that change, it is essential that the key issues and outcomes are understood:

- It is not OK to use chemicals once, partially remediate them and dump them into the environment
- We need reduced net chemical consumption
- We need reduced net discharge into the environment

These are easier to sell to the fashion industry than a somewhat nebulous (in the eyes of the industry) concept.

Chemical Leasing is part of the solution to this very complex business and not the solution. The core concept of chemical leasing – the function of a chemical – is very much at the heart of the solutions to introduce non-linear use models.

In many respects, non-linear use models are already established in certain specific pockets of the industry, but they have never been packaged as a concept in the same way as ‘recycled’, ‘organic’ or ‘biodegradable’ have.

Despite the complexity of the problem and the potential complexity of multiple solutions, a simple message to frame the problem, highlight high-level solutions and promote good practice are needed.

It is therefore recommended to package this whole approach under the banner of ‘Chemical Circularity’ from the outset.

As far as consumers are concerned, it is fair to say that they are aware of certain issues in the world, such as climate change and plastics pollution, and that they are aware of certain fashion industry specifics, such as child labour. However, there is very little evidence that there is mass awareness of chemical issues, and any awareness there is tends to be centred on traces of harmful chemicals on products at point of sale.

Initially, there is little or no point in hoping for a big collective pull-through from consumers because, as we have seen, their collective thirst for fast fashion demonstrates how little they really do care at this moment in time.

Consumers have to be presented with responsibly made products, and it is the job of governments and regulators to push brands and the industry to do that as the norm and not as low volume pilots.

However, the clear concept of Chemical Circularity and the reason it is needed should be promoted to consumers because at some stage they may understand and may start to care.

At the outset, it is clear that there is the potential for multiple stakeholders to become involved in and initiate change – which is of course a good thing. However, there is also the potential for duplication, conflicting approaches and lack of co-operation. There is therefore an opportunity to create a coherent programme from the start.

The key recommendation is therefore to create a multi-stakeholder advisory group/board as part of a recognised, respected industry organisation.

This could be the C&A Foundation (Laudes Foundation) itself, a multi-stakeholder member group such as the ZDHC foundation or Sustainable Apparel Coalition, an independent scheme such as Oekotex or Bluesign or a certifying body such as the Textile Exchange.

The key is to assemble the right group of influential people with a 'can-do' mindset and then position this group in the appropriate organisation, at an appropriately high level, such that it can actually make things happen (a 'task force' or 'working group' has insufficient power and influence).

It is important to resist the temptation to aim too high, where you have a high-profile group of 'industry celebrities' with little understanding of the intricacies of the industry. That said, the group must also contain thinkers who envision a better future and can see through and beyond immediate barriers.

This group would then oversee a policy and roadmap, the drawing up of guidance, promotion schemes, standards and measurements.

In short, they would create a framework and structured technical programme for:

- Processes/actions that can be implemented immediately
- Concepts that are industrially unproven and require large-scale evaluation
- Concepts that may require R&D and investment
- Benchmarking current data and measuring progress

They would also work on mindset and behavioural change to support the implementation of technology:

- Promoting circularity

- Using policies from governments, brands and industry to act as levers that encourage or force change
- Helping change to happen organically because it is the right thing to do and/or sending a clear message out to the industry, brands and consumers that the linear use model is fundamentally wrong.

Above all, the move away from an almost total reliance on the single-use linear model has to be viewed and packaged as achievable and realistic.

Recent history with sustainability and chemical initiatives has shown that an absence of targets or the presence of unachievable targets results in slow progress.

Long-term targets for reduced net chemical use in textile processing and reduced discharge to the environment make sense, and these should be presented in terms of total cumulative tonnages and per unit produced. Over the past two decades, we have seen rapid growth in the volume of textiles produced, and it is important that any improvements per unit produced more than offset the increased number of units produced.

The immediate priority is to challenge everyone involved in the chemical, textile and fashion industry to momentarily step away from their day-to-day roles and ask themselves whether it is acceptable to use chemicals for their own personal or corporate gains and then dump them in the environment for the world to share the damage.

Getting the industry to acknowledge its current models are not sustainable and morally questionable would be a huge first step.

