The development of waterless processes and water-saving measures in textile dyeing and finishing could help save a precious natural resource and reduce one of the world's most visible sources of water pollution.

Waterless in the works

The World Bank estimates that 17% to 20% of industrial fresh water pollution comes from textile treatment and dyeing. The general consensus is that 100 litres of water are needed to dye 1kg of cotton, so when a new process arises that substitutes water with carbon dioxide, with nearly no discharge, the improvement can only be welcomed.

Like many industrial innovations, carbon dioxide dyeing is making its way into the market step by step, or rather unit by unit. High-pressure waterless DryDye machines made by Dutch company DyeCoo have been installed at two locations: in Thailand at the Tong Sian Company, part of the Yeh Group, where they have been in operation since 2010, and in Taiwan, at Far Eastern New Century, since late 2013, a total of seven units. The waterless process is applied to knit polyester fabrics and is said to reduce energy use by 50% and require 50% fewer chemicals compared to conventional jet dyeing. The range of colours has expanded to 58 shades and 40 different types of knits, says Brad Poorman, former chief executive of Cocona and now chief marketing and sales officer for DryDye.

During the DryDye process, supercritical carbon dioxide ($scCO_2$) is heated to 120°C and pressurised to 250 bar, said Ian Spoelstra, DyeCoo Textile Systems sales director, during a presentation at Performance Days in 2013. In its expanded liquid state, the CO_2 penetrates the textile fibres, acts as a swelling agent and enhances the diffusion of dyes into the fibres. The glass-transition temperature of the fibres is lowered, which accelerates the rate the dye penetrates the textile. "For polyester fibres, dyeing with $scCO_2$ plasticises the fibres and increases the diffusion coefficients of dyes inside the polyester by one order of magnitude compared to aqueous dyeing," he explained. The process also removes the need for detergents and salts, used to dissolve hydrophobic disperse dyes in water.

These very sophisticated machines are used in dry cleaning and high-end filtration, says Mr Poorman, who describes the supercritical fluid state as "in essence, a liquid gas". Carbon dioxide comes in various forms: at standard air temperature, it is gaseous (found in soft drinks),



Stella McCartney's spring summer 2014 collection for adidas includes 39 sustainable pieces, including items dyed with DryDye, which the women's sportswear brand started using in F-W 2012.

adidas

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when frozen, it solidifies (into dry ice), and when pressure and temperature are increased above its critical point, its properties fall midway between a gas and a liquid. The International Society for the Advancement of Supercritical Fluids (ISASF) adds that supercritical fluids possess high solvent power vis-à-vis many compounds, which can be modified by varying pressure.

"Carbon dioxide is cheap, readily available worldwide and it meets industry standards in terms of performance. When looking for an alternative to water, there is nothing much that fits the bill like carbon dioxide," says Richard Kinsman, CEO of another carbon dioxide specialist, CO_2Nexus, though adding that it is not a one-for-one replacement for water. The Denver-based company, in which Patagonia has recently invested, uses liquid carbon dioxide as a solvent for cleaning, disinfecting and coating textiles, a process branded Tersus, while DyeCoo's DryDye focuses on dyeing. The two companies do not intend to compete with each other, says Mr Kinsman, as they share a same investor. Dr Geert Woerlee, the CEO of FeyeCon which spun out DyeCoo Textile Systems, is also one of the founders of CO_2Nexus with Richard Kinsman and CO_2 expert Steve Madsen.

In the process developed by CO_2Nexus for cleaning and coating, "a substrate is fed into the system, which is then pressurised at 50 bar, bringing carbon dioxide to a gaseous or plasma state. The process, whatever it may be, is run and can be as short as 20 minutes. The chamber is then depressurised, the CO_2 reclaimed as a gas, distilled, cleaned of the chemistry, and 99% of the original carbon dioxide is recovered. There is no wastewater or effluent and the fabric comes out dry," says Mr Kinsman, adding that the process can be conducted at low temperatures (15-21°C range), thus lending itself to fragile fibres. The company is the only official cleaner of Patagonia Encapsil jackets.

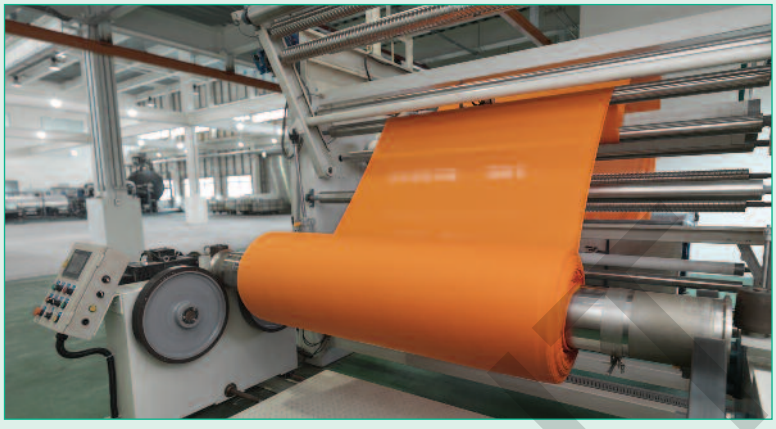
CO_2Nexus is emerging out of the development phase and into a commercial phase, says Mr Kinsman and is pursuing several markets, including clean-room applications and performance textiles, the company's "sweet spot" he points out. Much of its research and development will be dedicated to Patagonia and a new product suitable for performance fabrics may be released later this year. Though Mr Kinsman declined to state what that development would be, an innovative coating could be a possibility.

Colours count

Two big names in sportswear, adidas and Nike, have both signed up to market clothing dyed with the DryDye process. Adidas uses the process in its Prime T-shirt range, one of the best-selling training T-shirts in the brand's sports performance offering, since 2012, resulting in a saving of over 25 million litres of water for one million yards of DryDye fabric. The products are dyed by Yeh Group. The Thai company has recently expanded its DryDye branded offering to base, mid and shell fabrics.

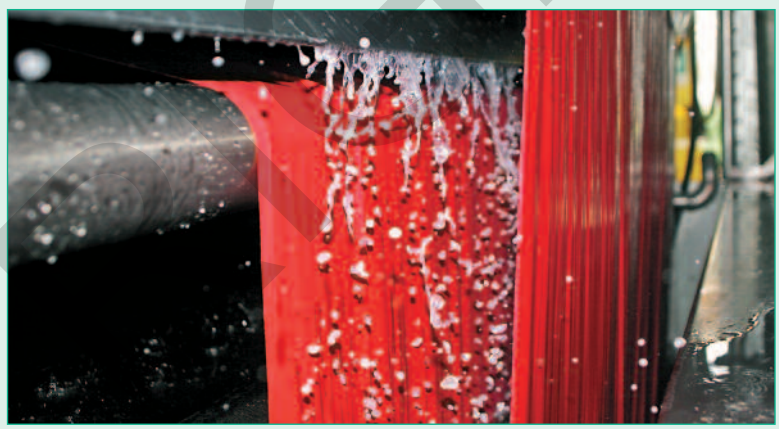
Nike first tested DryDye during the London Olympics, and has since released a range of ColorDry branded T-shirts for spring 2014. The range is dyed by Far Eastern New Century Corp (FENC) in Taiwan, and Nike says this eliminates the usual 30 litres of water necessary to dye one T-shirt, and that the process is 40% faster and requires 63% less energy than traditional dyeing. The Beaverton-based sportswear brand invested in DyeCoo in February 2012, along with Ikea GreenTech, the Swedish furniture giant's venture capital arm.

Supercritical carbon dioxide dyeing appears best suited to plain colours and long runs, while sublimation printing, also a waterless process, is tailored to short and multiple-colour runs.



DyeCoo's DryDye machines installed at Far Eastern New Century (FENC) in Taiwan, a company that supplies Nike with ColorDry branded fabric. "Compared to traditional dyeing methods, the ColorDry process reduces dyeing time by 40%, energy use by around 60% and the factory footprint by a quarter. It's also the most saturated, intense and consistent colour we've seen," said Kuenlin Ho, FENC executive vice president last December.

Nike



The introduction of Ecoprint at Eurojersey has reduced water consumption by 16 million litres per year. It is one of many initiatives within the SensitivEcoSystem, launched in 2008.

Eurojersey SPA

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Kinetic Coloring, a process developed seven years ago by Katmandu, a company based in Southern California, offers what it calls an advanced form of sublimation. The process uses a donor paper (that is recyclable) to transfer colour or prints via "kinetic emitters" instead of heat, pressure or temperature, needed in traditional transfer printing. The so-called kinetic emitters send "a pulse of energy, or light-waves, pre-tuned at a specific frequency adapted to each fabric," says managing director Mark Robinson. The process, which was "discovered by accident", works on nylon and polyester grounds, the colour or pattern is applied to one side of the fabric, and both sides can be treated. Kinetic printed garments are said to possess high UV resistance and can be bleached without any colour fading, which has made them a good option for swimwear.

With E.Volution, Italian print specialist Miroglio has developed a direct sublimation, paperless, digital printing process in a collaboration with US-based Sensient. "We are now past experimental phase and market ready," says Chiaretto Calo, Miroglio global commercial director. E.Volution reduces water consumption by 90% and energy use by 57% the company says, but can only be applied to polyester fabrics. Miroglio is currently also investigating plasma for textile processing. "Within the next two years, thanks to the combination of several innovative technologies, our processes may not be totally water-free but possibly 90% water-free," says Mr Calo.

Improving cotton's footprint

In addition to improvements brought to synthetic fabric treatments, cotton is also benefitting from new processes and dyestuffs that help reduce the number of rinse baths the natural fibre generally undergoes during dyeing.

Headquartered in Singapore, Dystar's water-saving solution for cotton is the Remazol RGB range of reactive dyes combined with a process called Sera Eco Wash that reduces the steps in the dyeing process down to a single rinse bath. "This range has been on the market for a few years now and we try to push its use for sustainability reasons," says Hans Jansen, Dystar Textile Solutions key account manager for Europe.

In addition to working with DyeCoo to develop dyes and chemicals that are soluble in $scCO_2$, Huntsman Textile Effects has also introduced water-saving dyestuffs for cotton under the Avitera label. These bring water use down from 26 gallons (98 litres) to 3 to 5 gallons (11 to 19 litres) per kilogramme of material, the company says. Huntsman also claims that 90% of the dye bonds to the cotton fibres, leaving far less unfixed dye to rinse off. In the first six months after its launch in 2010, the Singapore based company estimated that the cotton mills using the product had saved 121 million litres of fresh water.



Supercritical carbon dioxide specialist CO_2Nexus cleans Patagonia's Encapsil parkas, made with plasma-treated high-fill power down (a process developed by Aeonclad). New developments should be coming following Patagonia's investment in CO_2Nexus.

Patagonia

New York-based ColorZen is working on a pre-treatment for cotton fibres that alters the material's molecular structure and improves its affinity to dye, leading to savings in the amount of water, chemicals and time needed to dye cotton. The process is said to reduce water consumption by 90%, energy use by 75%, chemicals by 95%, dye by 50% and to obtain a 97% exhaustion rate (80% is the industry standard). In addition, salts, alkali or bleach are no longer needed, resulting in zero toxic discharge. CEO Michael Harari says ColorZen is not yet ready for market, but should be by the end of 2014. "Our primary focus right now is to perfect the technology with cotton, but our R&D team has identified several other possible applications in other fibres," he says.

Water-saving measures

Carvico group companies Carvico and Jersey Lomellina have shared their dyeing facilities for years and the implementation of water-saving measures is an ongoing concern. A new co-generation electrical plant was put into operation in January this year enabling the company to further reduce its carbon footprint, saving 639 tonnes of CO_2 from being emitted. The plant heats water for several production stages, and the water is used three times before being treated and discharged. The group keeps a close eye on evolving regulations and continually tests new dyes and chemicals. "The challenge is to

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A precious and endangered resource

Global water demand is projected to increase by 55% by 2050, mainly because of growing demands from manufacturing (400%), thermal electricity generation (140%) and domestic use (130%), according to the United Nations World Water Assessment Programme. As a result, freshwater availability will be increasingly strained over this time period, and more than 40% of the global population is projected to be living in areas of severe water stress through 2050.

achieve the required level of performance while saving water and energy," says Giorgio Cavallini, area manager for the two knitting companies.

Eurojersey, another Carvico group company, has also invested in new equipment that is less energy- and water-hungry. The Eco-printed Sensitive fabrics have cut water use by 54%, energy consumption by 19% and greenhouse gas emissions by 47% compared to traditional printing. In this process, the pigment is applied directly to the fabric, achieving high-definition patterns while offering a softer hand and higher dimensional stability.

In Taiwan, Kingwhale developed a Low Impact Technology (L.I.T.) polyester that helps reduce the company's environmental footprint. The process is based on a modified polyester fibre that can be dyed at 110°C instead of 130°C. The lower temperature gives the fabric a softer handle, says Leslie Chen, account manager for the Taipei-based company. L.I.T. was developed with the Taiwan Textile Research Institute (TTRI) and is said to result in reduced dyestuff (15%) and water use (60%), as well as 22% less electricity and 50% less thermal energy needed to create steam.

Dope-dyeing is yet another way to reduce a product's carbon footprint, and is being offered by many yarn manufacturers, including Taiwan-based Libolon. The company's Ecoya yarns are said to cut CO_2 emissions by 62%, minimise the use of water by 89% and that of chemicals by 63% compared to traditional dyeing processes, while offering higher colour-fastness.

Industry-changing impact

Each of these developments in resource-saving dyeing and printing has its strengths and weaknesses. Dope-dyed yarns are used mainly for basics as they often come in short colour ranges, while supercritical carbon dioxide is restricted to synthetics and has yet to be deployed on a large scale. Reservations remain as to the energy needed for the high-pressure process and of possible risk to workers. Meanwhile, digital printing is said to be reaching speeds compatible with industrial standards.

Looking forward, waterless processes may have a wider industry-changing impact as they suggest that textile plants no longer need to be located near a source of water. "This means a portion of textile finishing could be reshored to the US or to Europe," says Chiaretto Calo, Miroglio global commercial director. For US-based Katmandu, despite high interest in waterless processes, brands are reluctant to make the switch: "Many talk about sustainability, few act," says Mr Robinson. Convenience, cost and performance come first and the environment remains, unfortunately, low on the list of priorities.

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