Skin ageing, cancers and irritations are increasing. And so is the need for protecting the human skin from harmful ultraviolet radiation. Our intrepid explorer, Till Gottbrath, considers the technologies of textile-provided UV-protection as well as test and certification standards.

Fun in the sun?

In 1997, I participated in an expedition in South America. We tried the first non-stop North-South traverse of the Southern Patagonian Icecap. It was the year when the ozone hole over Antarctica was larger and had reached further north than ever before. Even though the average elevation of the icecap is only about 1,300 metres above sea level – so altitude didn't matter that much – the three of us felt like chunks of meat on a giant barbecue. We were using the best skin protection available and put on various layers of it, yet still we were seriously burnt. We put hats on top of our face-covering balaclavas and only exposed our faces during drinking and lunch breaks, but my lips were almost fried and bled frequently at night. I even suffered from blisters inside my nostrils.

Of course, the human body needs sunlight to produce vitamin D. However, UV-B rays with a wavelength of 280–320 nm damage the human skin. The effects of excessive exposure to the sun on skin are horrible: UVR (ultraviolet radiation) is causally connected with skin cancer, premature skin ageing, and photo-dermatoses. To make things even worse, according to the latest research projects, UV-A rays are not as harmless as they were considered in the past.

Poor Aussies & Kiwis

While we were exposed to the sun due to our expedition, most other people in the western world appear to be actively seeking a 'healthy sun tan'. The trend of spending vacations on the beach, in warm and sunny regions is as strong as ever. Others have no choice: the skin of people in southern hemisphere countries such as New Zealand, Australia, South Africa, Chile and Argentina is almost permanently exposed to high ultraviolet radiation, due to the thinner ozone layer over the South Pole. Since the 1930s, the number of people with skin cancer in Australia has doubled every ten years!

Of course, the human body is able to create a certain level of auto-protection by producing the pigment melanin which turns the skin browner and darker. But, as everyone who has suffered from sunburn knows, it needs some time to produce melanin and certain skin types (such as the pale skins of ginger - or blond-haired people) can never produce enough of it. Even more sensitive is the skin of children, as it is thinner and the auto-protection mechanism doesn't work that well. On top of this, children simply spend more time outdoors. According to a research project by the Arbeitsgemeinschaft Dermatologische Prävention e.V., an average German child receives 80% of its lifetime UVR dose before it is 18-years-old. This is probably the case with most children in the western world.

So it is no surprise that it is compulsory for those in kindergartens and schools in New Zealand and Australia to wear special clothing with UV-protection. You not only see them wearing baseball caps with additional flaps to cover the neck, but they also wear long sleeved t-shirts and long pants on sunny summer days. Even on the beach they dress in catsuits to protect the skin.

UV protection is a must

Scientifically, it is proven that we must protect our skin from ultraviolet radiation. The easiest way is no exposure to the sun at all – stay indoors. But many people work outside, farmers, gardeners, construction and forestry workers and a host of others. Even more people simply enjoy being outside, for straightforward leisure pursuits. So we need the additional protection provided by sunscreens or clothing.

With Australia suffering from strong UVR, the Aussies were the first to create test standards and a certification system for clothing. The Australian, as well as all other test and certification systems, results in a UV-Protection-Factor (UPF). Similar to SPF (skin protection factor) that is provided by sun lotion, the UPF also tells the user how many times longer he or she can expose themselves to the sun.

Test Standards

Currently, there are various independent test and certification systems.

AS/NZS4399

The world's first UV-protection test for fabrics. It uses a transmission spectrometer to measure the level of protection provided by a textile fabric. However, tests do not specify any conditioning. They are carried out only on dry, new (unlaundered), and non-stretched samples. A garment may be sold with the AS/NZS4399 label when tested with a minimum UPF of 15.

Crossing the Southern Patagonian icecap.
www.gottbrath.com

Protection category (Australia)	*UPF ratings*	*% UVR blocked*
Excellent protection	40, 45, 50, 50+	More than 97.5
Very good protection	5, 30, 35	95.9 to 97.4
Good protection	15, 20	93.3 to 95.8

As AS/NZS4399 is the oldest test standard (dating from 1996) and relatively easy (inexpensive) to carry out, it is the most common certificate worldwide, particularly used by textile manufacturers in the Far East.

UV-Standard 801

The UV Standard 801 was developed jointly by the Österreichisches Textil-Forschungsinstitut, the Schweizer Textilprüfinstitut Testex and the Bekleidungsphysiologisches Institut Hohenstein in Germany. Measuring the permeability of UV A and UB B rays on dry, wet, washed and stretched fabric samples, as well as after abrasion tests, it reaches way beyond AS/NZS4399. The UV 801 standard does not only include apparel, but all types of fabrics that may provide protection from UVR. Labelling according to UV 801 standard does not require a minimum UPF, instead it gives the actual UPF rating. The UV 801 standard is the most common in German-speaking countries.

EN 13758-1 and EN 13758-2

The European standard EN 13758-1 is based on British Standard BS 7949:1999 which provides the UV protection requirements for children's clothing. Other than the Australian standard and similar to UV 801 standard, it stipulates that fabric samples are to be conditioned at a specified temperature and humidity before testing. While EN 13758-1 (released in March 2002) specifies the test procedures of the garments to determine the protection against UVR, EN 13758-2 (released in 2003) defines the classification and labelling of such apparel. The minimum requirement for garments with EN 13758 certification is a UPF of 40.

AATCC 183 and ASTM D6544

In the USA, sun protection clothing standards have existed since 2001. The testing is performed according to the standard AATCC 183 (available from the American Association of Textile Chemists and Colourists); or to ASTM D6544 (available from the American Society for Testing and Materials). Testing specifies that fabric samples should be conditioned with laundering, UV exposure and chlorinated pool water equivalent to two years of normal use. Labelling in the USA is specified in ASTM D6603.

Comparabilty of UPFs

Unfortunately, the different test set-ups lead to different test results. Geography also matters, though not significantly: EN 13758-1 and AATCC 183 uses a solar spectrum measured in Albuquerque whereas AS/NZS 4399 uses a solar spectrum measured in Melbourne. It is said that a UV-801 rating of 20 may provide better protection than a 40+ of AS/NZS 4399.

It is hoped that all standards will result in clothing that provides the necessary protection from UV radiation. But testing and certification alone doesn't help much: there must be a balance between protection, labelling, and marketability. The latter is not so easy to achieve: depending on where they want to sell their products, textile manufacturers have to provide certification according to the Australian, European, or North American test standards. And even though large companies in the textile industry, such as Invista, Clariant, Ciba, Burlington, Enka, Lenzing, Tomen, Toray, or Toyobo are global players, a certification for every single fabric in every single colour does not contribute to making the product more affordable…

General principles

There are four general principles – the why and how textiles may protect from UV radiation:

1. ***Reflection:*** Some or all of the light received is reflected. It simply does not penetrate into or through the fabric.
2. ***Absorption:*** The fabric absorbs the light. As light is a form of energy, the question is: Where does the energy go? It is converted into heat.
3. ***Dispersion:*** In this specific case, the separation of light into colours by refraction or diffraction with formation of a spectrum converts UV-B rays into a less harmful wavelength.
4. ***Refraction:*** The deflection from a straight path, undergone by a light ray in passing obliquely from one medium (as air) into another (textile fibres) reduces its velocity.

Factors determining the UPF

Density: The density of the fabric is fundamental to the level of UPF. Naturally, knits offer a higher level of protection than wovens, as the yarns overlap more. On the other hand, the density is reduced

considerably when stretched, while wovens are more stable.

Weight: Closely related to density is the weight of the fabric. The rule is simple: the heavier and thicker the fabric, the better the UPF.

Colour: Colour, depth of colour, and the dye absorb a certain part of visible light – and often enough to result in UPF. As a rule of thumb: the darker the colour, the better the UPF. Obviously, different studies led to different conclusions – while one favours black and dark blue, others prefer very dark green and red.

Fibres: If you have yarns / fabrics of the same weight, polyester offers the best UPF of all fibres followed by polyamid, while good old wool is the best natural fibre followed by silk. Viscose or polyacrylics don't perform as well, nor does cotton or linen. While raw cotton contains a large amount of the natural pigments, pectin, and wax, this is washed out with bleaching.

Wetness: Have you ever watched a 'wet t-shirt contest'? Yes, you can see through the wet fabric. No wonder, harmful UVR may also pass through the fabric more easily than in dry conditions. The water in and in-between the fibres increases the UVR-permeability by reducing the diffusion of the light.

Considering that men want to wear less and less the warmer and sunnier it gets, the dilemma of apparel with a UPF of value becomes obvious: clothing must be lightweight, airy, and protective. This has led to the development of additional protection technology. To give you an idea of how big the differences in UPF may be an old, white and wet cotton t-shirt might provide a UPF of only 3! A dark polyester t-shirt with additional protection can have a UPF of 50+ or even more.

UV-Absorbers

One way to provide additional UPF is the use of so-called UV absorbers. Most UV absorbers are applied by immersion as finishes on the fabric. As with all finishes, there is the question of permanency. How does it withstand abrasion during climbing? How does it cope with the numerous washes of running or cycling wear? How long will it last during trekking under a rucksack shoulder strap? Talking to the product managers of important outdoor and sportswear brands, we understand that long-lasting UV absorbers are available. But there are others that won't withstand 20 washes.

Another major question that nobody in the industry wanted to answer satisfactorily was: How safe are UV absorbers? None of the test and certification standards requires medical tests of the ingredients. Consumer protection organisations are not too positive about oxalic anilide, benzotriazole, and chlorotriazine. Anilide is toxic to blood and liver, oxalic acid must not get into human kidneys. Benzotriazol is considered a cause of cancer and damages organisms in ground water.

Pigments

While UV absorbers are mostly applied onto the fabric's surface, pigments can be built into the matrix of the polymer. So the protection lasts as long as the garment. Another advantage of this construction is the protection from ceramic particles themselves. As they are highly abrasive themselves, possibly reducing the lifetime of the fabric, they are well kept inside the fibres. As a result, this method can provide a much higher level of protection against the frequency below 400 nm. Most common is the use of titanium dioxide. These ceramic particles are well known to the industry, as they were developed to make shiny yarns dull and give it a more cotton-like touch.

The challenge to master is the incorporation of the particles within the polymer matrix. With the arrival of nano-size particles, textile researchers have found a new playing field. A challenge is the even distribution of the pigments in the polymer, because too much titanium dioxide would affect other desired properties (reduction of tear strength) of the fibre. It is not sufficient to throw a handful of pigments into granulate. The entire production process has to be adapted to the process.

Again, the question about health risks arises. Ultramid BS416N is a polyamide granulate with titanium dioxide pigments for a high UPF made by BASF. With a size of approximately 400 nm, the titanium dioxide particles are not yet nano-size (the industry is starting to agree that everything below 100 nm should be called 'nano'). Still, they are incredibly small. Dr. Melanie Urtel, a public relations officer at BASF, claims that titanium dioxide implies no health risk at all: "We are one of the major suppliers to the health and cosmetic industry. Titanium dioxide is used all around the world in sun lotion, tooth-paste, etc. in very high quantities. We have carried out numerous research projects, and we are sure that it is safe. With Ultramid BS416N we are more than sure, as the titanium dioxide is inside the polymer."

Currently, the EU is working on "Nanosafe2", a huge project to research the impact of nano-particles on the human body: are they actually getting into the human body? If yes, how do they get there? Where do they go? What happens there? The project is being carried out under the guidance of the association ECRIN in Paris, but final results have not been published yet.

Marketing

The last big question is about the marketing of UPF apparel. Currently, the outdoor clothing manufacturers are experiencing a big buzz around softshells. It's new, it's promising and it sounds sexy. However, the same companies have never managed to create such an awareness for UPF-clothing, nor did the producers of clothing for team sports, golf, running, cycling, fishing, etc. (at least not outside New Zealand and Australia). Why is this? From a logical point of view, everybody who exposes his skin to the sun should worry about it. Still, UPF clothing is not as successful as it could be.

A reason might be that the industry has to approach the consumer with a somehow negative message: "It's dangerous to be out in the sun. If you don't use clothing with a UPF then…" Ralf Bärwald, marketing manager apparel at Jack Wolfskin, looks at it in a positive way: "We will take the cosmetic industry as an example. They were able to communicate the benefits of sun lotions with SPF: Get out there, enjoy the sun and the outdoors. This is the way we are dealing with it. Generally, Jack Wolfskin – and I think many others in the industry too – strongly believe in apparel with UPF. It is simply a must for reasonable people."

It must be seen as an opportunity.

Brand names and chemistry for UV Protection*

Brand Name	*Manufacturer*	*What it is*
Aquamiracle	Tomen	2-layer knit for sportswear with Sunpaque-fibres on the outside
Enka Sun	Enka / Akzo	Viscose with Titanium dioxide
Aerotac	Ploucquet	Fabrics for sportswear (and other) with UPF based on UV absorbers
MCS Blocker	Burlington	A family of wovens for sportswear and outdoor apparel, with UPF based on UV absorbers.
Reozon	Eschler	Eschlers brand name for UPF finishes (based on UV absorbers), minimum UPF of 50 on white fabric
Rayosan	Clariant	UV absorber
Solartex cel	Pfersee Chemie	UV absorber
Solartex cut	Pfersee Chemie	UV absorber based on Benzotriazol
Sunpaque	Tomen	Polyester fibres with titanium dioxide in the polymer. Tomen claims a UPF up to 80 according to UV 801 standard.
Tinosorb	Ciba	Reactive UV-Absorber (Oxalanilid) that can be used in detergents to add a UPF to untreated garments.
Tinofast CEL	Ciba	Reactive UV-Absorber (Oxalanilid) that can be applied on cotton, viscose, lyocell, polyamide and all blends.
Tinofast PES	Ciba	Same as above but designed for Polyester.
Ultramid BS416N	BASF	Polyamide granulate with titanium dioxide
Uvinul	BASF	A family of UV absorbers, some of them containing Benzotriazol and suitable for performance fabrics (amongst others)

** List is not exhaustive*