UV PROTECTION TEXTILE MATERIALS

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Abstract:

Ultraviolet rays constitute a very low fraction in the solar spectrum but influence all living organisms and their metabolisms. These radiations can cause a range of effects from simple tanning to highly malignant skin cancers, if unprotected. Sunscreen lotions, clothing and shade structures provide protection from the deleterious effects of ultraviolet radiations. Alterations in the construction parameters of fabrics with appropriate light absorbers and suitable finishing methods can be employed as UV protection fabrics. This paper deals with the deleterious effects of UV rays and protection against them through textile materials.

Key words:

erythema, absorbers, cover factor, UV index, swelling

Introduction

An appropriate amount of sun bath promotes the circulation of blood, invigorates the metabolism and improves resistance to various pathogens. Penetration of UVR into the top layer of the skin leads to damage in the lower layer and produces premature ageing of skin and other effects including roughening, blotches, sagging, wrinkles, squamous cells and basal cell cancer. Many people love sunbathing, thereby extending the long term risk to their health. Persons working in the open atmosphere are also prone to keratose, the precursor of skin cancer. Australia has high levels of solar UV radiation, mainly because of its geographical position; New Zealand, USA, Switzerland, Norway, Scotland, Britain and Scandinavian countries also have high melanoma rates.

UV radiation

Unravelling the mysteries related to ultraviolet rays, their properties, and their effects on various living creatures has been a gradual process spanning to the duration of almost three centuries starting from the seventeenth century [1 – 6]. Terms such as near UV ((290 – 400 nm), far UV (180 – 290 nm) and vacuum UV (below 180 nm) have been coined by physicists based on the properties of the radiation. The term UVA represents the region 320 – 400 nm, the term UV B represents the region between UV C and UV A, i.e. 290 – 320 nm, and UVC region represents the region below 290 m . The order of potency has been decided as UVC > UVB > UVA >. The proportion of the UV region is about 5 – 6 % of the total incident radiation, and the quantum energy of UVR is similar to the bond energies of organic molecules [1 - 3, 7 – 10].

UV exposure and human skin

Factors that affect solar UVR include cloud cover, the sun's altitude, geographical position, altitude, ozone layer, scattering in the atmosphere, environmental and related conditions. Much research has been carried out to assess the impact of the UV rays on various living organisms, especially humans [10, 11 – 18] and the relationship between skin cancer and UV dosage is well correlated. Changes in leisure behaviour, which has led to more frequent sun exposure, are one of the major reasons for malignant cutaneous melanoma. Skin cells that receive sunlight absorb harmful UV radiation, and slough off to excrete harmful UV from the body. But the absorption of too much UVR leads to scars that can induce diseases like skin cancer. Excessive UV radiation leads to cell damage and causes inflammation of human skin, the obvious consequences of which are erythema or sunburn [12]. The reciprocal value of these cuticle radiation doses is called erythema effectiveness whose maximum occurs at 308 nm. The total UVR dose reaching the skin is an important factor in the occurrence of both erythema and skin cancer, although there is no proven link between erythema and skin cancer [15]. In terms of sensitivity to light and tendency to pigmentation, there are 6 basic types of skin that demand different levels of UV protection [9, 10, 16, 19 – 22] as shown in Table 1.

Table 1. Effect of UV rays on different types of skin

Skin type (Appearance unexposed)	Critical dose mJ/cm^2	Self protection time (min)	Risk level
I - White	15 – 30	5 - 10	Burns easily, has the highest risk of premature skin ageing and greatest risk of developing skin cancer
II - White	25 – 35	8 - 12	Burn and only rarely tan
III - Brownish	30 – 50	10 - 15	Tan and occasionally burn
IV - Brown	45 – 60	15 - 20	Tan and occasionally burn
V - Brown	60 – 100	20 - 35	Sufficient levels of melanin and rarely burns, easily tan
VI – Dark Brown - Black	100 – 200	35 - 70	Sufficient levels of melanin pigment provide protection. Very rarely burns, easily tan

The minimal erithemal dose (MED) is apparently consistent with a fair complexion, but shows variations among people of types III and IV. For practical purposes, the population could be classified into two main groups, sensitive and less sensitive individuals [22].

Solar UV index, UV protection factor and solar protection factor

The effect of ultraviolet radiation on living biological organisms has been extensively studied, and various reporting methods such as UV index, UV protection factor (UPF) and solar protection factor (SPF) have been adopted to create awareness among the general public of the deleterious effects of UV radiations [6, 15, 23 – 27]. At a given wavelength, electromagnetic radiation may be reflected, absorbed or transmitted by any given object. If the response of the system at each wavelength is a linear function of the dose, then the response (R) by a broad spectrum is given [24] by the following formula:

$$R = \int_{t1}^{t2} \int_{\lambda 1}^{\lambda 2} \sigma(\lambda) I(\lambda, t) d\lambda dt$$

where I (λ, t) is the irradiance at wavelength λ, t is time and σ (λ) is the cross-section for eliciting this response at wavelengths λ. The changes in the spectrum have been covered by including time as an argument of the irradiance function and as a variable of integration.

The UV index is designed to provide the public with a numerical indication of the maximum potential solar UVR level during the day; the higher the number, the higher the solar UVR hazard [21]. The global solar UV Index is a measure of the highest level of UVR every day, and the UVI is calculated using various input parameters such as the ozone level, potential cloud cover, water vapour and aerosols [28]. The UV index is reported as the maximum biologically effective solar average UVR (UVR_{eff}) for the day, and is an average taken over either 10 or 30 minutes. The UVR is usually highest around midday but the temperature is often highest later in the afternoon. UVR index values are grouped into five exposure categories [21, 25, 27], from low to extreme with different colour codes.

Ultra-violet protection factor

The protection extended by the textile materials, accessories and sun screen lotions are denoted by different terminologies known as UPF and SPF [7, 12, 14, 15, 21, 29]. Risk estimates of unprotected skin, protected skin and UPF are given by the following formulae:

$$\text{risk unprotected} = \sum S_\lambda A_\lambda \Delta_\lambda$$

$$\text{risk protected} = \sum S_\lambda A_\lambda \Delta_\lambda T_\lambda$$

$$\text{UPF} = \text{risk unprotected} / \text{risk protected}$$

where S_λ is the source spectrum (Wm^2 nm^{-1}), T_λ is the transmittance, A_λ is $_{the}$ action spectrum for measured response and Δ_λ is the bandwidth in nm. Since the relative erythemal spectral effectiveness is higher in the UV B region compared to the UV A region, the UPF values depend primarily on the transmission in the UV B region [3]. UV rays falling on textiles are partly reflected, absorbed and partly transmitted through the fibres & interstices, and the optical porosity of a fabric limits its potential to provide protection against UVR.

The solar protection factor (SPF) is defined as a quotient from a harmful dose without, and a harmful dose with, sun protection. This can be calculated from erythemal effectiveness (EW (λ)), (P(λ)) and from the wavelength dependent transmission of the sun protection agent [12]. The difference between the values of UPS and SPF arises mainly because of the 'hole effect' in the fabrics.

Effect of UV radiation on textile materials

UV radiation is one of the major causes of degradation of textile materials, which is due to excitations in some parts of the polymer molecule and a gradual loss of integrity, and depends on the nature of the fibres [8, 30 – 38]. Because of the very large surface volume ratio, textile materials are susceptible to influences from light and other environmental factors. The penetration of UVR in nylon causes photo oxidation and results in decrease in elasticity, tensile strength and a slight increase in the degree of crystallinity [33, 35]. In the absence of UV filters, the loss in tensile strength appears to be higher in the case of nylon (100% loss), followed by wool, cotton and polyester, with approximately 23%, 34% and 44% respectively after 30 days of exposure [36]. Elevated temperature and UVB radiation on cotton plants result in severe loss of bolls [38]. Naturally-coloured cottons contain pigment ranges from light green to tan, brown and inherent long-term UV protection properties [61] with a UPF of 64 and 47, whereas normal cotton shows a UPF of 8.

UV absorbers

UV absorbers are organic or inorganic colourless compounds with strong absorption in the UV range of 290 – 360 nm [8, 12, 13, 20, 30, 36, 39 – 46]. UV absorbers incorporated into the fibres convert electronic excitation energy into thermal energy, function as radical scavengers and ?singlet oxygen quenchers. The high-energy, short-wave UVR excites the UV absorber to a higher energy state; the energy absorbed may then be dissipated as longer-wave radiation [13]. Alternately, isomerisation can occur and the UV absorber may then fragment into non-absorbing isomers. Sunscreen lotions contain UV absorbers that physically block UVR [13, 48, 47]. The most widely used UVB screens, 2-ethyl hexyl-4-methoxy cinnamate with high RI, make a substantial contribution to the RI matching of skin, i.e. 'refractive index matching' [48]. An effective UV absorber must be able to absorb throughout the spectrum, to remain stable against UVR, and to dissipate the absorbed energy to avoid degradation or loss in colour [36].

Organic UV absorbers are mainly derivatives of o-hydroxy benzophenones, o-hydroxy phenyl triazines, o-hydroxy phenyl hydrazines [8, 13, 30]. The orthohydroxyl group is considered essential for absorption and to make the compound soluble in alkaline solution. Some of the substituted benzophenones penetrate into synthetic fibres much like disperse dyes [36]. Commonly-used UV absorbers are 2-hydroxy benzophenones, 2-hydroxy phenyl benzotriazoles, 2-hydroxy phenyl-S-triazines and chemicals such as benzoic acid esters, and hindered amines [40]. The strong absorption in the near UV of 2, 4 dihydroxy benzophenone is attributed to conjugating chelation between the orthohydroxyl and carbonyl groups. Organic products like benzotriazole, hydro benzophenone and phenyl triazine are primarily used for coating and padding processes in order to achieve broad protection against UV rays [12]. Suitable combinations of UV absorbers and antioxidants can yield synergistic effects [42]. Benzophenone derivatives have low energy levels, easy diffusibility and a low sublimation fastness. Orthohydroxy phenyl and diphenyl triazine derivatives have an excellent sublimation fastness, and a self-dispersing formulation can be used in high temperature dyeing in pad-baths and also in print pastes [44].

UV absorbers incorporated into the spinning dope prior to the fibre extrusion and dye bath in bath dyeing improve the light fastness of certain pastel shades and the weatherability of spun-dyed fibres [36, 49]. UV absorbers to the extent of 0.6 – 2.5% are sufficient enough to provide UVR protection fabrics [9]. The presence of UV absorbers in PET, nylon, silk and wool protects the fibres against sunlight-induced photo degradation. On wool, UV absorbers can retard the photo-yellowing that occurs upon exposure to sunlight [13]. Triazine class-hindered amine light stabilisers are used in PP to improve the UV stability. The addition of HALS to 0.15% weight is sufficient to improve stability substantially. Even pigmented PP requires UV stabilisers if the fibres are exposed to UV during their services [43]. High-energy UV absorbers suitable for PET include derivatives of o-hydroxyphenyl diphenyl triazine, suitable for dye baths, pad liquor or print paste.

UV absorbers have refractive indices of about > 2.55, by means of which maximum covering capacity and opacity is achieved [12]. The presence of inorganic pigments in the fibres results in more diffuse reflection of light from the substrate, and provides better protection [9, 12, 30, 32, 50 – 52]. TiO_2 added in the spinning dope for matt effects in the fibres also acts as a UV absorber [8]. Titanium dioxide and ceramic materials have an absorption capacity in the UV region between 280 and 400 nm, and reflects visible and IR rays; these absorbers are also added as dope additives [53]. For maximum effect, the particles have to be monomolecularly distributed, and are often applied in one bath [9, 12, 30, 54]. Nanoscale titanium gel particles strongly bound to the cotton fabrics can give a UPF ≥ 50 without impairing the tensile properties. Brighter viscose yarns provide the highest UV transmittance compared to the dull pigmented viscose yarns, modal yarns [55]. Zinc oxide nanoparticles, which have a very narrow size distribution (20-40 nm) and minimal aggregation, can result in higher levels of UV blocking [51]. Use of TiO_2, ZnO alone produces less absorption of UVR than a mixture of (67/33) titanium dioxide and zinc oxide on cotton and nylon fabrics [32]. Microfine nylon fabrics with a porosity of 0.1% are capable of giving UPF > 50 with 1.5% TiO_2 [52]. Incorporating UV absorber in dyeing decreases the dye uptake slightly, except in post-treatment application [40].

Many commercial products and processes have been developed to produce fabrics with a high level of UPF using various dope additions and topical applications for almost all types of fabrics produced from cellulosic fibres, wool, silk and synthetic fibres [1, 7, 10 - 12, 20, 36, 44, 56, 57]. Most of the commercial products are compatible with the dyes and other finishing agents applied to the textile materials, and these agents can be applied using simple padding, the exhaust method, the pad-thermo fix and the pad-dry-cure methods [7, 36, 39, 56, 58].

Textile materials and UV protection

Sun protection involves a combination of sun avoidance and the use of protective garments & accessories [15, 16]. Reducing the exposure time to sunlight, using sunscreens and protective clothes are the three ways of protection against the deleterious effects of UV radiation [17]. Apart from sunscreen lotions, textile materials and accessories made of textile materials are largely used for UV protection [2, 3, 7, 10, 12 – 14, 16, 25, 26, 33, 35 - 39, 45, 46, 51, 58, 60 – 67]. UV protection through textiles include various apparels, accessories such as hats, shoes, shade structures such as umbrellas, awnings, and baby carrier covers and the fabric materials to produce these items.

Nature of fibres

In textiles, UPF is strongly dependent on the chemical structure of the fibres. The nature of the fibres influences the UPFs as they vary in UV transparency [7]. Natural fibres like cotton, silk, and wool have a lower degree UVR absorption than synthetic fibres such as PET [19, 67]. Cotton fabric in a grey state provides a higher UPF because the natural pigments, pectin, and waxes act as UV absorbers [2], while bleached fibres have high UV transparency. Raw natural fibres like linen and hemp possess a UPF of 20 and 10 to 15 respectively, and are not perfect UV protectors even with lignin content [25]. However, the strong absorption of jute is due to the presence of lignin, which acts as a natural absorber. Protein fibres also have mixed effects in allowing UV radiation. Dyed cotton fabrics show higher UPF, and undyed, bleached cotton yields very poor UPF values. Wool absorbs strongly in the region of 280 – 400 nm and even beyond 400 nm. Exposure to sunlight damages the quality of silk's colour, strength and resiliency in both dry and wet conditions [66]. Mulberry silk is deteriorated to a greater extent than muga silk. Bleached silk and bleached PAN show very low UPFs of 9.4 and 3.9 respectively. Polyester fibres absorb more in the UV A & UV B regions than aliphatic polyamide fibres.

Moisture and swelling

The ability of textile fibres to provide UV protection varies depending upon the structure and other additives present in the fibres [2, 25, 65, 66]. Besides, the construction parameters and wear conditions of the textile materials, moisture and additives incorporated in processing also affect the

UPF of the textile materials [13, 16, 25, 64]. In the case of moisture, the influence largely depends on the type and hygroscopicity of fibres, as well as conditioning time, which result in swelling phenomena [50]. The RH and/or moisture content affect the UPF of the fabric in two ways, namely the swelling of fibres due to moisture absorption, which reduces the interstices, and consequently the UV transmittance. On the other hand, the presence of water reduces scattering effects, as the refractive index of water is closer to that of the textile polymer, and hence there is a greater UV transmission vis-à-vis a lower UPF [16, 25].

A typical cotton fabric could transmit 15-20% UVR, rising to more than 50% if the garment is wet. For adequate protection, the UVR transmission should be lower than 6% and 2.5% for extremely good protection [13]. Dependence of humidity is more pronounced in silk and viscose, of which viscose has a higher water absorption and swelling capacity, while silk has poor swelling properties. Even though silk has poor swelling properties, its very fine nature and a greater number of fibres in the cross-section of yarn results in higher swelling due to capillary absorption, and in turn less UV transmittance. Finishing treatments given to the fabrics to reduce swelling reduce the transmittance of UV rays. In general, hygroscopic fibres and their UPF show better correlation [64].

Fabric construction factors

When the ultraviolet radiation hits the textile materials, different types of interactions occur depending upon the substrate and its conditions [3, 11, 13, 15, 16, 21, 25, 41, 47, 60, 65, 68]. The UV protection by textile materials and apparel is a function of the chemical characteristics, physico-chemical type of fibre, presence of UV absorbers, construction of fabric, thickness, porosity, extension of the fabric, moisture content of the fabrics, colour and the finishing given to the fabric [12, 13, 16, 21, 60]. A part of the radiation is reflected at the boundaries of the textile surface. The UVR transmitted through textile fabrics consists of the unchanged waves that pass through the interstices of the fabrics as well as scattered waves that have interacted with the fabrics. Another part is absorbed when it penetrates the sample, and is converted into a different energy form. The portion of radiation that travels through the fabric and reaches the skin is appropriately referred to as the 'transmission component'.

The UPF increases with fabric density and thickness for similar construction, and is dependent on porosity (UPF = 100 / porosity) [7]. A high correlation exists between the UPF and the fabric porosity but is also influenced by the type of fibres [69]. The relative order of importance for the UV protection is given by % cover > fibre type > fabric thickness [65]. Cloth cover does not consider the flatness of the yarns, which might result in a higher cloth cover than the calculated value. A UPF with fabric weight and thickness shows better correlation than cloth cover [28]. Therefore fabrics with the maximum number of yarns in warp and weft give high UPFs. UPF values of 200, 40, 20 and 10 can be achieved with the percentage cover factors of 99.5, 97.5, 95 and 90 respectively [15]. The percentage UVR transmission of a fabric is related to the fabric cover factor by (100 – cover factor) and the UPF is given by UPF = 100 / (100-CF) [65]. To achieve a minimum UPF rating of 15, the cover factor of the textile must be greater than 93%, and a very small increase in CF leads to substantial improvements in the UPF of the textiles above 95% cover factor. In the case of terry cloth, a high variability in UPF exists due to irregularities in the fabric construction [3]. Woven fabrics usually have a higher cover factor than knits due to the type of construction [47]. Thick rib structures of hemp and linen can allow 10.52 – 12.70% and 9.03 – 11.47% of UV A and UV B respectively [25]. However, knitted structure made from a blend of synthetic fibres with Lycra offers the best protection against solar radiation [68], and warp-knitted blinds are capable of screening up to 80% of the solar radiation and bright glares.

Stretching reduces the UPF rating of the fabric during wear, as the effective cover factor is reduced [16]. However, the cover factor can be modified through many dry finishing processes through overfeed on the stenter, compressive shrinkage processes such as compacting and sanforising, which are normally used to obtain dimensional stability, incidentally increasing the cover factor and hence the UPF. Gentle milling employed in the case of lightweight wool fabrics can also enhance the cover factor and the UPF [15].

Dyeing and finishing

Depending upon the type of dye or pigment, the absorptive groups present in the dyestuff, depth after dyeing, the uniformity and additives, the UV protection abilities of the textile materials are considerably influenced [3, 7, 16, 35, 39, 41, 60, 64, 67]. In a given fabric, higher transmission of UV radiation is observed in the case of bright fibres (viscose) than dull fibres [39]. A protective effect can be obtained by dyeing or printing, which is better than using heavyweight fabrics which are not suitable for summer conditions. Darker colours of the same fabric type (black, navy, dark red) absorb UVR much more strongly than the light pastel colours for identical weave with UPF, in the ranges of 18 – 37 and 19 – 34 for cotton and polyester respectively [3, 35]. Some direct, reactive and vat dyes are capable of giving a UPF of 50+ [16]. Some of the direct dyes substantially increase the UPF of bleached cloth, which depends on the relative transmittance of the dyes in the UV B region. In many cases, a UPF calculated using a direct dye solution appears to be higher than that of the fabric after dyeing, mainly because the actual concentrations are mostly less than the theoretical concentration. Dyes extracted from various natural resources also show the UPF within the range of 15 – 45 depending on the mordant used [70].

Cellulosic fabrics transmit UV A and UV B equally with the transmittance ratio (T_A/T_B) 0.9. When dyed with the reactive dyes, the UPF increases from 4.7 to 5.0 – 14.0 depending upon the concentration, which is not sufficient to satisfy the minimum requirements [60]. Some of the vinyl sulphone dyes and monochlorotriazine dyes possess UVR absorption characteristics, which also increase with the concentration. Cellulosic fabrics dyed with these dyes show reduced UVR transmission from 24.6% to 10-20% and 27.8% to 8-22% for UV A and UV B respectively. When mixtures of these dyes are used, the UPF increases synergistically. Some combinations of disperse reactive mix can give prolonged UV protection with a UPF of 50+ for P/C blends [46].

Optical brightening agents or fabric whitening agents are used at the finishing operations, as well as in the wash cycles, and their effect on UPFs has been demonstrated extensively in the past [7, 16, 42, 46, 62, 67, 71, 72]. Optical brightening agents are often applied to enhance the whiteness of textiles by UV excitation and visible blue emission. The phenomenon of excitation and emission is caused by the transition of electrons involving p-orbitals from either conjugated or aromatic compounds [46]. Most optical brighteners have excitation maxima within the range of 340 – 400 nm. OBA can improve the UPF of cotton and cotton blends, but not of fabrics that are 100% polyester or nylon [16]. The presence of OBA in the P/C blends (67/33) to the extent of 0.5% can improve the UPF from 16.3 to 32.2, which is more or less closer to that obtained using the UV absorbers with 0.2% (UPF 35.5). Washing the fabrics leads to a loss of UPF in the case of OBA-treated fabrics, and the UPF reaches the level of that in untreated fabric after 10 washes, which shows the semi-permanent nature of the finish and protection [46]. Another limitation of many OBAs is that they mostly absorb in the UVA part of the day light spectrum (93%) but have a weak absorption in UV absorption around 308 nm (92%), which plays an important role in skin disease [6, 71].

UPF measurement systems

Appropriate precaution which were applied while carrying out the measurement should be sufficient to collect all the scattered and transmitted lights through an integrating sphere, to include all the erythemal active wavelengths (UVA & UVB) spectral measurements without any influence of fluorescence from FWA, if it is present in the fabric [63]. There are currently 12 sites in Australia and Antarctica installed with broadband UVR detectors to measure the total energy received over a range of wavelength in UVR region in both direct and diffuse radiation [21]. Polysulphone films have been widely used in the construction of personal dosimeters, which absorb strongly in the UV B region [5, 38, 73, 74].

The instrument for measuring fabric transmission includes broadband radiometers, spectroradiometers, or spectrophotometers, and Xenon lamps [14, 16, 19, 30, 46, 75]. Filters are placed next to the test specimen to prevent the effects of fluorescence reaching the integrating sphere [5, 7, 29, 55]. The spectral response of the detector is also important in determining system performance, and it must be capable of detecting UVR accurately and linearly over a very large range of intensities and discriminating the signal from the detector dark current. Many commercial systems have difficulty in measuring UPFs above 100 due to dynamic range, dark current discrimination at lower wavelengths of <300 nm, and fluorescence at wavelengths of >380 nm. Low light levels in the UVR source used for measurement can also lead to difficulty in distinguishing between the transmitted UVR and the natural dark current of the detector.

The measurement of UPF on a clothing material can be carried out by measuring the diffuse spectral transmittance *in vitro* or by measuring the increase in exposure time required to induce erythema or sun burn *in vivo* [14, 16, 19, 61]. The preparation of the fabric prior to the UV transmission test includes the exposure of specimen to laundering, simulated sunlight and chlorinated pool water, and to present in a state that simulate the conditions at the end of two years of normal seasonal use, so that the UV protection level finally stated on the label estimates the maximum transmittance of the garment fabric during a two-year life cycle [75].

UV protection care labelling

Initiatives for developing standards related to UV protection started in the 1990s, and standards related to the preparation of fabrics, testing and guidance for UV protection labelling have been formulated [12, 76, 77, 78] by different agencies. Care labelling similar to fabric and garment care labels has been developed for UV protection, and standard procedures have been established for the measurement, calculation, labelling methods and comparison of label values [12, 26, 61, 64, 71, 76, 77, 79 - 82] of textile products. Since 1981, the Skin Cancer Foundation, an international body, has offered a Seal of Recommendation for the photo-protective products which includes sunscreens, sunglasses, window films and laundry detergent additives, in accordance with AATCC TM 183 or AS/NZS 4399; the products recommended are reviewed annually [61].

Table 2. Grades and classification of UPF

UPF	Transmission (%)	Classification	Grade
> 40	< 2.5	Excellent protection	III
30-40	3.3 – 2.5	Very good protection	II
20-29	5.0 – 2.4	Good protection	I

UV labelling is an additional requirement besides other labelling requirements of garments including Permanent Care Labels and Fibre Content labels. Apart from the UPF label, block numbers can also be used based on the UV transmittance value in their respective UVR range [26, 61]. Table 2 shows the various grades and the related protection factors for the textile materials. The UPF value to be placed on the label is that of the sample, reduced by its standard error of UPF values, and then rounded down to the nearest multiple of 5 but not greater than 50. A UPF of 20 means that 1/20th, i.e. 5%, of the biologically effective UV radiation striking the surface of the fabric actually passes through it [71].

Conclusion

The best technique for reducing UV exposure is to avoid sun exposure, but this is an unacceptable solution to all. Recreational exposure accounts for most of the significant UVR exposures of the population, and occupational exposure is also significant. However, there is growing interest in reducing the UVR exposure of outdoor workers. This necessitates the development of stronger UV absorbers which will be especially suitable for low UPF fibres, which are highly preferred by the consumers. UVR exposure can be reduced by implementing by behavioural changes such as avoiding sunlight at its maximum, using protection such as hats, sunscreens, sun glasses, and clothing.

References:

1. *Perkin S.W., "Functional Finishes and High Performance Textiles", Text. Chemists and Colorists and American Dyestuff Reporter 32 (4) 2000 24 – 27*
2. *Palacin F., "Textile Finish Protects Against UV Radiation", Melliand International 1997 (3) 169 – 172*
3. *Srinivasan M., Gatewood B.M., "Relationship of Dye Characteristics to UV Protection Provided by Cotton Fabric", TCC and ADR 32 (4) 2000 36 – 43*
4. *Hockberger P.E., "A History of Ultraviolet Photobiology for Humans, Animals and Microorganisms", Photochemistry and Photobiology 76 (6) 2002 561 – 579*
5. *Morys M., Berger D., "The Accurate Measurements of Biologically Effective Ultraviolet Radiation" Proceedings of International Symposium on High latitude Optics, Norway July 1993*
6. *www.eere.energy.gov/solar/pdfs/solar_timeline.pdf accessed Sept 2005*
7. *Achwal W.B., "UV Protection by Textiles", Colourage 2000 (4) 50 – 51*

8. *Mallik S.K., Arora T., "UV Radiations: Problems and Remedies", Man Made Textiles in India 2003 (5) 164 - 169*
9. *Reinert G., Schmidt E., Hilfiker R., "Facts About the Application UV Absorbers on Textiles" Melliand English Edition 1994 (7-8) E151 – E153*
10. *Reinert G., Fuso F., Hilfiker R., Schmidt E., "UV Protecting Properties of Textile Fabrics and Their Improvement", AATCC Review 29 (12) 1997 31 – 43*
11. *Dayal A., Aggarwal A.K., "Textiles and UV Protection", Asian Textile Journal 1998 (9) 62 – 68*
12. *Rupp J., Bohringer A., Yonenaga A., Hilden J., "Textiles for Protection Against Harmful Ultraviolet Radiation", International Textile Bulletin 2001 (6) 8 – 20*
13. *Holme I., "UV Absorbers for Protection and Performance", International Dyer 2003(4) 9-10, 13*
14. *Menter J.M., Hatch K.L., "Clothing as Solar Radiation Protection", Curr. Probl. Dermatol. 2003 31 50 – 63*
15. *Pailthorpe M.T. Chriskis J.I., "Sun Protection of Apparel Textiles", Proceedings of 3rd Asian Textile Conference Vol. II 1995 904 – 914*
16. *Bajaj P., Kothari V.K., Ghosh S.B.," Some Innovations in UV Protective Clothing", Indian J. of Fibres and Textile Research 35 (4) 2000 315 – 329*
17. *Gerber B., Mathys P., Moser M., Bressoud D., Fahrlander C.B., "Ultraviolet Emission Spectra of sunbeds", Photochemistry and Photobiology 76 (6) 2002 664 – 664*
18. *Desai A.A., "Clothing that offer Protection Against Ultraviolet Radiation" Textile Magazine 2003 (1) 77 – 79*
19. *Djam M., Rosinskaja C., Kizil Z., Weinberg A., "Assessment Method for UV Protective Properties of Textiles" Melliand International 7(6) 2001 144 – 146*
20. *Sharma D.K., Singh M., "Effect of Dyeing and Finishing Treatments on Sun Protection of Woven Fabrics – A Study", Colourage Annual 2001 69 – 74*
21. *Aulstralian Guide for UV Protective products 2003 released by Australian Radiation Protection and Nuclear Safety Agency through www.arpansa.gov.au/uvrg/main.htm*
22. *Dornelles S., Goldim J., Cestari T., "Determination of the Minimal Erythema Dose and Colorimetric Measurements as Indicators of Skin Sensitivity to UV B Radiation", Photochemistry and Photobiology 79 (6) 2004 540 – 544*
23. *Ambach W, Blumthaler M, "Biological effectiveness of solar UV radiation in humans", Experientia 49(9) Sep 15 1993 747-53 http://www.arclab.org/medlineupdates/abstract_8405296.html accessed Sept 2005*
24. *Sutherland J.C., "Biological Effects of Polychromatic Light" Photochemistry and Photobiology 76 (2) 2002 167 – 170*
25. *Zimniewska M., Rawluk M., "Linen and Hemp Clothing and Their Sun Protection", Proceedings of "Smart Textiles: Their Production and Marketing Strategies", N. I.F.T., New Delhi, India 133 – 146*
26. *ASTM D6603 – 00: Standard Guide for Labelling of UV Protective Textiles, p 1194 – 1198*
27. *Gies P., Roy C., Javorniczky J., Henderson S., Deschamps L.L., Driscoll C., "Global Solar UV Index: Australia Measurements, forecasts and Comparison with the UK", Photochemistry and Photobiology 79 (1) 2004 32 – 39*
28. *Singh M.K., "Sun Protective Clothing", Asian Textile Journal 2005 (1-2) 91 – 97*
29. *Bilimis Z., "Measuring the Cover and Shade Protection Factors of Synthetic Shade Cloth",*
30. *Achwal W.B., "Use of UV Absorbers in Textiles", Colourage 1995 (10) 44 – 45*
31. *Reinert G., Schmidt E., Hilfiker, "Use of UV Absorbers in Textiles", Textilverendlung 1994 (75) 606*
32. *Gupta K.K., Tripathi V.S., Ram H., Raj H., "Sun Protective Coatings", Colourage 2002 (6) 35 – 40*
33. *El Zaher N.A., Kishk S.S., "Study of the Effect of UVR on the Chemical Structure, Mechanical Properties and Crystallinity of Nylon – 6 Films", Colourage 1996 (11) 25 - 30*
34. *"Microscopical Observations of the Abrasive and Ultraviolet Deterioration of Nomex Aramid Fibre", Textile Res. J. 1977 (3) 171 – 177*
35. *Hunt R., "Opportunities in UV Protection" Knitting International 2003 (2) 51 – 53*
36. *Gantz G.M., Sumner W.G., "Stable Ultraviolet Light Absorbers", Textile Res. J 27 (3) 244 – 251*
37. *Hustvedt D., Crews P.c., "The Ultraviolet Protection Factor of Naturally Pigmented Cotton", The Journal of Cotton Science 2005 (9) 47 – 55*
38. *Krizek D.T., Gao W., "Ultraviolet Radiation and Terrestrial Ecosystsm", Photochemistry and Photobiology 79 (5) 2004 379 – 381*

39. *Hanke D., Hoffman K., Altmeyer A., Schindler G., Schon U., Wirppertal, Klotz M.L., "UV Protection by Textiles", Chemical Fiber International 47 (4) 1997 130 – 131*
40. *Sekar N., "UV Absorbers in Textiles" Colourage 2000 (11) 27 – 28*
41. *Reinert G., "A New UV Absorbant For Polyester Fibres", Melliand English Edn 1993 (10) E352-54*
42. *Abrahart E.N., "Stilbene Dyes and Fluroescent Brightening Agents", in Dyes and Their Intermediates, Edward Arnold Publication, London 1977 178 – 184*
43. *Eng J.M., Samuels S.B., Vulic I., "Developments in UV Stabilization of PP", Chemical Fiber International 48 (12)1998 514 – 517*
44. *Achwal W.B., "Use of UV Absorbers for Minimising Photodegradation of Disperse Dyes As well As Polyester Fibres", Colourage 1994 (6) 21 – 22*
45. *Gupta D., "Developments in the Field of UV Protection of Textiles" through www.resil.com/articles/articlesdevuvprot.html, accessed on May 5, 2005*
46. *Aggarwal A.K., Bansal C.P., "Development of UV Resistant Polyester Cotton Blended Fabric", Presented in 45th JTC at BTRA, Mumbai, 26th and 27th February, 2004 179 – 187*
47. *Perenich T.A., "Textiles as Preventive Measures for Skin Cancer", Colourage 1998 71 – 73*
48. *Smith G.J., Miller I.J., Clare J.F., Diffey B.L., "The Effect of UV Absorbing Sun Screens on the Reflectance and the Consequent Protection of Skin" Photochemistry and Photobiology 75 (2) 2002 122 – 125*
49. *Teli M.D., Adoverelar R., Kuma V.R., Pardeshi P.D., "Role of Chelating Agents and UV Absorbers in Improving Photo-stability of Disperse Dyes", Journal of Textile Association 63 (5) 247 – 251*
50. *Morton H.E., Hearle J.W.S., Physical Properties of Textile Fibres, The Text. Institute 2000 580-83*
51. *www.advanced nanotechnology.com, accessed on May 10, 2005*
52. *"Practical Experiences with Solartex Products Finishing of Sun Protection Fabris", Melliand English 1997 (7-8) E111 – E112*
53. *Joshi M., G.V.R. Reddy, "UV Protection Textiles – Options and Opportunities", Asian Dyer 2005 (9-10) 76 – 81*
54. *Xu P., Wang W., Chen S.L., "UV Blocking Treatment of Cotton Fabrics by Titanium Hydrosol", AATCC Review 2005 (6) 28 – 31*
55. *Schindling G., Hoffman K., "UV Protection by Textiles", Melliand English 1997 (7-8) E115 – E118*
56. *Haerri H.P., Haenzi D., Donze J.J., "Application of UV Absorbers for Sun Protection", Melliand International 2001 (7) 59 – 61*
57. *Anon, "UV Cut Finishing", JTN 1998 (2) 102 – 105*
58. *Anon, "Wear Sunscreen", International Dyer 2000 (3) 31 – 32*
59. *www.solartex.com accessed July 2005*
60. *Rosinskaya C., Djam M., Weiberg A., Kizil Z., "Improvement of UV Protection of Cotton Fabrics Dyed with Binary Mixtures of the Reactive Dyes", Melliand International 9 (6) 2003 147 – 148*
61. *Edlich R.F., Cox M.J., Becker D.G., Horowitz J.H., Nichter L.S., Britt L.D., Edlich T.J., Long W.B., "Revolutionary Advances in Sun Protective Clothing – An Essential Step in Eliminating Skin Cancer in Our World", J. of Long Term Effects of Medical Implants 14 (2) 2004 -5 – 105*
62. *Alvarez J., Symonowicz B.L., "Examination of the Absorption Properties of Various Fibres in Relation to UV Radiation", AUTEX Res. J. 3 (2) 2003 – 0057*
63. *Bilimis Z., "Measureing UV Protection of Fabrics and Clothing", through Valianinc.com/image/viage/ducs/products/spectr/uv/atworks/uv67.pdf, accessed June 2005*
64. *Bohringer B., Schindling G., Schon U., Hanke D., Hoffman K., Altmeyer R., Klotz M.L., "UV Protection by Textiles" Melliand International 1997 (3) 165 – 167*
65. *Crews P.C., Kachman S., "Influences on UVR Transmission of Undyed Woven Fabrics", AATCC Review 31 (6) 1999 17 – 26*
66. *Gogoi, S., Baruah B., Sarkar C.R.., "Effect of Ultraviolet Light on Silk Fabric", Colourage 1999 (2) 23 – 29*
67. *Schuicrer M., "Practical Experience with Solartex Products in Finishing of Sun Protection Fabrics", Melliand International 1997 (3) 168 – 169*
68. *Slater K., "Protection of , or by, Textiles from Environmental Damage", in Environmental Impact of Textiles, CRC Press 2003 163 – 166*
69. *Algaba I., Va A.R., Crews P.C., "Influence of Fiber Type and Fabric Porosity on the UPF", AATCC 4(2) 2004 26 – 29*

70. *Gupta D., Jain A., Panwar S., "Anti UV and Antimicrobial Properties of Some Natural Dyes on Cotton", Indian Journal of Fibre and Textile Research 30 (2) 2005 190 – 195*
71. *Eckhardt C., Rohwer J., "UV Protector for Cotton Fabrics", AATCC Review 2000 32 (4) 21 – 23*
72. *Anon, "UPF Analysis of Textile", www.labsphere.com, accessed Nov, 2005*
73. *Kollias N., Bager A., Sadiq I., Gilles R., Yang H.O., "Measurement of Solar UVB radiations by Polysulphone Fims" Photochemistry and Photobiology 78 (3) 2003 220 – 224*
74. *Parisi A.V., Kimlin G., "Personal Solar UV Exposure Measurements Employing Modified Polysulphone with an Extended Dynamic Range" Photochemistry and Photobiology 79 (5) 2004 411 – 415*
75. *ASTM D6544 – 00 Standard Practice for Preparation of Textiles Prior to Ultraviolet (UV) Transmission Testing Page 1159 – 1162*
76. *Hatch K. L., "American Standards for UV protective Textiles ", Recent Results Cancer Res. 2002;160:42-47*
77. *Apel H., "UV/Vis Spectrophotometric Measurement of UV Protection", Melliand International 1997 (3) 173*
78. *Gies P., Roy C., Mc Lennan A., Pailthorpe M., Hilfiker R., Osterwalder U., Monard B., Moseley H., Sliney D., Wengraitis S., Wong J., Human s., Bilimis Z., Holmes G., "Ultraviolet Protection Factors for Clothing: An Intercomparison of Measurement Systems" Photochemistry and Photobiology 77(1) 2003 58 – 67*
79. *Hatch K.L., "Solar Violet Protective Clothing: What's Behind the Label?", AATCC Review 2005 (8) 31 – 34*
80. *Hatch K.L., "Making a Claim that a Garment Fabric is UV Protective", AATCC Review 2003 (12) 23 – 26*
81. *Thilo G., Peter A., Klaus H., "Comparison of Methods: Determination of UV Protection of Clothing", Recent Results in Cancer Research 2002 (160) 55 – 61*
82. *Gies H.P., Roy C.R., McLennan A., Diffey B.L., Pailthorpe M., Driscoll C., Whillock M., McKinlay A.F., Grainger K., Clark I., Sayre R.M., "UV Protection by Clothing: An Intercomparison of Measurements and Methods", Health Physics 1997 73 (3) 465 – 464.*

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