Measuring the UV protection factor (UPF) of fabrics and clothing

Application Note

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Introduction

Ozone depletion in the earth's atmosphere has made the headlines on many occasions and most people would be aware of the significant problem which exists. The extraterrestrial solar spectrum contains UVC (100 to 280 nm), UVB (290 to 315 nm) and UVA (315 to 380 nm) radiation. However, due to absorption by the ozone layer in the upper atmosphere, no UVC and only some of the UVB reaches the earth's surface, thus any reduction in the ozone layer could lead to an increase in the levels of solar UVB at the earth's surface[1]. Much of this ozone depletion has been attributed to the release of man-made fluorocarbons, in particular chlorofluorocarbons (CFCs), which react with the ozone high in the stratosphere to reduce the amount of ozone providing protection against the incoming solar Ultraviolet Radiation (UVR).

A decrease of 1% in ozone would lead to increases in the solar UVR at the earth's surface and may eventually lead to a 2.3 % increase in skin cancer[2]. In many cases the UVR exposures of the population could be reduced by a factor of 10 or more by implementing behavioural changes, such as avoiding the sun at its maximum, or using protection such as hats, sunscreens, sunglasses and clothing[1].

This paper focuses on how to assess the amount of UVR protection provided by fabrics and clothing. The Ultraviolet Protection Factor (UPF) of six textiles with variable construction (woven and knitted) and variable fiber content, were determined using a spectrophotometric method.

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Equipment

- Cary 3E UV-Vis Spectrophotometer
- Cary 1/3E Diffuse Reflectance Accessory (Integrating sphere)
- Cary Fabric holder
- Schott UG #11 filter UPF (Ultraviolet Protection Factor) Easy Menu software package

Discussion

Traditionally, the determination of the UPF of a fabric was analyzed by placing a template with various fabric samples next to human skin. Ultraviolet radiation up to 60 times as strong as the sun's rays was directed through the fabric and onto the skin for varying lengths of time. The resulting degree of sunburn to the exposed skin determined the fabric's Protection Factor. Unfortunately, this method exposes subjects to potentially unsafe levels of UV radiation. Dr Michael Pailthorpe, Professor in Textile Technology at the University of New South Wales, Australia, was part of a research team at Lidcombe Hospital Dermatology Centre that has developed an accurate and much safer method of analysis. This research group developed this new technique by measuring the direct and diffuse transmission of a fabric at 1 nm intervals over the UVA and UVB range, using a Diffuse Reflectance Accessory (integrating sphere) in conjunction with the Cary 3E UV-Vis spectrophotometer. The %Transmission results determined at each wavelength interval were used in the following formula to calculate the UPF[3].

$$UPF = \frac{\Sigma S(l)*E(l)d(l)}{\Sigma S(l)*E(l)*T(l)d(l)}$$

Where:

S(l) = The solar irradiance for the light source used (this file takes into account the strength of the summer sun at noon)

E(l) = The relative erythemal response (this file takes into account the human skin response)

T(l) = The fraction of incident radiation transmitted by the sample

Standards Australia Committee, TX/21 "Sun Protective Clothing" have been working towards setting a standard for fabric protection. Table 1 shows the proposed UVR rating scheme.

Table 1. Proposed UVR rating scheme for textiles

UVR Protection	UVProtection	Mean %UVR
Moderate	UPF 10 to 19	10 to 5.1
High	UPF 20 to 29	5.0 to 3.4
Very High	UPF 30 to 49	3.3 to 2.0
Maximum	UPF ≥50	≤2.0

The stated UPF values in Table 1 is the mean UPF, less the 95% confidence limit rounded down to the nearest multiple of five.

Accurate assessment of the amount of protection provided by various fabrics requires measurement of the spectral transmittance of each fabric across the wavelength range 280 to 390 nm, which includes the UVB (290 to 315 nm) and the UVA (315 to 380 nm). The reason for this is that UV radiation of different wavelengths has vastly different effects in producing biological damage such as erythema (sunburn). A given quantity of UVB is approximately a thousand times more damaging than the same quantity of UVA[4], so knowledge of which wavelengths are transmitted is important. Figure 1 shows examples of the transmittances of fabrics where, in some cases, the transmittance can vary markedly with wavelength.

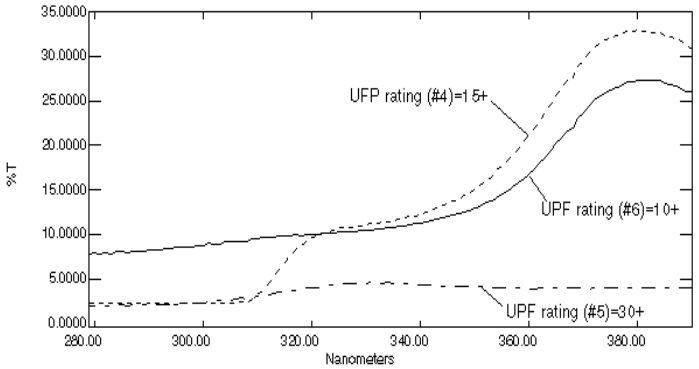

Figure 1. The spectral transmittance of selected fabrics. Fabric 4 is a white polyester woven, Fabric 5 is a white cotton knit and Fabric 6 is a white nylon knit. Fabric 5 would give the best protection

Results

The UV transmission (direct and diffuse) of the six fabrics was measured and the calculations were performed over the spectral region 280-390 nm using a Cary 3E UV-Visible Spectrophotometer fitted with an integrating sphere accessory and a fabric holder accessory. The following three criteria[5] were met to ensure accurate spectrophotometric assessments of the UPFs of the textiles:

1. All forward-scattered and transmitted light was collected by ensuring that the fabric sample was fixed closely to the entrance port of the integrating sphere.
2. Spectral measurements spanned the wavelength range that includes all the erythemally active wavelengths (i.e. the wavelengths which cause sunburn), including the UVA region.
3. The fabric was fixed closely against a UG11 filter which was fixed very closely to the entrance port of the integrating sphere. The light from the instrument is firstly transmitted through the fabric, then through the UG11 filter and into the integrating sphere. This arrangement ensures the elimination of the effects of fluorescence from the fluorescent whitening agents that may be present in the fabric.

The reported values are the average of eight measurements made on sub-samples taken from the fabrics. Four sub-samples were taken in the "machine" direction and four sub-samples were taken in the "cross-machine" direction.

Table 2 summarizes the results obtained from measuring six reference fabrics. Table 3 summarizes the mean UVR, UVA and UVB %Transmission results for the six reference fabrics.

Table 2. Reference fabrics

Sample No.	Sample Details	Measured UPF	UPF Rating	UV Protection Category
1	White cotton Woven	9.4 +/-0.3	5+	Not Rateable
2	White woven polyester (crepe)	119 +/-7	50+	Maximum
3	Cream woven wool	136 +/-24	50+	Maximum
4	White polyester woven	19.9 +/-1.6	15+	Moderate
5	White cotton knit	41.6 +/-8.5	30+	Very High
6	White nylon knit	11.1 +/-0.9	10+	Moderate

Table 3. Reference fabrics

Sample No.	Sample Details	Mean UVR 290-380 (nm)	Mean UVA 315-380 (nm)	Mean UVB 290-315 (nm)
1	White cotton	12.9 %T	14.3 %T	9.7 %T
2	White woven polyester (crepe)	2.6 %T	3.5 %T	0.3 %T
3	Cream woven wool	3.0 %T	4.1 %T	0.3 %T
4	White polyester woven	13.6 %T	17.6 %T	2.9 %T
5	White cotton knit	3.0 %T	3.4 %T	2.1 %T
6	White nylon knit	12.7 %T	14.4 %T	8.3 %T

All the results were generated using the Cary UPF Easy Menu software package which was specifically designed to automatically perform all of the required UPF measurements and calculations.

This software allows one to use a standard mesh of known UPF rating to ensure validation of UPF calculations. Also, there is a wavelength accuracy option which allows the operator to validate the wavelength accuracy of the UV-Vis spectrophotometer.

Figure 2 shows an example of a report generated by the UPF Easy Menu software package.

Project : Reference #4, White woven polyester

Operator : Zafira Bilimis

Client : University of NSW

Comment : Reference samples

Date : 8 Jul 1994

Instrument : Cary UV-Vis Wavelength range
: 280.00 - 400.00 nm

SBW : 4.0 nm

Scan speed : 900.000 nm/min

Number of scans : 8

ref 4 white woven polyester 1 UPF= 21.0

ref 4 white woven polyester 2 UPF= 19.0

ref 4 white woven polyester 3 UPF= 18.9

ref 4 white woven polyester 4 UPF= 19.8

ref 4 white woven polyester 5 UPF= 18.1

ref 4 white woven polyester 6 UPF= 20.0

ref 4 white woven polyester 7 UPF= 23.7

ref 4 white woven polyester 8 UPF= 18.7

Mean UPF = 19.9

SDev = 1.8

CV% = 8.9

95 %CL = 1.6

UPF Rating 15+:This textile provides MODERATE protection

Mean UV (290-380 nm) = 13.6 %T

Mean UVA (315-380 nm) = 17.6 %T

Mean UVB (290-315 nm) = 2.9 %T

Figure 2. The report which was generated for Fabric 4, a white woven polyester

Conclusion

The Cary 3E spectrophotometer, in conjunction with the Cary 1/3E DRA and the UPF Easy Menu, provide users with a user friendly, highly productive solution. This UPF analyzer enables the most novice user to perform fabric measurements because the UPF Easy menu software automatically takes care of all the calculations.

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