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Application News

No.A450A

Spectrophotometric Analysis

Measurement of the Ultra Violet Protection Factor assigned to Ultraviolet Protection Clothes

Introduction

Sunlight that reaches the earth is composed of various wavelengths designated as visible light (VIS), which can be seen by humans, ultraviolet light (UV), and infrared light (IR). The visible region of the spectrum lies between the shorter wavelength ultraviolet light and the longer wavelength infrared light. The ultraviolet radiation (UV) with shorter wavelengths has stronger energy associated with it and substances exposed to UV radiation for long periods of time can undergo deterioration and decomposition.

For humans, long exposure to UV radiation can cause skin blemishes such as freckles and in the worst case, cancers. Given the current concern for UV exposure, there are many UV protected textile fabrics on the market. In this application, we use UV-Visible spectrophotometry to measure the UV protection value for these items to verify how well they protect the wearer from harmful UV radiation. The Ultraviolet Protection Factor (UPF) value is a regulated Standard in Europe, America, and Oceania. Here we examine common UPF values for UV protected clothing.

Analytical Conditions for UPF

The UPF value is a number representing the ultraviolet protection factor, and is an indication of how well the item protects the user from sun burn. The UV wavelength of interest is specified to be between 280-400 nm (in some cases it is specified as 290-400 nm). In this wavelength range further categorization can include the UVA at 315-400 nm, and the UV-B at 280-315 nm (in some case 290-315 nm). Various regulations currently use different measuring conditions and formulas to calculate UPF values. Table1 shows the different measuring conditions that are specified by the Germany / British, America, and Australia / New Zealand regulations.

Table1 Test methods of Germany / British, America, and Australian / New Zealand

	Germany / British DIN EN13758-1 BS EN135758-1	America AATCC 183	Australian / New Zealand AS/NZS 4399
Wavelength	290 - 400 nm	280 - 400 nm	290 - 400 nm
Sampling Pitch	1 nm	2 nm	5 nm
Value	UPF (290 - 400 nm)	UPF (280 - 400 nm)	UPF (290 - 400 nm)
	UVA (315 - 400 nm)	UVA (315 - 400 nm)	UVA (315 - 400 nm)
	UVB (290 - 315 nm)	UVB (280 - 315 nm)	UVB (290 - 315 nm)

Table2 Calculation Formula for UVA, UVB and UPF

	Germany / British DIN EN13758-1 BS EN135758-1	America AATCC 183	Australian / New Zealand AS/NZS 4399
UVA	$\frac{1}{86}\sum_{\lambda=315}^{\lambda=400} T_i(\lambda)$	$\frac{\sum_{315\,nm}^{400\,nm} T_\lambda \times \Delta\lambda}{\sum_{315\,nm}^{400\,nm} \Delta\lambda}$	$\frac{T_{315}+T_{320}+T_{325}+\cdots+T_{395}+T_{400}}{18}$
UVB	$\frac{1}{26}\sum_{\lambda=290}^{\lambda=315} T_i(\lambda)$	$\frac{\sum_{280\,nm}^{315\,nm} T_\lambda \times \Delta\lambda}{\sum_{280\,nm}^{315\,nm} \Delta\lambda}$	$\frac{T_{290}+T_{295}+T_{300}+T_{305}+T_{310}+T_{315}}{6}$
UPF	$\frac{\sum_{\lambda=290}^{\lambda=400} E(\lambda)\varepsilon(\lambda)\Delta\lambda}{\sum_{\lambda=290}^{\lambda=400} E(\lambda)T(\lambda)\varepsilon(\lambda)\Delta\lambda}$	$\frac{\sum_{280\,nm}^{400\,nm} E_\lambda \times S_\lambda \times \Delta\lambda}{\sum_{280\,nm}^{400\,nm} E_\lambda \times S_\lambda \times T_\lambda \times \Delta\lambda}$	$\frac{E_{eff}}{E'} = \frac{\sum_{290}^{400} E_\lambda \times S_\lambda \times \Delta\lambda}{\sum_{290}^{400} E_\lambda \times S_\lambda \times T_\lambda \times \Delta\lambda}$

Calculation Formula for UPF

Table 2 shows the formulas used by each country for the calculation of UVA, UVB, and UPF. UVA is calculated in the wavelength range of 315-400 nm, and UVB is calculated in the wavelength of 280-315 nm (some case 290-315 nm).
Where:

E_λ : relative erythemal spectral effectiveness (see each regulation)
S_λ and $\varepsilon(\lambda)$: solar spectral irradiance (see each regulation)
T_λ : average spectral transmittance of the specimen(measured)
$\Delta\lambda$: measured wavelength interval(nm)

Measurement of Ultraviolet Protection values for Clothes and Umbrellas

Fig. 1 shows the UV Protection provided by clothes (both light and dark areas) and the UV protection provided by an umbrella. The samples were analyzed by a SHIMADZU UV-2600 UV-Vis Spectrophotometer and an ISR-2600 Plus integrating sphere accessory. Table 3 shows the measurement analytical conditions, and Fig. 2 shows transmittance spectra. The transmittance spectrum of the umbrella (green) shows that very little UV radiation transmits through the umbrella. In regards to the clothing, the black areas block more UV radiation than do the white areas. Table 4 shows each calculated UPF value as defined by each regulation. The table shows that the same clothing area can have differing UPF values depending upon the regulation used to calculate the value. When a sample is measured to have a UPF value that is greater than 50, then only "50+" or "UPF>50" need be reported, as specified in each regulation. In table4 the calculated UPF values are displayed as specified by each regulation for comparison purposes.

Fig. 1 Photograph of clothing and an umbrella that can be used for Ultraviolet Protection and used in this application news

Table 3 Analytical Conditions

Apparatus	: SHIMADZU UV-2600 Integrating Sphere ISR-2600Plus
Wavelength	: 280-400 nm
Scan Speed	: Medium
Sampling Pitch	: 1.0 nm
Measurement Mode	: Transmittance
Slit	: 5 nm

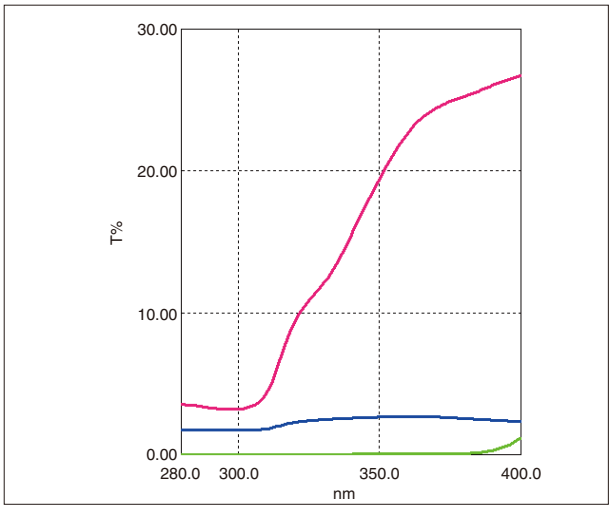

Fig. 2 Transmittance Spectra of Ultraviolet Protection Clothes (light areas red and dark areas blue) and Umbrella (green)

Conclusion

Each piece of clothing tested had the same catch phrase "UV cut-off", but as the spectral measurements demonstrate exhibit different spectral transmittance. In addition, the same spectrum may give different UPF values depending upon a specific Country's formulation for UPF calculation.
Because of this it is necessary to refer to each governing regulation when analyzing UV protection materials.

[References]
- DIN EN13758-1
  Textile Solar UV protective properties-
  Part1: Method of test for apparel fabric(includes Amendment A1: 2006)
  English version of DIN EN 13758-1: 2007-03
- BS EN 13758-1
  BRITISH STANDARD
  Textiles-Solar UV protective properties-
  Part1: Method of test for apparel fabrics
- AATCC Test Method 183-2010
  Transmittance or Blocking of Erythemally Weighted Ultraviolet Radiation through Fabrics
- Australian / New Zealand Standard
  Sun Protective clothing-Evaluation and classification

Table 4 UPF for ultraviolet protection Clothes and Umbrella

	Germany / British DIN EN13758-1 BS EN135758-1	America AATCC 183	Australian / New Zealand AS/NZS 4399
White part of UVprotected clothes	16.2	16.2	19.0
Black part of UVprotected clothes	UPF>50 (51.7)	50+ (51.7)	50+ (53.2)
UVprotected Umbrella	UPF>50 (3640)	50+ (3740)	50+ (4060)

First Edition: Nov, 2012

Shimadzu Corporation
www.shimadzu.com/an/