Application Note: 51664

Measuring the UV Protection Factor of Fabrics

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Key Words

- DRA
- Erythema
- Melanoma
- Sun Protection
- Sunburn
- UPF
- UV-Visible Spectrophotometry

Introduction

Sun protection fabrics are designed to absorb or reflect the sun's UV radiation as a means of protecting the skin from damage. The rating system for fabrics specifies an Ultraviolet Protection Factor (UPF) value, which can be thought of as a time factor for the protection of Caucasian skin compared to exposure without any protection. For example, if a person would show visible erythema (sunburn) after five minutes of exposure, fabric with a UPF of fifty extends that time to five minutes times the protection factor, i.e. 250 minutes, or roughly four hours. Scientific methods of evaluating the UPF of fabrics have been developed and specified according to Australia/New Zealand (AS/NZ) standard 4399:1996[1]; other nations and regions have produced their own standards modeled after this original work, e.g. AATCC 183:2004[2] with ASTM D6544 and ASTM D6603 in the United States and EN 13758-1 in Europe. The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) maintains an excellent website[3] with many details concerning UV protection and monitoring. A summary of the requirements of the various standards, reproduced from that website[4], is included in the gray box on the following page.

The standards call for diffuse transmittance measurements obtained on a UV-Visible spectrophotometer equipped with an integrating sphere accessory. The AATCC 183:2004 standard specifies that the integrating sphere used must have a port fraction no greater than 3%. This requirement eliminates most smaller (< 150 mm) spheres on the market from consideration for use in this application. The Thermo Scientific DRA-EV-600 75 mm sphere, however, has a port fraction of 2.86% when configured for transmission measurements, so it is compatible with this standard. The methods also require that a fluorescence filter such as a Schott UG11 be placed between the fabric sample and the integrating sphere. Brighteners, i.e. chemicals included in certain fabric dyes that absorb in the UV and fluoresce in the blue, have the potential to cause erroneous measurements of UPF by making transmission appear high. Inclusion of the fluorescence filter overcomes this problem.

This application note describes the measurement of UPF using a Thermo Scientific Evolution™ 600 UV-Visible spectrophotometer, a DRA-EV-600 Integrating Sphere accessory with fluorescence filters, and VISION*lite*™ MaterialsCalc software.

Background

Sunburn, skin cancers, premature skin aging and suppression of the immune system are all linked to exposure of skin to UV light. The UV spectrum lies between 200 nm and 400 nm and is commonly divided into three regions:

UV-A: 320-400 nm

UV-B: 280-320 nm

UV-C: 200-280 nm

The highest energy region, UV-C is absorbed completely by ozone in the stratosphere. Of the solar UV radiation reaching the earth's surface, 6% is in the UV-B region and 94% in the UV-A.

The potential of UV radiation to cause skin damage rises exponentially with decreasing wavelength. UV light at 280 nm is 1000 times more damaging than light at 340 nm so a fabric's ability to block UV-B is the most important factor in preventing the negative side affects of sun exposure. The international standard for quantifying the damaging effects of UV radiation on skin is the erythemal action spectrum, shown in Figure 1.

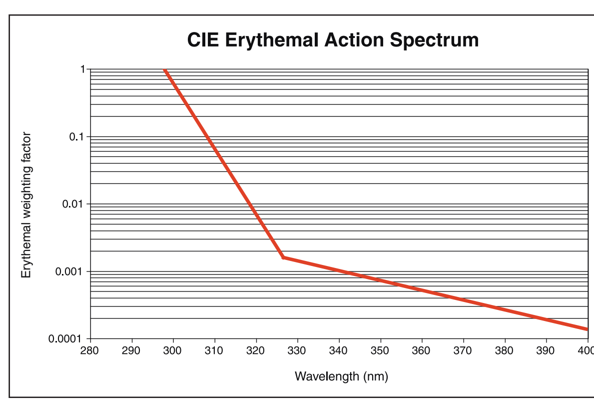

Figure 1

Calculations to determine UPF as defined by AS/NZS 4399:1996, AATCC 183:2004 and EN 13758 involve measurement of the percent transmission of a fabric sample across the UV spectrum weighted by the erythemal weighting factors at different wavelengths. The AS/NZS 4399:1996 method is particularly convenient because it does not specify any preconditioning of the fabric and involves only measurements on dry fabric.

Clothing standards in the USA[4]

There have been sun protective clothing standards in the USA since 2001. In the USA, testing is performed according to the standard AATCC 183 available from the American Association of Textile Chemists and Colorists (*http://www.aatcc.org*). In Australia, the fabric is tested in new condition. In the USA there is an additional preparation stage in which the fabric is first laundered, exposed to simulated sunlight and chlorinated water. This is done according to ASTM D6544 available from the American Society for Testing and Materials (*http://www.astm.org*). Labeling in the USA is specified in ASTM D6603.

British and European clothing standards

The recently-released European standard EN 13758-1 replaced BS 7914. BS 7949 (UV protection requirements for children's clothing) remains current but will eventually be replaced by EN 13758-2.

Similarities and differences among clothing standards

The calculation and expression of results is similar in EN 13758-1, AATCC-183 and AS/NZS 4399. All three standards report results as a UPF rating. When samples are found to have a UPF rating over 50, EN 13758-1 reports them as >50 whereas ASTM D6603 and AS/NZS4399 report them as 50+.

EN 13758-1 (and BS 7914) stipulates that fabric samples are to be conditioned at a specified temperature and humidity before testing. AS/NZS 4399 does not specify any conditioning. ASTM D6603 specifies that the fabric samples should be conditioned with laundering, UV exposure and chlorinated pool water equivalent to two years of normal use.

EN 13758-1 and AATCC 183 uses a solar spectrum measured in Albuquerque whereas AS/NZS 4399 uses a solar spectrum measured in Melbourne. UPF results calculated with either spectrum do not differ significantly.

EN 13758-1 and AATCC 183 provide for reporting of measurements made when the fabrics are wet and/or stretched. AS/NZS 4399 currently specifies testing in the dry and relaxed state only.

AS/NZS 4399 specifies testing and labeling requirements whereas EN 13758-1 is concerned only with testing. ASTM D6603 specifies USA labeling requirements.

The various standards require that UPF rated clothing be labeled as fitting into a particular range of protection, rather than stating a single measured number. AS/NZS 4399:1996, for example, calls for the measured value to be rounded down to the nearest multiple of five. At the limits, ratings below fifteen are not recognized and any measured value above fifty may only be labeled as 50+. ASTM D6603 requires both a numeric UPF value and a description of the garment as providing good, very good or excellent UV protection. These terms are based on UPF values of 15-24, 25-39 and > 40 respectively.

As transmittance of UV light drops below 2%, the calculated UPF increases dramatically with very small reductions in transmittance. For this reason, standards do not permit labeling with numbers higher than 50.

Standards also require that clothing made of different fabrics, or different colors of the same fabric, have each area tested separately. The garment must then be labeled according to the lowest level of protection afforded.

Experimental Methods

A swatch of each fabric was mounted under moderate tension at the transmittance port of the integrating sphere. Spectra of fabric samples were collected from 280-400 nm using VISION*lite* MaterialsCalc software. The VISION*lite* MaterialsCalc software automates the determination of UPF, average UVA transmittance and average UVB transmittance according to AS/NZS 4399:1996, EN 13758-1:2001 and AATCC 183:2004. VISION*lite* MaterialsCalc also enables the user to import data and perform calculations on transmission spectra that were acquired by other programs in VISION software family.

Results

Measurements were made on several fabric swatches or portions of intact articles of clothing. Some test pieces were labeled with hang tags stating the UPF at time of sale, others were not. An example of the software output is shown in Figure 2. Results are summarized in Table 1. Samples 1-4 show data for fabric taken from a Sun Runner Cap™ purchased at an outdoor recreation store. As specified in the AS/NZ standard, two measurements were recorded with the weave and two at 90° to it. The data show good reproducibility and confirm the clothing maker's labeling.

Samples 5 and 6 were from a two color swim shirt and sample 7 from a sun hat. There is a significant difference in the protective value of the two fabrics in the swim shirt. All three were marketed as children's sun protection products and performed according to their labeling.

Samples 8 and 9 were two different areas from the back of an adult shirt sold as a sun protection product. The shirt was labeled as offering a UPF of 30+ at time of sale. This shirt had been worn and washed extensively. The average measured UPF of ~24 supports the expectation that exposure and wear lead to a reduction in UPF performance of a fabric.

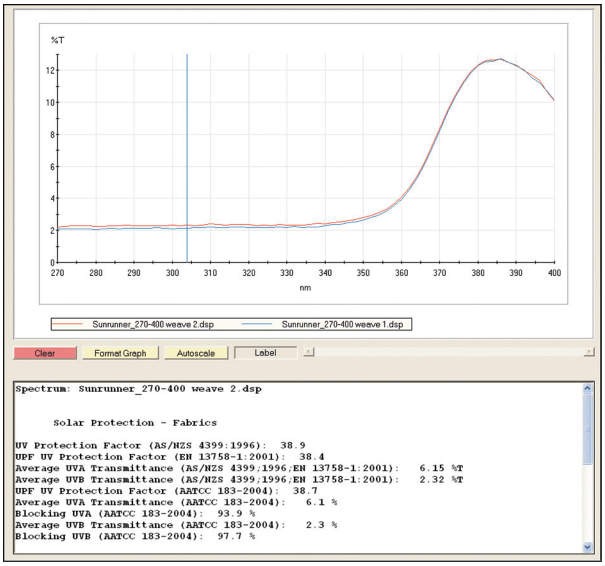

Figure 2: Example VL_MaterialsCalc output

Samples 10, 11 and 12 were taken from a youth group uniform. While these fabrics were not rated for UPF when sold, the results demonstrate that all fabrics provide some level of UPF protection whether intended for the purpose or not. The lightweight nylon material uniform trousers used for sample 10, for example, if subjected to proper testing, could be marketed as offering UPF 50+ sun protection without the manufacturer having to alter them in any way. The polyester/cotton blend uniform shirt that is the subject of samples 11 and 12 demonstrates the effects of weave and fabric thickness. The relatively thin fabric and loose weave of this shirt allows a lot of light through a single layer, leading to a relatively low UPF value. Two layers of the same fabric, however, serve to cover the gaps in each layer and give a dramatically higher UPF.

Conclusion

Data for determining UV protection factors of fabrics can be obtained using an Evolution 600 spectrophotometer equipped with a DRA-EV-600 Integrating Sphere accessory. VISION*lite* MaterialsCalc software performs calculations using two standards (AS/NZS 4399:1996, EN 13758-1) leading to values of UPF and percent transmittance in the UV-A and UV-B regions.

Fabric samples tested confirmed manufacturer claims for new garments and demonstrated the expected effects of wear and weave density on reducing UPF effectiveness. Unrated fabrics tested in our laboratory demonstrated the scope for manufacturers to promote existing garments in the sun protection market after suitable testing. Increased UPF observed on layering shows how garment construction can be optimized to provide maximal protection using existing fabrics. For example, a double layer of cloth across the shoulders of a shirt would provide optimal protection in the area of greatest exposure.

References

1. Sun protective clothing – Evaluation and classification AS/NZS 4399: 1996, available from SAI Global.
2. AATCC = American Association of Textile Chemists and Colorists, *www.aatcc.org*
3. *http://www.arpansa.gov.au/uvrg/rginfo.htm*
4. *http://www.arpansa.gov.au/uvrg/rginfo_p21.html*

Ordering Information

Description	Part Number
Evolution 600 PC-controlled spectrophotometer	10600501
DRA-EV-600 Diffuse Reflectance Accessory	222-219000
VISION*lite* MaterialsCalc Software	869-124500

Recommended system for fabric UPF analysis.

Sample No.	Fabric	Listed Rating	UPF (AS/NZS 4399)	UPF (EN 13758-1)	Average UVA Transmittance (%)	Average UVB Transmittance (%)
1	Sun Runner weave 1a (nylon)	30+	35.4	35.0	6.86	2.56
2	Sun Runner weave 1b (nylon)	30+	35.6	35.2	6.89	2.53
3	Sun Runner weave 2a (nylon)	30+	39.0	38.5	6.45	2.31
4	Sun Runner weave 2b (nylon)	30+	39.5	39.0	6.37	2.28
5	Swim Shirt (white fabric)	50+	221.1	213.6	1.19	0.35
6	Swim Shirt (teal fabric)	50+	78.7	75.6	3.97	0.91
7	Child's Sun Hat	50+	111.7	107.8	2.71	0.69
8	6 year old sun shirt swatch 1	30+	24.9	24.6	9.57	3.50
9	6 year old sun shirt swatch 2	30+	22.8	22.5	9.80	3.85
10	Uniform trousers (nylon)	unrated	156.3	155.7	0.81	0.63
11	Uniform shirt (poly/cotton)	unrated	26.6	26.3	6.27	3.21
12	Uniform shirt doubled	unrated	> 700	> 700	0.50	0.09

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