The ultraviolet confusion unravelled

Ronald Rabbetts and **Alick Taylor** look at the ultraviolet absorbing properties of spectacle lenses and the legislative framework within which appliances must be dispensed

What should the patient expect from a UV-blocking ophthalmic lens?

A PATIENT ORDERED a pair of spectacles, requesting that they blocked all UV radiation. The optician dispensed a pair of lenses in a 1.6 index material that was listed as absorbing all UV. Because she was undergoing PUVA treatment, they were tested by a medical physicist and she was told that they did not block all UV. Had she been advised incorrectly or even under false pretences that they did?

For many years, ophthalmic optics and spectacle lenses have regarded UV-A as covering the range 315nm to 380nm, and all lens literature is based on this. This range is that used in BS EN ISO 1836:1997 *Personal Protective Equipment – General purpose sunglasses* and BS EN ISO 8980-3:2004 *Ophthalmic Optics – Uncut finished spectacle lenses – Transmittance requirements* (Table 1).

The table indicates that there is no requirement to block all UV in the 315nm to 380nm range or to have a cut-off at or below 380nm, only that the relevant percentages given in column 4 shall be satisfied. Even when a luminous transmittance of 8 per cent is required, 0.5τv at 4 per cent would still be met by standard CR39 product since the average UV-A transmittance over the 14 points taken at 5nm intervals between 315nm and 380nm is (52.75 per cent ÷ 14) = 3.77 per cent. Because of the ophthalmic optical definition of UV-A, if a lens is claimed to block all UV, then it is expected that the transmittance at wavelengths between 280nm and 380nm should be zero or very close to zero, but there is no requirement on transmittance above 380nm.

The confusion arises because there is no single definition of the wavelength range for ultraviolet radiation, particularly for the upper limit of UV-A. The Commission International de l'Eclairage (CIE) in the 1930s set the limits for UV-A as 315nm to 400nm. This upper limit was based on the bio-actinic effects of radiation, and overlaps with their limits for visible radiation. The CIE's publication, *International Lighting Vocabulary* (CIE Publication no 17.4, which is jointly titled IEC – International Electrotechnical Commission – publication 50 (845)) term 845-01-03 states: 'visible radiation: the lower limit is generally taken between 360nm and 400nm', the variation depending 'upon the amount of radiant power reaching the retina and the responsivity of the observer'.

At a recent meeting of the Fundamental Standards Subcommittee of

TABLE 1. Categories for luminous transmittance and related permissible transmittance in ultraviolet solar spectral range

<table>
<tr><th>Categories</th><th colspan="2">Visible spectral range</th><th colspan="2">Ultraviolet spectral range</th></tr>
<tr><td></td><td colspan="2">Range of luminous transmittance τ_v</td><td>Maximum value of solar UV-A transmittance τ_{SUVA}</td><td>Maximum value of solar UV-B transmittance τ_{SUVB}</td></tr>
<tr><td></td><td>from over per cent</td><td>to per cent</td><td>over 315nm to 380nm UV-A</td><td>over 280nm to 315nm UV-B</td></tr>
<tr><td>0</td><td>80.0</td><td>100</td><td rowspan="3">τ_v</td><td>τv</td></tr>
<tr><td>1</td><td>43.0</td><td>80.0</td><td rowspan="3">$0.125\tau_v$</td></tr>
<tr><td>2</td><td>18.0</td><td>43.0</td></tr>
<tr><td>3</td><td>8.0</td><td>18.0</td><td rowspan="2">$0.5\ \tau_v$</td></tr>
<tr><td>4</td><td>3.0</td><td>8.0</td><td>1.0 per cent absolute</td></tr>
<tr><td colspan="5">Note to paragraph 5.2 of the standard states: those spectacle lenses of category 0 for which no specific claim is made as to UV transmittance performance are excluded from the UV requirements of Table 1.</td></tr>
<tr><td colspan="5">Part of paragraph 6.4 of the standard states that, when calculating bio-actinically-weighted solar ultraviolet transmittance values τ_{SUVB} from 280nm to 315nm and τ_{SUVA} from 315nm to 380nm, the step width shall not exceed 5nm and shall be equal to the spectral bandwidth used for the spectral transmittance measurements</td></tr>
</table>

Reproduced from BS EN ISO 8980-3:2004

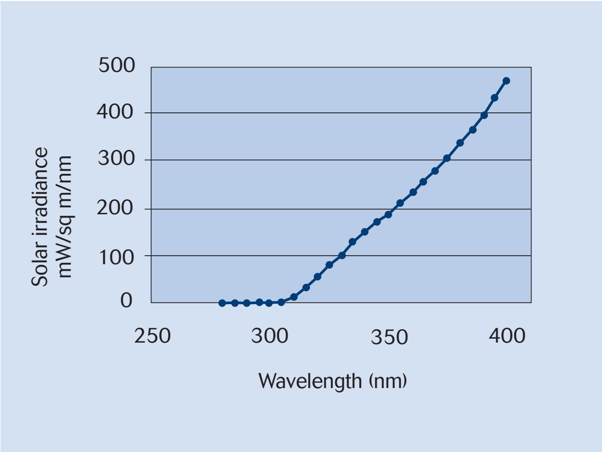

FIGURE 1. The solar irradiance function, from the data in BS EN ISO 13666

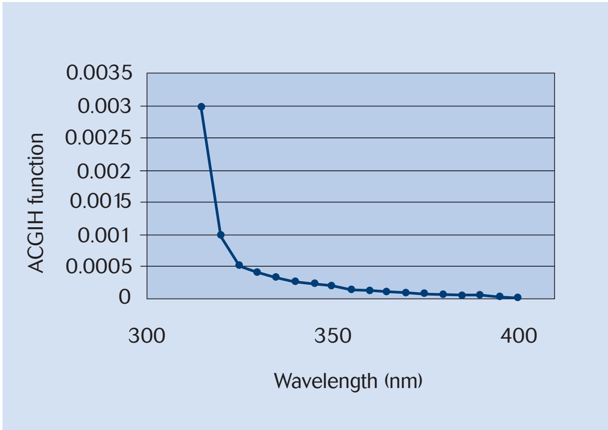

FIGURE 2. The relative spectral effectiveness function for bio-actinic damage, from the ACGIH data given BS EN ISO 13666

the ISO Optics and Photonics Technical Committee (Committee 172), it was agreed that, while the CIE definition generally takes precedence, for purposes of applications, differing definitions may be applicable.

The confusion is also demonstrated in the recent DOCET Update in its description of the Optometric Quarterly tape 52, which has a diagram showing the UV-A band as reaching 400nm, while in the interview on the tape, Bench gives 380nm as the upper limit.

The suggestion put forward at the ISO meeting is therefore that whenever reference is made to UV-A, the limits should either be given as numerical values, or stated to be in accordance with either of the optics standards already mentioned or to BS EN ISO 13666:1999 – *Ophthalmic Optics – Spectacle Lenses – Vocabulary*.

Does this difference matter? Apart from those patients who are sensitised to ultraviolet, the answer is almost certainly 'probably not'. This is because the bio-actinic or hazardous effect for short-term damage depends upon the relative spectral effectiveness of the radiation, and as the wavelength increases, so the damaging effect decreases.

Figure 1 shows the increasing solar irradiance as a function of wavelength in the UV-A region, while Figure 2 shows the decreasing relative spectral effectiveness function for short-term bio-actinic ▶

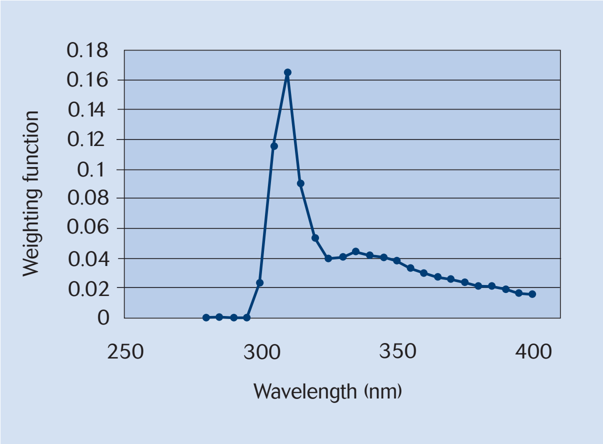

FIGURE 3. The spectral weighting function

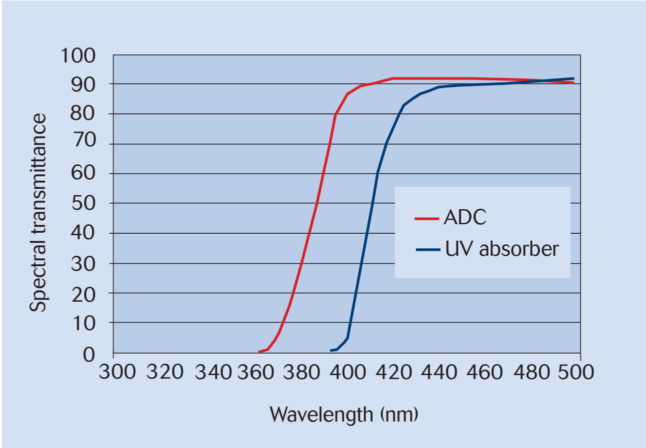

FIGURE 4. The spectral transmittance of standard ADC material and that treated with a good additional UV absorber

damage, for example photopic keratitis or conjunctivitis.

Figure 3 gives the spectral weighting function, which is obtained for each wavelength by multiplying the values given in Figures 1 and 2. As can be seen, this peaks in the longer wavelength zone of the UV-B band (280-315nm, as adopted by both CIE and optics), and decreases in a uniform manner from about 340nm.

Calculations by Dr H Hoover, a leading expert in this field and a member of the International Standards Spectacle Lens and Sunglass Committees, show (personal communication) that although the waveband 380nm-400nm has 25.7 per cent of the unweighted 290nm-400nm corneal irradiance, it has only 3.0 per cent of the bio-actinically effective ACGIH-weighted irradiance.

He concluded that even if a spectacle lens absorbs only 50 per cent of the radiation in the 380nm to 400nm region, the weighted transmittance in this zone still represents less than 3 per cent of the incident radiation between 290nm and 400nm.

What are the implications for spectacle lenses if the waveband limits for UV-A were extended to take the range 315nm-400nm? Apart from the obvious one that all catalogues and literature would have to be revised, the transmittance values in the UV-A range would mostly have to be increased. Figure 4 shows the spectral transmittance for standard allyl diglycol carbonate (ADC, often called CR39 after the trade name of its original manufacturer) which incorporates a UV absorber, although the authors have heard of lenses that do not possess this in-built protection and therefore would not meet ISO/CEN requirements.

Figure 4 also shows a plot for a lens that has been 'dyed' or treated with an additional UV absorbing dye. This lens is likely to display a pale straw colour, but it will be seen that the average transmittance over 315-380 mm is less than that of the standard ADC lens.

Higher index materials such as polycarbonate and 1.60 etc, have an intrinsically better UV absorptions with a UV cut-off point around 380nm compared with a cut-off of 350-360nm for CR39, depending on the amount of UV absorber used at the time of original manufacture. However, the material mentioned at the beginning of the article could not be treated further in order to achieve the required protection.

Figure 5 shows the transmittance of Transitions (standard ADC version) and clear polycarbonate material. The transmittance of most 1.6 index resins is similar to that of polycarbonate.

Some treatments, and sunglasses, claim UV 400. Sadly, at present, there is no definition for this term in any European or International Standard, something the UK experts hope to achieve.

In a proposed revision of BS 7394 – *Complete spectacles – Specification for complete spectacles*, the BSI Spectacles committee has proposed that the requirements for claiming UV 400 should be a transmittance of less than 0.5 per cent at all wavelengths between 280nm and 380nm, a transmittance no greater than 1 per cent at 395nm and no greater than 5 per cent at 400nm. This is to allow a clear lens to provide excellent UV protection without becoming yellow, or needing a faint blue dye to be added to counteract a yellow tinge.

The requirement of the British Association of Dermatologists for patients undergoing PUVA treatment is that the lens should transmit no more than 10 per cent of the incident radiation at 400nm and no more than 1 per cent at 360nm.

It should be noted that BS EN ISO 8980-3 is not the only standard controlling the transmittance properties of spectacle lenses – BS EN ISO 14889: 2003 *Ophthalmic optics – Spectacle lenses – Fundamental requirements for uncut spectacle lenses* also imposes additional transmittance requirements for lenses intended for use when driving.

All the standards mentioned are available from the BSI, 389 Chiswick High Road, London W4 4AL, 020 8996 9000. Members of the College of Optometrists may be able to download them with a password obtainable from the librarian.

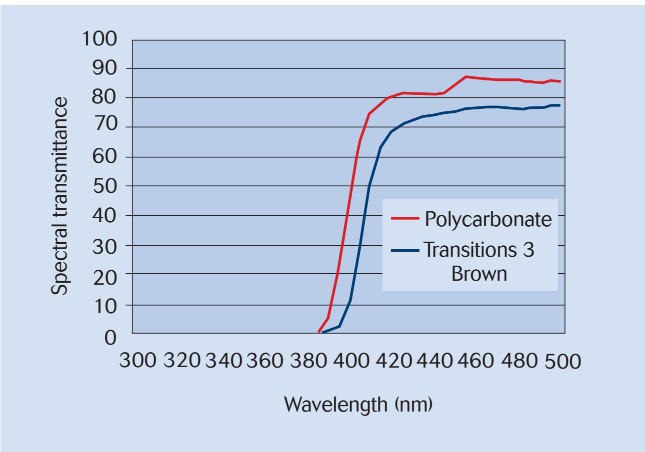

FIGURE 5. Transmittance of clear ophthalmic optical polycarbonate and of Transitions 3 Brown standard resin in its faded stage

◆ *Optometrist Ronald Rabbetts and Alick Taylor, technical manager at Sola Optical UK, are members of the British and International Standards Spectacle Lens and Sunglasses Committees*