Photochromic cards for indication of solar UVR

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Abstract. The properties of a number of different types of photochromic cards were characterised which would provide an attractive means to roughly indicate the instantaneous erythemal solar UV irradiance. Several parameters which may influence the color of the cards were examined with both outdoor trials under solar UV as well as indoor trials using a filtered xenon arc lamp. The findings show that the tested cards do not give an appropriate estimation of the effective irradiance due to their spectral sensitivity and their temperature dependence.

Photochromic cards

The five tested erythemal UV irradiance indicator cards are credit card sized and are made out of cardboard. A test field on the cards alters its color in a reversible way depending upon the instantaneous irradiance level of UV radiation incident upon the indicator field. Ideally, the change of color should be related to the erythemally weighted effective irradiance. A low effective irradiance should result in a pale color of the indicator field, while a high effective irradiance should lead to the appearance of a dark color in the indicator field.

For the application of the cards, the color change of the indicator field has to be compared to the color of printed reference fields which are generally associated to advice concerning personal protection against solar UV radiation such as to apply sunscreens with a certain SPF or to seek shade. The appearance of one of the tested UV irradiance indicator cards is shown in figure 1.

Bu kart güneşin zararlı mor ötesi (UV) ışınlarının şiddetini ölçmektedir. Kartı güneşin altında 10 saniye bekletin. Ortadaki şeridin rengi güneşin şiddetine göre değişecektir. Işınlar ne kadar güçlü ise renk o kadar koyulaşacaktır.

ANTHELIOS Güneşten Koruyucu Serisi'nden cildinize uygun ürünü seçerek güneşin zararlarına karşı tam koruma sağlayabilirsiniz. Bunun yanında güneşin zararlarından korunmak için, güneşin şiddeti arttıkça aşağıda açıklanan önlemleri de almayı unutmayın.

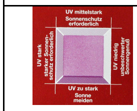
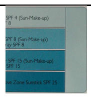
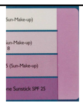
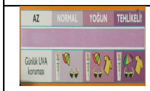
Cilt tipinize uygun Anthelios için dermatoloğunuza veya eczacınıza danışın.

Figure 1. Example of a UV irradiance indicator card with indication of the indicator field and the reference fields.

Photochromics are used to generate the alteration of color in the indicator field. The UV radiation causes the photochromics to absorb particular wavelengths in the visible and then change back to the original appearance when the UV source is removed. The back reaction (fading of the color) can be also driven thermally, by visible light or by a combination of both [*Parry et al.*, 2003]

To quantify the color of the reference fields the tested cards were photographed with a digital camera (C-3040, Olympus) and evaluated with the software corel photo paint. The RGB-color coordinates and the shades of grey of all reference fields of each card are shown in table 1.

Table 1. RGB-color coordinates and shades of grey values for the reference fields of the tested sun check cards.

card	reference field	RGB colour coordinates	shades of grey values
	'nornal'	135/118/129	124
	'attention'	113/69/102	85
	'hazard'	96/40/83	61
	'low UV'	217/220/219	218
	'medium UV'	204/198/206	200
	'strong UV'	189/163/185	173
	'UV too strong'	158/102/150	124
	'low UV'	138/152/148	147
	'medium UV'	67/126/134	109
	'strong UV'	26/103/120	81
	'UV too strong'	4/85/105	63
	'low UV'	211/207/203	207
	'medium UV'	192/174/180	180
	'strong UV'	175/136/156	149
	'UV too strong'	137/85/128	105
	'AZ'	205/208/206	206
	'normal'	182/172/179	175
	'yogun'	170/128/145	142
	'tehlikeli!'	139/92/128	110

Measurements

To measure the spectral irradiance at the location of the card a calibrated double monochromator (DM150, Bentham) and a temperature stabilized photomultiplier tube as detector were used. A plane circular PTFE-diffuser with angular cosine response served as an input optic. The UV index [*WHO*, 2002] was calculated from the spectral irradiance measurements.

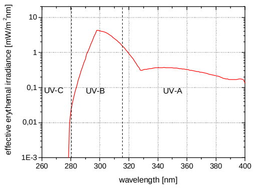
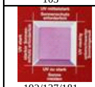
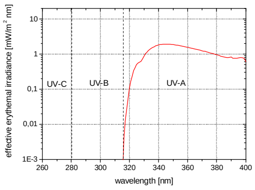
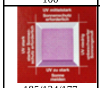
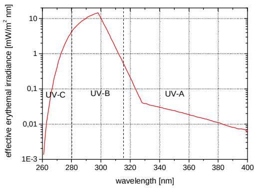
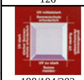
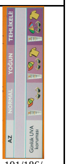
The color change of the indicator field was photographed with a digital camera under reproducible lighting conditions. The color change of the indicator field was quantitatively evaluated with the aid of the software corel photo paint. Additionally, the color change was visually estimated and compared to the color of printed reference fields (as the user of the card would do it). With the photographs of the cards and the spectral irradiance measurements it was possible to compare the indicated colors with the UV index (UVI).

Spectral sensitivity

The discoloration of the indicator fields for three different spectral distributions of the radiation that was incident on the card is shown in table 2. Table 2 shows that the tested UV irradiance indicator cards are mainly sensitive to UVA and show only very little sensitivity to UVB radiation. When the cards are irradiated with an UVA dominating spectrum (Filter Schott WG 335), a noticeable discoloration of the indicator field occurs at a moderate UV index of 4 which is in accordance with the color evoked by the spectrum of the laboratory sun (Schott KG 4) at the same UVI. However a UVB dominating irradiation (Schott WG 280) at a very high UV index of 11 evokes only a minor change and pale color of the indicator fields.

This comparison shows that the spectral sensitivity of the tested cards corresponds badly with the action spectrum for the UV erythema [*CIE*, 1987]. According to the action spectrum, UVB is much more effective than UVA in causing erythema. As a consequence, for irradiation with a given UV index, the discoloration of the indicator fields depends on the ratio between UVA and UVB.

Table 2. Color of the indicator fields for different spectral distributions and UV indices.

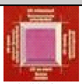
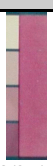
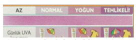
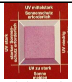
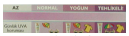
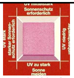
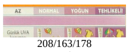
UVI	Filter	spectral erythemal irradiance	discoloration, RGB coordinates, shades of grey		
4	KG4		 115/94/118 103  192/137/181 158	 175/121/144 139  122/146/145 138	 184/150/ 175 163
4	WG 335		 116/89/119 100  185/134/177 154	 178/130/159 147  138/155/150 149	 173/137/ 160 150
11	WG 280		 127/126/126 126  198/194/202 196	 180/163/166 168  158/167/162 163	 191/186/ 190 187

Effect of temperature and UVI on color of indicator field

Measurements concerning the temperature dependence of the discoloration of the index field were made in a climatic exposure test cabinet (Vötsch VT 4021) where air temperatures between 0°C and 45°C were realized.

Table 3 shows that a temperature dependence of the discoloration of the indicator field can be noticed for all tested cards. The lower the ambient temperature, the more intense is the discoloration at the same UV index. Trials with varying UVI showed that the ambient temperature has a stronger impact on the discoloration of the indicator field than the UVI. At high UVI (≥ 8) and high temperatures (> 30 °C) the color of the indicator field does not correlate well with the UV exposure, as the color of the indicator field gradually fades due to the increasing temperatures.

Table 3. Color of the indicator fields for different environment temperatures at an UVI of 5 (artificial UVR).

UVI	Temp.	discoloration of indicator field, RGB coordinates, shades of grey				
5	0°C	 100/53/83 70	 192/90/134 125	 178/94/126 122	 195/137/168 157	 126/154/147 144
5	20°C	 110/81/106 92	 192/127/146 148	 182/120/140 140	 174/151/156 158	 166/189/175 180
5	40°C	 114/94/113 102	 222/148/173 172	 185/139/151 154	 208/163/178 178	 171/192/170 183

Reproducibility and Stability

When several cards of the same type are exposed to UV-radiation at the same time under the same conditions, the colors of the indicator fields do not differ noticeably from each other. Even with software analysis, no remarkable differences were found in the discoloration.

Only one card type was tested for stability. When this card type is continuously exposed to UV radiation, the discoloration properties of the indicator field slowly begin to change. Therefore, to increase the stability of the card continuous exposures of the cards should be prevented.

Conclusions

From the observed properties of the cards, the following results can be derived for the practical use of these cards:

- At low ambient temperatures the tested UV indicator cards tend to overestimate the potential hazard, while they underestimate it at higher temperatures.
- Due to the spectral sensitivity of the cards the potential hazard of the UV emitted by the sun is overestimated in the morning, in the late afternoon and in spring and autumn.
- The highest overestimation of the erythemal hazard occurs at low environmental temperatures and with a low ratio of UVB in the radiation; conditions which are correlated in respect of the time of day (morning) and the season (spring).
- The highest underestimation of the potential hazard will occur at high temperatures and with UVB dominating sources.

In summary, the application area of the tested cards is limited as they might not give an appropriate estimation of the potential hazard due to their observed properties.

References

H. Parry, N. Corns, A. Towns and J. Robinson, New uses for photochromics, Reprinted from *Speciality Chemicals Magazine*, 2003

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CIE (International Commission on Illumination), A reference action spectrum for ultraviolet induced erythema in human skin, *CIE J.*, 1987, **6**, 17-22