Comparison of different UV sensors for use in an XP radiometer

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v1.1

1 Introduction

A number of different UV sensors are currently used, or being considered for use, in radiometers for Xeroderma Pigmentosum (XP) patients. Although it is known that wavelengths below 320 nm are the most dangerous for XP patients, the exact action curve for XP UV hypersensitivity is unknown, and the principle of precaution has led medical experts to suggest using a radiometer with sensitivity up to 400 nm [1]. A potential risk of this approach is that a sensor which is over-sensitive to long wavelength UVA could give a non-zero meter reading in an environment which is considered "safe", e.g. behind a UV-filtered window. The user would then define this reading as a "safe" level, but the same meter reading in a more UVB-intense environment, such as unfiltered sunlight, could correspond to unsafe levels of UVB. The calculations presented here are intended to assess whether this is a real risk.

2 Method

The effect of different sensor spectral responses on the radiometer reading has been estimated by calculation from published light source and sensor response curves. Simulated radiometer readings were calculated for three situations:

- Natural unfiltered sunlight
- Sunlight filtered through plain glass
- Sunlight filtered through a combination of plain glass and UV-absorbing film

Six different sensors were considered, using spectral response curves found in the literature (Figure 1):

- A Solarlight PMA2101 erythema weighted sensor as used in the UV Minder 3D XP radiometer [2]. Taken from the published curve below 390 nm, extrapolated to 10^{-8} at 400 nm.
- An erythema weighted SiC photodiode sensor from sglux [3]. Taken from the published curve below 392 nm, extrapolated to zero at 400 nm.
- An unfiltered SiC photodiode from sglux [4].
- An SG01D-B5 SiC photodiode from sglux [5]. Taken from the supplied curve below 356 nm, extrapolated to 10^{-8} at 400 nm.
- A Hamamatsu G5842 GaAsP photodiode as used in the Solarmeter 5.7 [6].

- A hypothetical sensor with a response identical to the CIE 1987 erythema action spectrum [7].

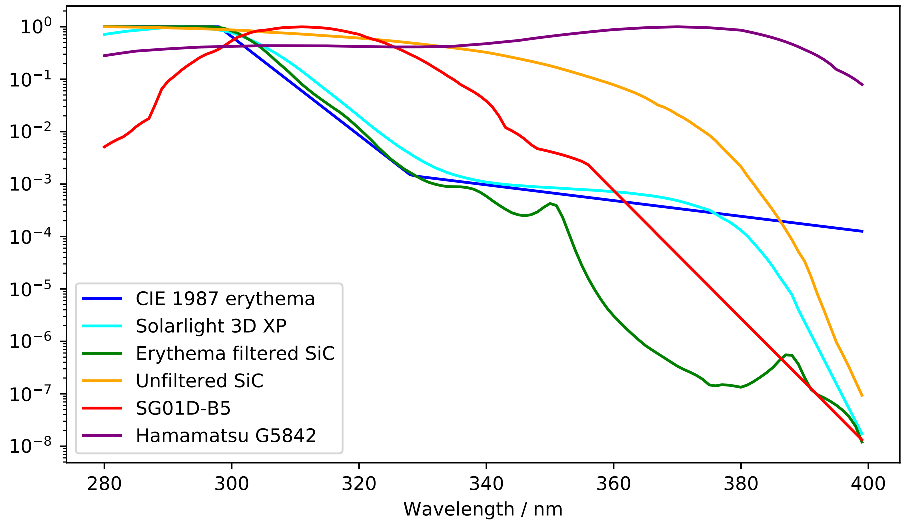

Figure 1: Sensor spectral response curves

Transmission curves of plain glass [8] and glass plus UV-attenuating film combinations are shown in Figure 2. Two different films are considered: GWF Neutral 50 Residential [9] and Madico UV Gard [10].

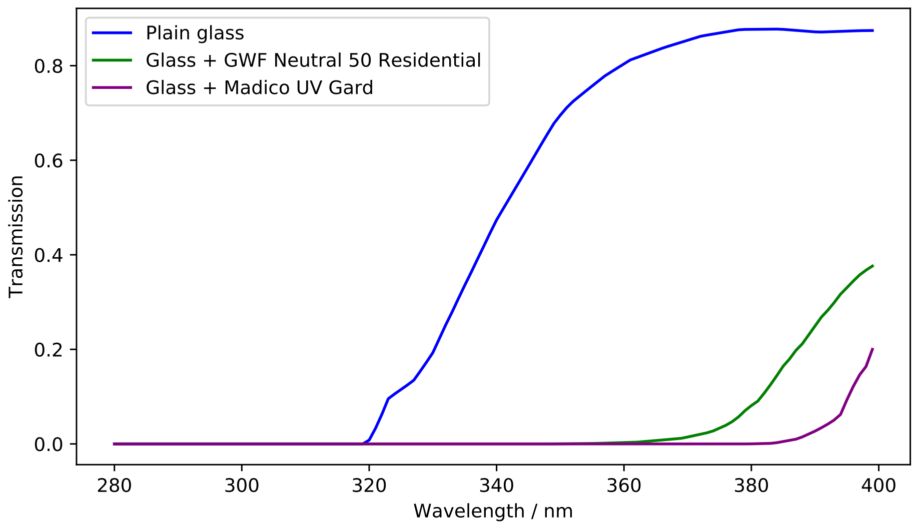

Figure 2: Transmission spectra of plain glass and glass/UV film combinations.

A standard sunlight spectrum, ASTM G173-03 Global Tilt [11], was scaled using the CIE 1987 erythema action curve to give 0.25 W/m^2 erythema effective power density which corresponds to 10 UVI or 4.31 MED/hr (Minimum Erythema Dose per hour). This was multiplied by the transmission curves in Figure 2 to obtain the source spectra shown in Figure 3.

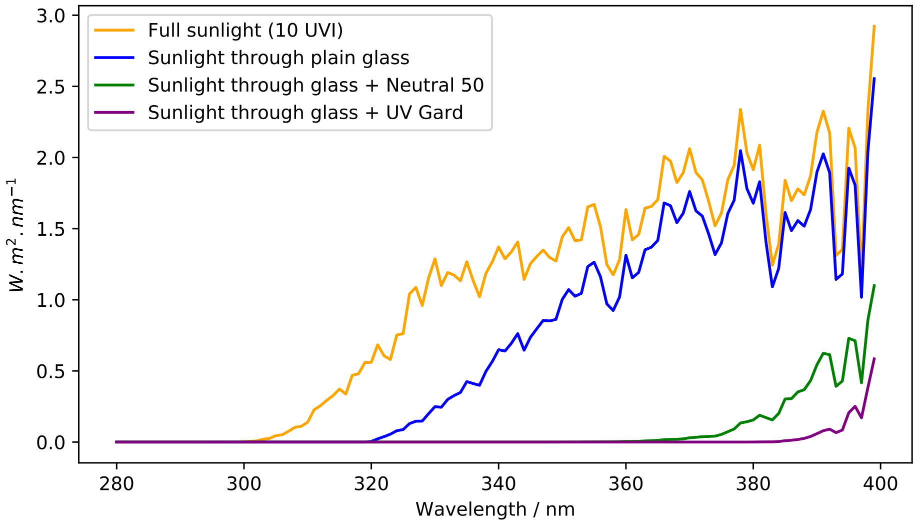

Figure 3: Source spectra of sunlight, unfiltered and filtered through plain glass and glass/UV film combination.

The unfiltered sunlight spectrum was multiplied by the sensor responses and the resulting spectrum was integrated between 280 and 400 nm to give a simulated meter reading for each sensor. Each sensor response was scaled to obtain a reading with numerical value 4.31, corresponding to 4.31 MED/hr (10 UVI) for the CIE 1987 erythema action curve (Figure 4).

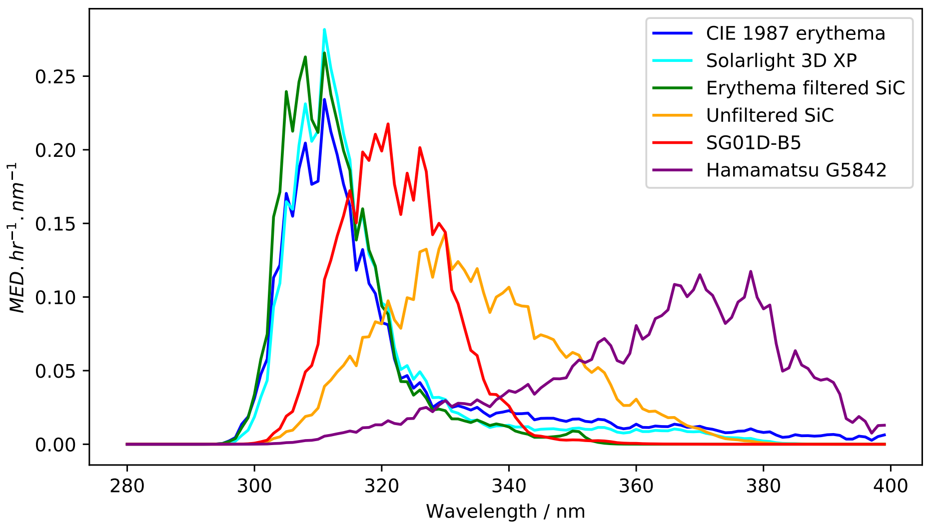

Figure 4: Scaled sensor responses to unfiltered sunlight.

The glass and UV-film filtered source spectra were then multiplied by the scaled sensor responses to obtain the response curves shown in Figures 5 to 7.

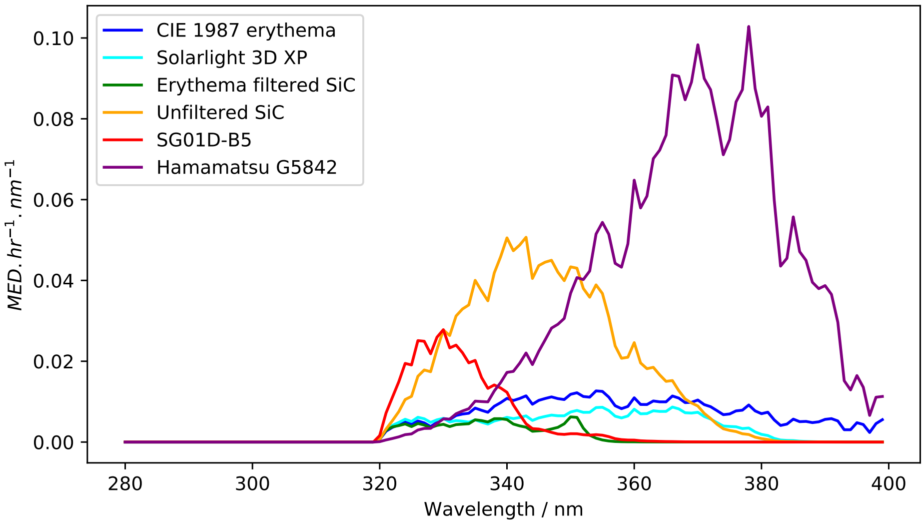

Figure 5: Scaled sensor responses to sunlight filtered through plain glass.

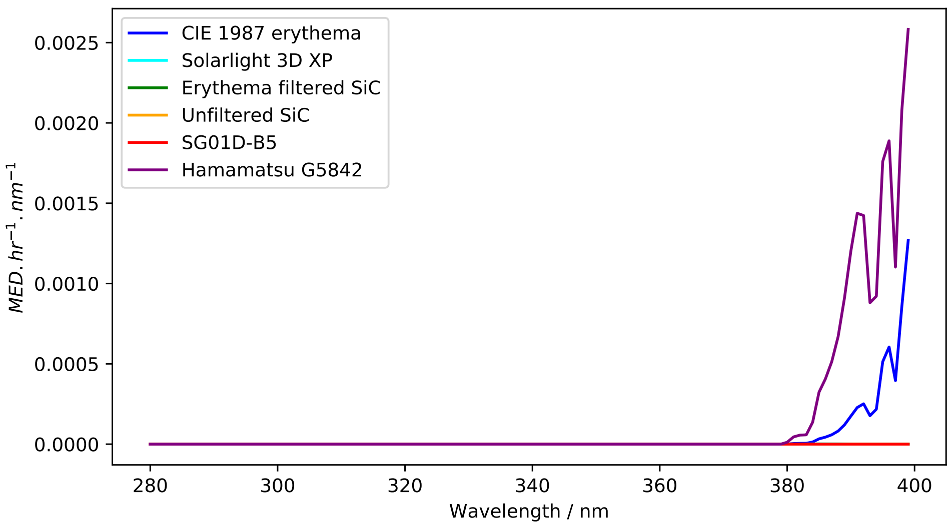

Figure 6: Scaled sensor responses to sunlight filtered through glass/film combination (Madico UV Gard).

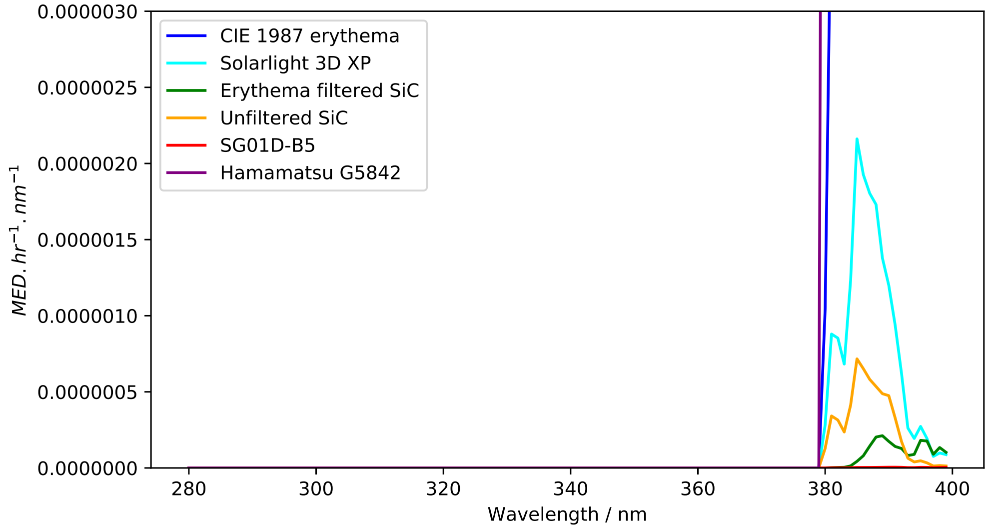

Figure 7: Scaled sensor responses to sunlight filtered through glass/film combination (Madico UV Gard), expanded vertical axis.

The integral between 280 and 400 nm of each of these source × sensor responses was taken to obtain an estimated radiometer reading for each combination. A summary of the results is shown in Table 1.

The readings in Table 1 are scaled to give values in MED/hr when the source spectrum is that of natural unfiltered sunlight. The first column is for unfiltered sunlight at 10 UVI which corresponds to 4.31 MED/hr for all sensors. Note that only the true CIE 1987 erythema weighted sensor will give correct readings in MED/hr for other source spectra. However, for comparison purposes, we express the readings for all sensors as MED/hr even if this is not strictly correct. Note also that the preferred unit is in fact SED/hr (Standard Erythema Dose, where 1 SED is equivalent to an erythemal effective radiant exposure of 100 J.m^{-2}), but since the Solarlight 3D XP displays in MED/hr, we retain MED/hr as the unit for the readings.

Table 1: Simulated readings in MED/hr for the different sensors exposed to the different light sources.

	Full sunlight (10 UVI)	Sunlight through plain glass	Sunlight through glass + Neutral 50	Sunlight through glass + UV Gard
CIE 1987 erythema	4.310	0.611	0.029	0.005
Solarlight 3D XP	4.310	0.361	0.003	0.000
Erythema filtered SiC	4.310	0.143	0.000	0.000
Unfiltered SiC	4.310	1.454	0.003	0.000
SG01D-B5	4.310	0.430	0.000	0.000
Hamamatsu G5842	4.310	3.148	0.195	0.018

3 Discussion

Given the cumulative nature of UV-induced damage to the skin of XP patients, medical experts have not been willing to define a "safe" level of UV exposure, but instead, have adopted the principle of "as low as reasonably achievable". In the French XP community the "safe" level is taken as a zero reading on the Solarlight 3D XP which has a least significant digit of 0.001 MED/hr, and so in current usage we can consider the upper limit to be 0.001 MED/hr. With film-protected windows the reading indoors is almost always found to be zero on the 3D XP. This is the situation represented by the last column of Table 1, with the UV Gard film having a very high attenuation below 280 nm. Two things can be noted here: First, the Hamamatsu G5842 gives a reading of 0.018, which if taken as a "safe" threshold, would allow an exposure in unfiltered sunlight of 0.018 MED/hr, 18 times higher than the current acceptable level. Thus, according to the above criterion, the Solarmeter 5.7, which uses the G5842, is not suitable for use as an XP radiometer. Second, the CIE 1987 erythema response gives a significantly positive reading due to its non-zero value close to 400 nm, while the erythema-weighted 3D-XP and SiC sensors, whose responses drop below the erythema curve towards 400 nm, give zero readings. The SG01D-B5 and the unfiltered SiC also read zero.

The situation is similar for the Neutral 50 film, except that due to its less effective attenuation above 360 nm, the readings are higher, with the 3D XP and the unfiltered SiC both giving a reading of 0.003 MED/hr. It should be noted that the light source corresponds to full mid-day sun traversing a window pane with normal incidence, which is not a usual situation, and in normal circumstances the readings may well be below 0.001 MED/hr even with this lower performance film. It is also important to note that the unfiltered SiC sensor does not give a higher reading than the 3D XP in this situation.

Under plain glass, all sensors give a significantly higher reading which would be clearly and correctly interpreted as unsafe.

4 Conclusions

Simulated readings were calculated for each of the sensors and checked against the criterion that the radiometer reading should be less than 0.001 MED/hr in a "safe" situation, such as behind a window equipped with UV-blocking film.

- The G5842, and hence the Solarmeter 5.7, do not fulfil this criterion as they show a reading higher than 0.001 MED/hr in a safe environment.
- The 3D XP, the erythema weighted SiC and the SG01D-B5 fulfil this criterion.
- The unfiltered SiC sensor, despite its higher UVA sensitivity, also fulfils this criterion. Indeed, with its broadband response up to nearly 400 nm, it may be a good candidate to satisfy the requirements suggested by the medical community.

5 Acknowledgements

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References

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[6] https://www.solarmeter.com/model57.html

[7] *Erythema reference action spectrum and standard erythema dose*, ISO 17166:1999(E)/CIE S 007/E-1998

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[11] *Standard Tables for Reference Solar Spectral Irradiances: Direct Normal and Hemispherical on 37° Tilted Surface*, ASTM G173 - 03(2012)

Revision History

Revision	**Date**	**Author(s)**	**Description**
1.0	December 16, 2018	AB	Published
1.1	December 18, 2018	AB	Sensor descriptions list corrected