Electronic UV Dosimeters for Research and Education

M. W. Allen

Department of Electrical and Computer Engineering, University of Canterbury, Christchurch 8140, New Zealand

R. L. McKenzie

National Institute of Water and Atmospheric Research (NIWA), Lauder, Central Otago, New Zealand

Abstract. Electronic dosimeter badges are replacing chemical (polysulfone) film as the optimum method of measuring personal exposure to UV radiation. Advantages include integration times of the order of seconds rather than hours/days, re-usability and cost. A miniature wearable version, developed locally in New Zealand, has been intensively trialled at Mt Hutt ski-field to measure personal UV exposures of skiers during 2005 – 2009. Typical UV exposures varied from 3 – 16 SED during the course of the ski-season (mid-June to early-October). The average UV dose received by ski-instructors during a 10-day period in September 2008 was 6.3 SED which is comparable to those received by outdoor workers during summer months in New Zealand. To date these dosimeters have principally been used in behavioural/epidemiological studies but, provided cost and ease-of-use issues are addressed, their largest impact is likely to be in school-based educational programmes, particularly in conjunction with other tools such as NIWA's web-based UV Index Maps and 'on-line' UV Index instruments.

Introduction

Any instrument designed to measure personal UV exposure requires a sensor with a spectral response that matches the erythemal action spectrum (EAS) for human skin. Two ternary semiconductor systems AlGaN and ZnMgO have spectral responses in the UVB spectrum that can be tuned by varying the Al/Ga and Zn/Mg ratios respectively. Both material systems are capable of providing a close match to the EAS combined with more than fours orders of magnitude of visible rejection provided crystal defects that can cause absorption in the green part of the visible spectrum are carefully controlled. Currently AlGaN photodiode sensors with an Al fraction of approx. 27% are used, although future ZnMgO sensors are expected to provide significant performance advantages in terms of responsivity, reliability and cost.

The electronic design of a UV dosimeter is essentially straightforward requiring an amplifier which converts the tiny (1 – 10nA) AlGaN photodiode current into a measurable voltage in the 0 – 2.4 V range. A microcontroller is then used to sample the output voltage at predetermined time intervals and store the results in non-volatile memory. The dosimeter is powered by a 3V Lithium (CR1632) 125 mAh coin cell providing more than 3 months operating life at a sampling interval of 8 seconds. Total on-board memory capacity is 128 kbytes or 64,000 data samples (~ 12 days at 8 second sampling). The dosimeter dimensions are 35 x 10 mm, weight 20 grams and is either pinned to clothing or used with a velcro arm- or wrist-strap. A shaped PTFE front cap acts as a UV diffuser giving an overall angular response to within 10% of a true cosine and is attached via a waterproof seal to a powder-coated brass backing plate.

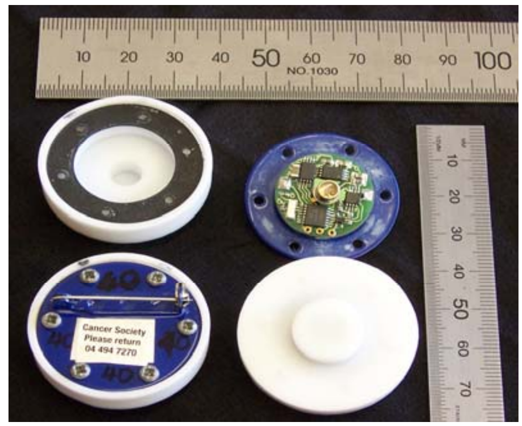

Figure 1. Electronic UV dosimeter badges + PTFE diffuser cap.

Research - Mt Hutt Ski-Field Case Study

Initial studies [*Allen and McKenzie*, 2005], [*Allen and McKenzie*, 2007] into the UV exposures at Mt Hutt ski-field (1590 – 2086 m, 43°30' S, 171°32' E) showed that during spring months (Sept & Oct) peak UV Index (UVI) values were ~ 30% higher than at an equivalent sea level site (Christchurch, 43°53' S, 172°61' E) with daily doses exceeding 16 SED towards the end of the season. In this updated work, UV exposure measurements were extended to cover the entire ski-season which typically runs from mid-June to early-October each year. Measurements were carried out on predominantly cloudless days from 9:00 am to 4.00 pm, at 8 second intervals, with the dosimeter badge worn using a velcro strap on the right arm. Separate badges were also deployed on horizontal surfaces at the base and summit of the ski-field to measure the UV Index at these sites.

Figure 2. UV dosimeter badges deployed at Mt Hutt during the 2008 and 2009 ski-seasons.

The calibration of the UV dosimeter badges was maintained at regular intervals against a Yankee Environmental Systems meter which is in turn maintained and calibrated against NIST standards by NIWA.

Figure 3 shows the typical UV exposure of a skier at Mt Hutt on clear sky days during each month of the ski-season. Each plot gives the erythemally-weighted UV irradiance versus time. Although the term UV index is only strictly defined for horizontal surfaces, it is used here as a convenient unit with 1 UVI = $25 mWm^{-2}$. Each plot was integrated to calculate the total daily dose in units of SED where 1 SED = $100 Jm^{-2}$ of erythermal exposure. The UV environment varies significantly over the course of the ski-season with peak irradiances and daily doses increasing dramatically during September and October.

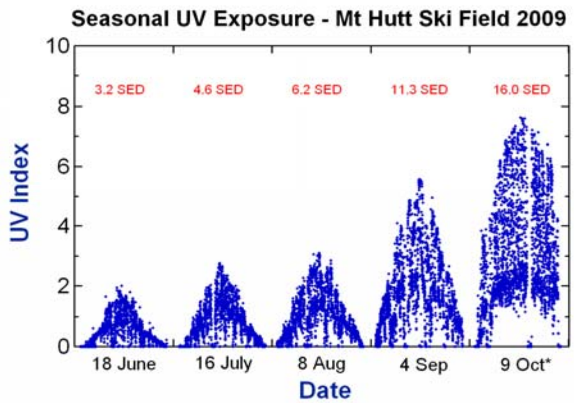

Figure 3. Typical clear-sky UV exposure for a skier at Mt Hutt during the 2009 ski-season (*data taken in a previous year).

Figure 4 shows the UV exposure of a ski-instructor during a 10-day period in September 2008. The mean daily dose was 6.3 SED compared to an average of 5.3 SED measured using the same dosimeter badges during a study [*Hammond et al.* 2009] of outdoor workers from mid-January to early-March 2007 in Central Otago, NZ.

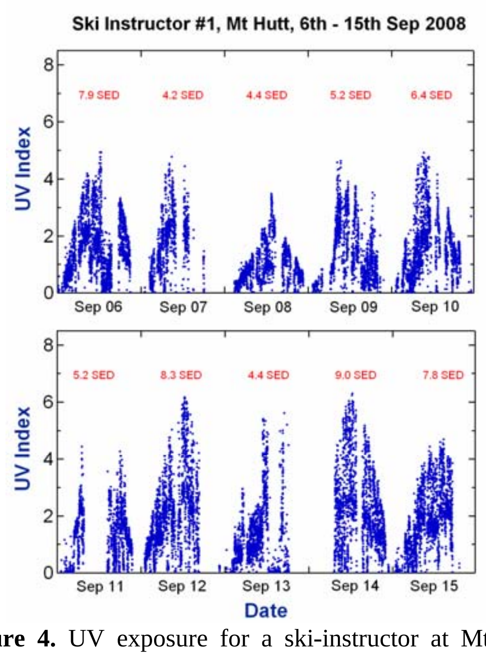

Figure 4. UV exposure for a ski-instructor at Mt Hutt over the course of a 10-day period in September 2008.

Education

To date these dosimeter badges have been used in a number of behavioural/epidemiological studies:

- "UV exposure of primary school children," University of Otago/NIWA, Nov 2004 – Apr 2005.
- "UV exposure of outdoor workers," University of Otago/NIWA, Jan - Mar 2007.
- HRC-GA207 - "Quantifying the association between sun exposure and vitamin D status in New Zealanders", University of Auckland/University of Otago/NIWA, 2008 – 2009.

In addition to such studies, the dosimeter badges have significant potential in promoting sun-smart awareness and safe-sun practices when used in school-based educational programmes. The key assumption here is that health messages are more likely to be adopted when reinforced with hands-on activities that provide supporting evidence which students can evaluate for themselves. In other words, "finding things out for yourself is more powerful than being told what to do!" Examples of activities in which the dosimeter badges can provide quantitative data to reinforce health messages include:

- Measuring the daily UV cycle (11 am – 4 pm; high exposure period).
- Measuring the effectiveness of shade in reducing UV exposure.
- Measuring the effectiveness of different sun-screen products.
- Measuring the effectiveness of sun-glasses and different types of protective clothing.

Significantly, the UV data provided by the dosimeter badges can be used in conjunction with NIWA's web-based UV Index Maps and 'on-line' UV Index instruments at selected sites across the country to provide the means for students to draw their own conclusions about the nature of UV radiation in New Zealand.

Conclusions

The utility of electronic UV dosimeter badges has been demonstrated in a number of behavioural/epidemiological studies conducted in New Zealand. Recent improvements to the ease of operation of these badges (in conjunction with D. Sherman, Scienterra Ltd.) allows their use in school-based educational programmes designed to achieve improved sun-smart behaviour through self-discovery of the issues involved.

References

Allen M and McKenzie R, 2005. Enhanced UV exposure on a ski-field compared with exposures at sea level. Photochem. Photobiol. Sci. 4(5), 429-437.

Allen M and McKenzie R, 2006. UV exposure on New Zealand ski-fields. "UV Radiation and its Effects: an update 2006", Dunedin, 19-21 April, RSNZ Miscellaneous Series 68, 1-2.

Hammond V, Reeder A and Gray A, 2009. Patterns of real-time occupational UV exposure among a sample of outdoor workers in New Zealand. Public Health 123, 182–187.

Wright C, Reeder A, Bodeker G, Gray A and Cox B, 2007. Solar UVR Exposure, Concurrent Activities and Sun-Protective Practices Among Primary School Children. Photochem. Photobiol. 83(3), 749-758.