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Simple experiments to visualise and simulate the biological impact of ultraviolet radiation

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Abstract. Simple and effective visual experiments using ultraviolet (UV) radiation sensitive paper are provided to illustrate the effect of sunscreen preventing a biological effect; and biological effects over time using low cost equipment. High ambient UV radiation means Australia has one of the highest incidence rates of skin cancer in the world. One of the keys to reducing these rates is by education.

Introduction

The importance of understanding the impact of UV radiation, and providing this information to the younger generations (and indeed the general public) is paramount. Often it is the visualisation of a similar biological or chemical impact that helps to cement the importance of UV radiation awareness. Skin cancer awareness promotion will regularly illustrate the result with images of sunburn and cancerous lesions, however these images only provide evidence after the fact. It is proposed that these simple experiments will additionally provide the illustration of the continuous and fast impact UV radiation has during real time and can be carried out with anyone from ages 5 and up.

Literature

Simple experiments such as newspaper fade (McKean 2008) and ink fade (Downs 2008 & 2010) can be used to demonstrate the effect of sunscreen application and dose response of UV radiation respectively. However, for both of these techniques, whilst useful for longer periods of time (hours to days), the effect is not visible in the short term. There is UV sensitive paper available commercially, which will change colour over two to five minutes in full sunlight. After development the colour change is permanent. This paper uses a chemical process that is used for blue printing and additionally used by photographers and artists, called cyanotyping. Information regarding the chemical process is available (Lawrence & Fishelson, 1999) and prodigiously documented by Ware (1999). The chemical process is commonly used in chemistry education and has been developed into a dose measurement technique using wet lab materials (Downs 2012). However, this experiment cannot be taken outside the areas past the immediate lab environment. Using commercially available paper, the techniques used in Downs (2010) and Downs (2012) can be replicated simply and safely with students from a range of ages and backgrounds, without the need for a wet lab, just access to water. The paper is currently available through www.sunprint.org and www.natureprintpaper.com, as well as other companies and is distributed around most of the world.

The Experiments

Use of Sunscreen

Students can be involved in a simple experiment that shows how sunscreen works. The students are supplied with a sheet of UV sensitive paper, a plastic sheet protector, a permanent black marker and sunscreen (applied either with the fingers, or using cotton tips). The students place the sheet of paper inside the plastic sheet protector (with the blue colour side up) and can draw pictures (or their name) using the black marker on the plastic. Students are advised to apply sunscreen in varying thicknesses to their picture. After completing their picture, the students take the paper and sheet protector outside and expose the paper for a few minutes. Direct sunlight works best, but can also work on a cloudy day. The paper is extremely sensitive and can produce a result in as little as 10 seconds at noon on a winter's day in Australia at sub-tropical latitudes. This is confirmed by information from Ware (1999) who reports the sensitivity of the cyanotype technique as low with a required radiant energy density of 34 J/m^2. Exposed paper will cause the blue colour in the paper to turn a greenish-white, whilst unexposed paper will remain the same blue. After exposure students take the paper back inside, remove it from the sheet protector and carefully wash the paper in water for approximately one minute. Any unexposed salts will be removed, and the previous reported colours will switch from white to blue and vice versa. Any exposed areas will result in a final colour of blue. This blue will deepen as it dries. Variations on previous published experiments suggest using glass or acrylic sheets to place over the paper, however glass can be expensive and dangerous to students if broken, and both glass and acrylic are absorbers of UVB radiation (Figure 1) therefore cutting out some of the UV radiation that affects the paper. Children aged from 5 to 17 years have successfully carried out and enjoyed this activity. The children appear to be cognizant of the implications, where after one session, a child was observed to explain to his friend, "The paper is like your skin".

Dose response

The above implies the extremely fast reaction time of this UV sensitive paper. Initial dose response tests found that the paper would saturate in less than one minute exposure on a sunny day in winter (producing maximum colour saturation). This duration is somewhat impractical to carry out UV exposure measurements at the same time in order to correlate UV radiation exposure. A neutral density filter was employed to extend the UV sensitive paper exposure times. The filter used was white rubbish bin liners, which has an average UV radiation transmission of about 8% (see Figure 1).

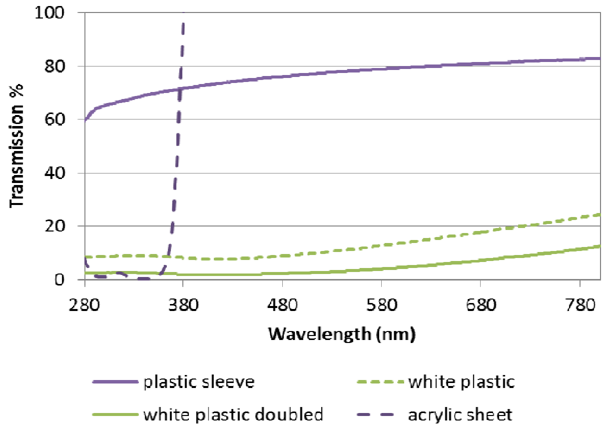

Figure 1. Spectral transmission of different types of plastic. The plastic sheet protector (plastic sleeve) has maximum transmission across the UV and visible spectrum. White thin plastic has low transmission.

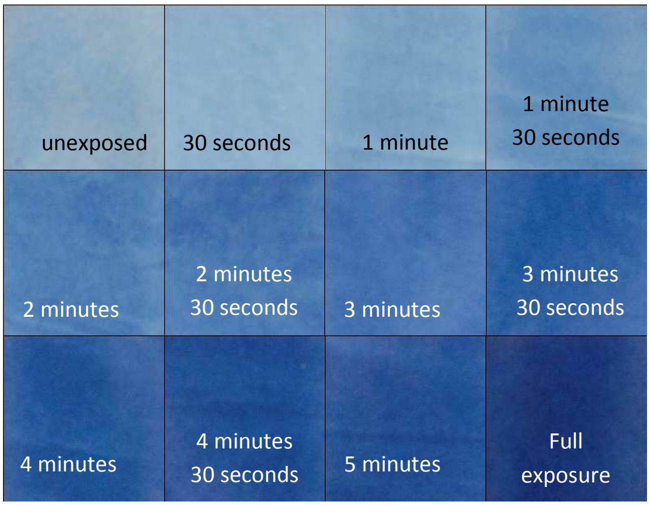

Figure 2. Colour scale of the five minute dose response produced with one layer of neutral density filter.

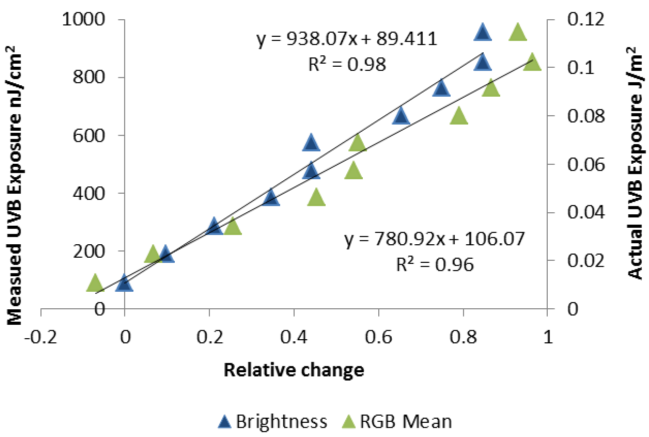

Figure 3. Dose response for measured (line of best fit) and actual UV exposures for changes in brightness and RGB means.

In the test used in Figure 2, an IL1400 radiometer ('A' Series, International Light, Newburyport, MA, USA) measured the UVB irradiance with a neural density filter over the sensor, whilst exposure of the paper was carried out. Work by Downs (2010) has shown that if instrumentation like this is not available, a UV checker (such as those supplied by Edison and The Educator) provides a reasonable estimate of UV Index and conversion to UV exposure. Either small pieces of the UV sensitive paper can be used or whole pieces, but both will produce a similar result to Figure 2. Small pieces can be photographed in one image. Once the paper has been exposed, it is washed and left to dry for at least 24 hours. The paper is then photographed on a white background, using a pre-set white balance, with the same ISO, aperture and shutter settings to ensure no colour variation between images. The images used in Figure 2 were photographed in the same image and cropped individually to be used in the dose response calculation process. There are two ways the change in colour can be calibrated to the change in UV exposure. One method involved converting each image to grey scale and calculating the brightness of the image as detailed in Downs (2008). The second method involves using software such as Photoshop or GIMP that provides information about image histograms. The mean or median RGB values can be calibrated to UV exposure in the same way the brightness can be (Figure 3). Both the change in brightness and change in mean RGB can be calibrated against the measured UV exposure or the actual UV exposure (without the neutral density filter). There is a slight variation between each method in the relative change, but both shows an extremely similar pattern of calibration against UV exposure. This dose response can be used in further experiments to help students' judge UV exposure in different environmental situations including outside shade and indoors.

Conclusion

These experiments are low cost effective experiments that can be used to educate students and the general public by providing a simple visual experiment that can be observed in real time over short periods.

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