

# Environmental Shade for Protection from UVR: A design & teaching resource

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*ABSTRACT: This paper presents a resource for designing shade to control exposure to solar ultraviolet (UVR). The resource is formatted to enable a design practitioner to design an effective UVR protective shade as well as provide background information, suggested design processes and reference material for an academic teaching building science or leading a design studio. Firstly, the need to provide UVR protective shade for different peoples in different locations around the world is presented. Secondly, the science of solar UVR and principles of shielding it is explained. Thirdly, suggestions and advice for inclusion of this knowledge within architectural education programmes are discussed. References to key information resources and research papers are provided plus specifications for useful equipment to measure ultraviolet levels and exposure.*

*Keywords: UVR, UVR protection, skin cancer, sunshade*

## INTRODUCTION

Excessive solar ultraviolet radiation UVR is the major cause of skin cancer and cataracts in eyes. These diseases caused 1.5 million disability adjusted life years (DALY) and 60,000 premature deaths in the year 2000 [1]. Alongside behaviour, sunscreens, hats and clothing, built shade has a role in preventing sunburn and excessive cumulative exposure. This paper presents a resource for understanding and designing effective shade. Firstly, the need for UVR protective shade for different peoples in different locations around the world is highlighted. Secondly, the science of solar UVR and principles of shielding it are explained. Thirdly, a process for application in design Studio is presented. References to key information resources and publications are provided plus specifications for useful equipment to measure ultraviolet levels and exposure.

## UVR AND SKIN CANCER

Overexposure to ultraviolet light (UVR) is recognised as a key skin cancer risk factor known to cause skin cancer in humans [2]. People are more at risk if they have red or fair hair, blue eye colour, a presence of nevi and a family history of skin cancer especially melanoma [3]. Skin cancers are grouped into melanoma and non-melanoma types. Cutaneous melanoma develop from nevi and can be fatal if left untreated. Non-melanoma skin cancers (basal cell carcinoma and squamous cell carcinoma) are a result of cumulative exposure to UVR and are events of older age. They cause disfigurement but are rarely fatal.

Melanin is the body's natural resistance to skin cancer. Therefore, dark skin is common in peoples from equatorial regions where UVR levels are highest. Internationally, those most at risk of melanoma are white populations with the highest incidence rates in Australasia and the southern states of the United States.[4] In northern European countries, melanoma rates are lower but have increased threefold to fivefold in the last decades. This increase is related to changing attitudes of leisure time behaviour and of sun exposure [4]. The trend of taking holidays in low latitude destinations where UV levels are typically high is considered to be a significant factor [5]. This type of intermittent sun exposure is an added risk factor for melanoma [6]. The reason for lower rates in the Mediterranean is attributed to darker skin type and different attitudes to recreational activities. [4] Excess UVR exposure in childhood and adolescence also increases life-time risk of basal cell carcinoma and probably melanoma [7]. UVR also has a profound effect on the eyes. Every year, globally, approximately 3 million people lose their sight because of UV-related damage resulting in cataracts. Paradoxically, adequate sun exposure is essential for human health. Our entire requirement of vitamin D is satisfied by exposing our skin to UVR, causing its synthesis in the skin [8]. Southern Australians are advised to expose the face, arms and hands to sunlight for just a few minutes a day in summer and 2-3 hours a week in winter. People unable to access sunlight are advised to take Vitamin D supplements orally [9]. In North America, milk is fortified with vitamin D.

## HUMAN BEHAVIOUR

Prof Brian Diffey, a long-standing skin cancer researcher, concludes the ‘the solar ultraviolet (UV) to which a person is exposed depends upon the local UV climatology and his or her behaviour,..’ [5]. In Europe, at the beginning of 20th Century, a sun-tan was considered both healthy and fashionable among fair skin populations. By 1930’s health professionals were advising that UV was a carcinogen but sun-tanning continued to be popular [10]. In response to expected increases in UVR levels due to ozone depletion, in 1992, World Health Organization (WHO) set up the Intersun programme [11] to research and disseminate the health risks of excessive UVR exposure. First initiatives focused on developing and promoting the Global Solar UV Index [12], an international measure of UVR used in weather forecasting. Children and adolescences were identified as a key target group. Intersun also produces resources to support other at-risk groups: outdoor workers, users of artificial tanning sun-beds and holiday makers in low latitude destinations. Internationally, over this time incidence rates of melanoma have increased and are predicted to do so for the next two decades. However, rates of melanoma in younger people in Australia seem to have stabilized, maybe as a result of long-lasting primary prevention campaigns [4].

## UVR LEVELS

A global network of meteorological authorities measure, estimate and disseminate information on UVR levels. Satellite data are used to estimate UV intensities; through in polluted locations they tend to overestimate the values [13]. Some countries have on-ground stations and can provide actual historical hourly, daily and/or monthly data. On-ground UVR levels are influenced by a number of factors [14]. UVR levels reduce as its path through the atmosphere is lengthened, therefore, UVR levels decrease from the equator towards the poles, decrease from summer to winter and either side of solar noon. For similar reasons, UVR levels increase with altitude. Ozone in the stratosphere absorbs UVR (primarily UVB). Depletions in the ozone layer can lead to increased UVR levels in some locations. UVR is ‘scattered’ in the atmosphere. On a clear day on a flat plain no more than 50% of a UVR total dose is generally received from direct sun and typically more than 50% is received from indirect scattered UVR. Cloud cover has a significant effect on the amount of UV at a given time, usually reducing levels. Low-level air pollution is shown to significantly diminish measured UVR levels, especially in highly urbanized areas. Surface albedo, or reflectivity, can increase levels although only snow (<90%), sand (<30%) and choppy water (<20%) have a significant effect. Knowledge of on-ground local UVR levels is important. To clearly understand the changing

pattern of UVR levels, climate data can be plotted as per the following example.

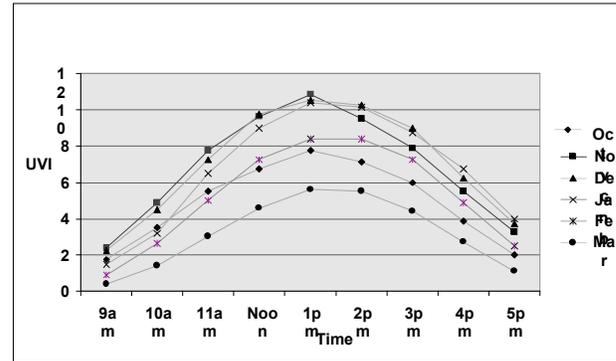


Figure 1: Plotted average hourly UVR levels (UVI) for the days of months October 2005 to March 2006 in Wellington, New Zealand [14].

Because of the success of the Montreal protocol on ozone depletion, UV intensities in many places have levelled off, or are declining [15]. At mid-southern latitudes, such as New Zealand and south Australia peak UV intensities are  $\approx 40\%$  more than than at corresponding northern latitudes. [16].

## THE ROLE OF UVR SHADE

The role of any form of sun protection is to block or filter UVR to safe levels for the person or people involved. WHO recommend that sun protection when  $UVI > 2$ . At UVI 2, the  $UVR_{eff}$  in standard erythmal doses would be 1.8 SED per hour. Generally 2 SED is sufficient to cause erythema or sunburn in people with sensitive skin. This level is aimed at the needs of the fairest skin type group. Health risk relative to skin-type is displayed on the following chart.

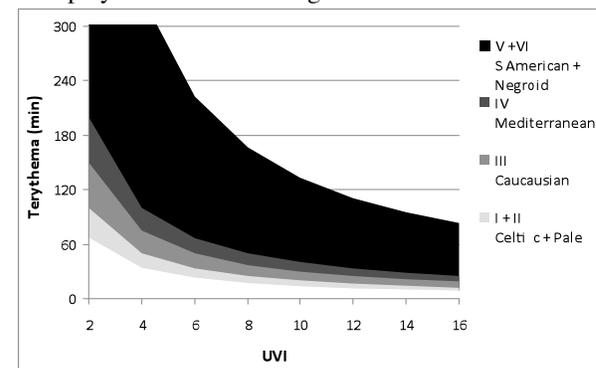


Figure 2: The variation in time to achieve erythema ( $T_{erythema}$ ), at UV intensities, for different skin-types I - VI as defined by Fitzpatrick (1988) [17]

Firstly, the level of sun protection required is related to the skin type of the user group and local UVR levels. It is also useful to understand the exposure time at different UVI required to achieve erythema. Sunscreen

manufacturers use SPF (sun protection factor) as a rating. E.g. using SPF 15 a person will receive 1/15 UVR that they would have received if using no protection. Alternatively, a person could stay out in the sun for 15 times longer than using no protection. The protection factor (PF) rating for shade follows the same principle.

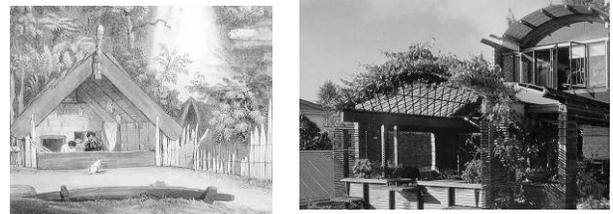
$$\text{PF (protection factor)} = \frac{\text{UVI (in open)}}{\text{UVI (under shade)}}$$

Dermatologists have focused on sunscreen applied to the skin as the primary means of protection. Sunscreens have become increasingly sophisticated [18] but the human factor of inadequate application and re-application is always a risk. WHO recommend a combination of sun protection measures: limit time in the midday sun, watch for the UV Index, use shade wisely, wear protective clothing, use sunscreen and sun-lamps and tanning parlours. The advice to 'use shade wisely' warns 'Seek shade when UV rays are the most intense, but keep in mind that shade structures such as trees, umbrellas or canopies do not offer complete sun protection. Remember the shadow rule: "Watch your shadow – Short shadow, seek shade!"' [19]. In practice, personal protection of hats, clothing, glasses and sunscreen is best for outdoor work, active sports and recreation. Generally shade is most appropriate for passive activities, communal gatherings and in the space between the interior and exterior.

The publication, 'Undercover' [20], identifies 'settings' where shade is most relevant: early childhood services and schools, swimming pools, beaches, sports grounds and facilities, parks and reserves, general streetscape, resorts, motels and hotels outdoor restaurants, cafes and beer gardens, the home and the workplace. Further research has been carried out on some of these environments. A study of 10 New Zealand primary schools [21] surveyed 29 shade structures and identified successful shade types: well established trees, communal shade structures (commonly sails or PVV membrane), verandahs to classrooms (commonly solid, some translucent roofing and PVC membrane), shade cloth over junior courts and play equipment. These structures provided PF 4 – 8 (sufficient for use over the lunch hour) [22]. Some verandahs had a negative impact on the daylight and thermal environment of adjacent classrooms. A study of Swedish pre-schools confirmed that a shady playground reduced daily UVR exposure when compared to a sunny playground [23]. A New Zealand study revealed that playground outdoor passive pursuits attracted the highest UVR exposure [24]. These studies confirmed benefits adequate shade provision in schools. New Zealand and Australia promote Sunsmart schools programmes which include shade guidelines. In USA, CDC provide an internet resource, Shade Planning for America's Schools [25]. However, this resource is

aimed at schools and communities (not design professionals) and does not give detail on effective shade design. Many swimming pools are indoor, which provide UVR free environments. Outdoor pools pose an interesting problem as they are associated with sun-bathing. With the aim of providing a safe sun-bathing area, a laminated glass canopy was installed at an outdoor pool in Wellington, NZ. The glass would allow users to enjoy the heat of the sun at safe UVR levels. A study of the canopies in use and interviews with users confirmed this was possible. Users valued the warmth of the sun after swimming in the cool pool and only 18% were seeking a sun-tan [26].

UV measurements in urban environments reveal some interesting issues. A pilot study of UVI in central Wellington, NZ revealed that generally the tall buildings, narrow streets and verandahs over pavements combined to produce safe summer UV levels. (UVI<2) Glass or polycarbonate verandahs gave excellent protection while creating a light outdoors ambience for a café lifestyle. In contrast, the neighbouring Wellington waterfront was completely exposed with no protection and maximum UVI. The dramatic contrast between the two environments is a risk factor especially for unwary visitors to the city. Outdoor living associated with the home is common in many cultures. An historical review of outdoor living space in New Zealand [27] revealed that using available materials, many traditional Maori whare were well adapted for outdoor living. The mahau (porch) generally faced east to collect and store the morning sun's heat, allow mid summer noon shade and shield prevailing winds. The space was deep enough for group activities, with good natural light and shelter from the rain.



Figures 11 & 12: A mahau from a lithograph by J.W.Giles (1822-86) and the porch of Stout/Mitchell House (1995) [27].

For 150 years, architects of European heritage followed overseas architectural traditions and fashions with little adapting to the local climate. Only in the last decade refinement of indoor-outdoor living is apparent: the opening up of interiors to become verandahs or pavilions, the use of transparent or translucent materials to transmit the warmth of the sun, controlling breezes, designing different shady spaces for different times of day and using the surrounding landscape and trees to reduce UVR. However, the need for UVR protection was not recognised in any architectural text reviewed.

## SHADE DESIGN PRINCIPLES

The aim of UVR protective shade is to create a situation where people can enjoy the attributes of the outdoors – fresh air, warmth, breeze but be protected from UVR over-exposure. The goal is to prevent sunburn and eye damage. The protection rating (PF) needs to be appropriate for the proposed period of use, the UVI levels of geographic location and the skin types (and/or personal protection) of the users. Shade can be designed to be very effective (PF>15) by using a 100% UVR barrier to shield direct UVR and screening the ‘sky view’ completely. This would allow all day protection. However, in many situations filtered screening, natural vegetation or openings to a view are desirable for aesthetic reasons. However any amount of ‘sky view’ permits indirect scattered UVR and this will reduce the protection factor (PF) rating.

$$\text{PF estimated (under shade)} = \frac{1}{\text{UV transmittance (of shading material)} \times 0.5 + \text{sky factor}^* \times 0.5}$$

\*‘sky factor’ is the proportion of the total hemisphere of the sky than can be viewed from a location under the shade.

Shading materials need to be chosen with care, as people can assume that all shade is the same. Solid materials provide a 100% UV barrier and perforated materials the percentage proportional to the solid area. Normal glass filters only part of the UVR erythemal range, but the interlayer of laminated glass is a 99% barrier. As UVR degrades most materials, coatings used to protect the base material can protect people as well. The coating on polycarbonate sheeting does this. Some uncoated clear PVC’s often offer little protection (and break down quickly). Fabrics provide varying degrees of protection. Generally dark colours absorb more UVR and therefore create a slightly better barrier but usually this is not significant. Before selecting any material, it is important to check the manufacturer’s specifications for UVR transmission.

The sky factor can be estimated by various means. For existing structures, a fish-eye lens photography and a UV sun chart [28] can be used. For proposed shade, the sky factor can be calculated by modelling of the surrounding site and shade design. The proportion of the sky hemisphere viewed can be estimated measuring view angles and assessing the proportional area in view. The proportional areas of hemisphere ‘rings’ are a guide: 0°- 30°= 0.5, 30°- 45°= 0.21, 45°- 60°= 0.16 and the cap 75°- 90°= 0.13. A working example would be as follows: Design of a shade to accommodate fair skinned people for 1 hour (max) where UVI = 8 in summer. From *Figure 2*, exposure of UVI 2 under the shade would be acceptable. The shade would need to provide protection PF 4 (UVI 8/UVI 2) to achieve this. As previously discussed, UVI in the open will be made up

of approximately 50% direct and 50% indirect scattered UVR. By 100% shielding the direct sun and shielding more than half the hemisphere of the sky;  $PF = 1/(0.5 + 0.5 \times 0.5) = 1/0.25 = 4$ . The resulting exposure under the shade would be UVI 2. Surface albedo is not significant except for sand and snow conditions.

To attract use, outdoor living space also needs to be warm, comfortable and attractive. In some locations UVR levels can be high when temperatures are too cool for comfort. Cooling sea breezes in a New Zealand location caused this to happen 69% of the time [29]. Such locations require ‘warm shade’; the use of a shading material which transmits heat but blocks UVR (i.e. laminated glass or polycarbonate). Ideally, to facilitate vitamin D production, outdoor spaces should be designed to encourage sun exposure in winter.

## DESIGN FOR UVR PROTECTION IN ARCHITECTURAL EDUCATION

Past initiatives from the Health sector have initiated workshops on the design of shade for skin cancer prevention. In 1997, Britain’s Health Education Authority (HEA) targeted architecture students at the Bartlett with a shade structure design competition [30]. At the time, HEA sent a publication, ‘the architecture of shade’ [31], to all architectural schools, practices and local councils. In 2000, Cancer Society (NZ) Inc sponsored public Sunshade workshops, delivered by Australian architect, John Greenwood. At the Design for Shade 2003 conference, ‘a number of Toronto sites were re-imagined with a provision of shelter from damaging ultraviolet sunrays’ [32]. John Greenwood has also developed a web-based shade-design tool [33].

Research carried out over the last decade has given a clearer perspective on the role of shade in sun protection and priorities in implementation and design. Skin cancer is an issue in white populations especially in Australia, New Zealand and southern USA, where summer UVI> 12 avoiding the summer sun is a daily reality. It is in these locations that architects need to be educated on design for UVR protection. The relevance of in-depth study of UVR protection principles at locations where maximum UVI = 6 is debatable, as a pale skinned person would have adequate protection (UVI<2) just by shielding the direct sun. At high latitudes, if sun-seeking behaviours are related to ‘heat-seeking’ rather than ‘sun-tanning’, then the use of laminated glass and polycarbonate could be exploited to achieve this. Also, the relevance of the in-depth study of UVR protection principles in equatorial regions is debatable too. At the extreme UVI = 14, a brown skinned person would have adequate protection (UVI<5) just by shielding the direct sun. Indigenous populations have a long history of

refining their relationship to their climate and modifying their behaviours to suit.

Early education initiatives, promoted by health authorities, focused on new sunshade structures whereas, in reality, UVR filtering requires to be integrated into the fabric of our cities and living spaces. Rather than teach UVR protective principles in an isolated project, they require integration into building science curriculum and to be applied routinely in the full range of design studio programmes from residential to landscape and urban design. In most situations, outdoor occupation is about quality of life during extreme UVR levels, not about necessity. The brief could be any brief involving outdoor occupation. Alternatively, critical shade environments are pre-schools and schools.

The steps in a suggested process for the UVR protection aspect of a design project are as follows -

**1. understand the science of UVR protection** using this paper and key references (5, 10, 14 & 15) or by requesting the student group to research different aspects of UVR protection and present findings for discussion. Investigate the local environment by measuring UVR levels with a hand-held UVR meter [34] to understand PF ratings of different urban landscape, building form and materials.

**2. understand the local climate** by obtaining data from the national meteorological authority, plotting seasonal daily UVR levels alongside environmental thermal comfort measures. Ascertain when the heat of the sun is required for comfort and when daily maximum UVI<2 and direct exposure to sunshine is necessary for vitamin D synthesis.

**3. research shading precedents** especially the local indigenous and vernacular shade solutions and sun protection behaviour patterns.

**4. assess the out-door occupation requirements** of the brief including time and duration of use

**5. assess the sun protection needs of the users** (skin-type and other personal protection likely to be used)

**6. assess the protection factor (PF) requirement** for the space.

**7. explore and test creative alternative designs** by modelling and checking the shielding pattern of **direct sun** during times when UV levels are unsafe. This could be done by physical modelling and testing with a heliodon or digital modelling using a 3D CAD modelling software with sun-path capability for different geographical locations (e.g. Sketch-up). Secondly, consider the size of the '**sky view**' and explore and test ways to reduce, shield or filter. The site and/or building context will be required to be included in the model. Explore strategies for accessing **winter sunshine**, the **warmth of the sun** when required and **cooling breezes** when required.

**9. estimate an PF rating for the final design** using the process outlined in the 'shade design principles' section and confirm this meets the users needs.

For in-depth research UVR exposure measuring devices (dosimeters), which have been developed for assessing personal exposure, could be used to investigate performance of shade. Polysulfone patches give a measure of cumulative exposure. Personal UV monitors with miniaturized lithium battery-powered UVR detectors and onboard data-logging capabilities and a clock provide more detailed data [35].

## CONCLUSION

Research findings confirm a role for UVR protective shade in reducing excessive UVR exposure, especially for white skinned populations living in locations where UVR levels are extreme. Understanding of the basic science of shade design needs to be included in building science curriculum, and routinely considered in all scales of projects within Schools of Architecture. This paper presents understanding and resources to allow this to happen. Creative refinement of living outside with the sun has the potential to both enrich our life experience and to keep us healthy.

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