Physical Hazards: Non-Ionising Radiation -Electromagnetic

Core Body of Knowledge for the Generalist OHS Professional

Safety Institute of Australia Ltd

Australian OHS Education Accreditation Board

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The OHS Body of Knowledge for Generalist OHS Professionals has been developed under the auspices of the **Health and Safety Professionals Alliance**

The Technical Panel established by the Health and Safety Professionals Alliance (HaSPA) was responsible for developing the conceptual framework of the OHS Body of Knowledge and for selecting contributing authors and peer-reviewers. The Technical Panel comprised representatives from:

The Safety Institute of Australia supported the development of the OHS Body of Knowledge and will be providing ongoing support for the dissemination of the OHS Body of Knowledge and for the maintenance and further development of the Body of Knowledge through the Australian OHS Education Accreditation Board which is auspiced by the Safety Institute of Australia.

Synopsis of the OHS Body of Knowledge

Background

A defined body of knowledge is required as a basis for professional certification and for accreditation of education programs giving entry to a profession. The lack of such a body of knowledge for OHS professionals was identified in reviews of OHS legislation and OHS education in Australia. After a 2009 scoping study, WorkSafe Victoria provided funding to support a national project to develop and implement a core body of knowledge for generalist OHS professionals in Australia.

Development

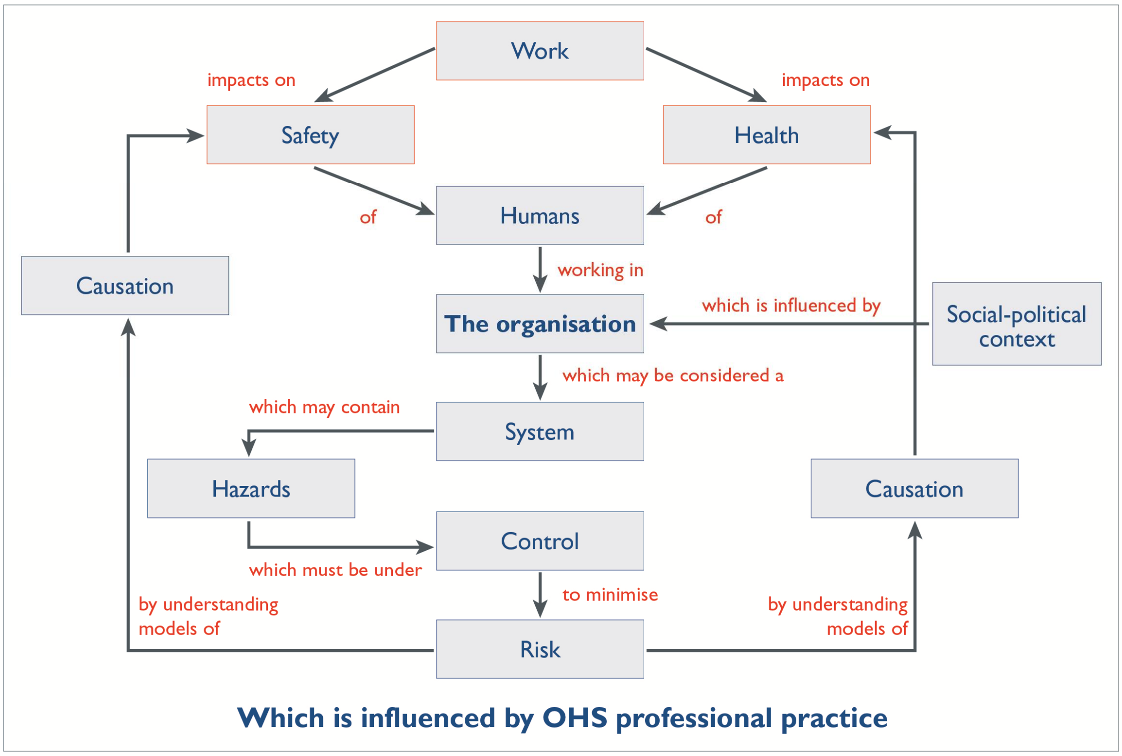
The process of developing and structuring the main content of this document was managed by a Technical Panel with representation from Victorian universities that teach OHS and from the Safety Institute of Australia, which is the main professional body for generalist OHS professionals in Australia. The Panel developed an initial conceptual framework which was then amended in accord with feedback received from OHS tertiary-level educators throughout Australia and the wider OHS profession. Specialist authors were invited to contribute chapters, which were then subjected to peer review and editing. It is anticipated that the resultant OHS Body of Knowledge will in future be regularly amended and updated as people use it and as the evidence base expands.

Conceptual structure

The OHS Body of Knowledge takes a ćconceptualô approach. As concepts are abstract, the OHS professional needs to organise the concepts into a framework in order to solve a problem. The overall framework used to structure the OHS Body of Knowledge is that:

> **Work** impacts on the **safety** and **health** of humans who work in **organisations**. Organisations are influenced by the **socio-political context**. Organisations may be considered a **system** which may contain **hazards** which must be under control to minimise **risk**. This can be achieved by understanding **models causation** for safety and for health which will result in improvement in the safety and health of people at work. The OHS professional applies **professional practice** to influence the organisation to being about this improvement.

This can be represented as:



Audience

The OHS Body of Knowledge provides a basis for accreditation of OHS professional education programs and certification of individual OHS professionals. It provides guidance for OHS educators in course development, and for OHS professionals and professional bodies in developing continuing professional development activities. Also, OHS regulators, employers and recruiters may find it useful for benchmarking OHS professional practice.

Application

Importantly, the OHS Body of Knowledge is neither a textbook nor a curriculum; rather it describes the key concepts, core theories and related evidence that should be shared by Australian generalist OHS professionals. This knowledge will be gained through a combination of education and experience.

Accessing and using the OHS Body of Knowledge for generalist OHS professionals

The OHS Body of Knowledge is published electronically. Each chapter can be downloaded separately. However users are advised to read the Introduction, which provides background to the information in individual chapters. They should also note the copyright requirements and the disclaimer before using or acting on the information.

Physical Hazards: Non-Ionising Radiation-Electromagnetic

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Core Body of Knowledge for the Generalist OHS Professional

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Physical Hazards: Non-Ionising Radiation - Electromagnetic

Abstract

Non-ionising radiation includes electromagnetic radiation spanning the spectrum from extra low frequency fields produced from power lines, through to very short wavelength ultraviolet radiation. Humans have evolved in an environment bathed in electromagnetic radiation, principally received from the sun and other natural events including lightning. However, in the last century, humans have developed focused sources of such radiation for communications and other industrial uses that, if not controlled, can cause adverse health effects. In relation to some electromagnetic radiation bands, the epidemiology of possible health effects is still evolving.

The measurement of electromagnetic radiation and the design and control of plant that produces this is, with some exceptions, a specialised field requiring the services of an expert. However the generalist OHS professional needs to understand the basic epidemiology, physics and control actions required to manage electromagnetic radiation and its risks. With industrial sources of radiation, this will generally mean involvement at the design stage to ensure relevant standards are met, and to ensure appropriate maintenance programs for such engineering controls. The OHS professional will also be required to develop administrative control programs, particularly relating to outdoor worker exposure, and selection and use of relevant personal protective equipment.

Keywords

non-ionising radiation, electromagnetic radiation, extra low frequency, radiofrequency, microwaves, infrared, visible light, ultraviolet, laser

Contents

1 Introduction

Radiation is energy that moves in the form of particles or waves (CDC, 2006) and humans have always been exposed to radiation from natural sources. However with the development of technology, particularly in relation to work activities, this exposure has increased. There are two types of radiation: ionising and non-ionising. This chapter deals with some aspects of non-ionising radiation. Ionising radiation is discussed separately.[1]

Within various references such as ICNIRP (2002) and SA/SNZ (2005), non-ionising radiations include electromagnetic radiations, sound and ultrasound. Sound is covered elsewhere in this Body of Knowledge[2] and ultrasound is not covered at this time.[3] This chapter deals exclusively with non-ionising radiation contained within the electromagnetic spectrum (Figure 1). This consists of electromagnetic waves at different frequencies covering most of the electromagnetic spectrum from extra low frequency (ELF) radiation emitted from power lines, through radio (RF) and microwave (MW) frequencies, and infrared (IR), visible and low energy ultraviolet light (UV). IR, visible and UV radiations are also known as optical radiations (ICNIRP, 2002). The bands of electromagnetic radiations (EMR) are categorised according to their frequency or wavelength (see, for example, Ng, 2003).The electromagnetic spectrum continues through x-rays and gamma rays, but these high energy waves are ionising. EMR can be generated by a variety of methods, such as a discharging spark, arc or electronic device. EMR consists of oscillating electric and magnetic fields that undulate in phase as sinusoidal waves in two mutually perpendicular planes.

This chapter will look at some historical issues around non-ionising EMR. However, each band of EMR has largely different applications, health effects and control mechanisms. Accordingly, the use and management of each band is discussed separately in the order of increasing frequency (or reducing wavelength): ELF, RF including MW, IR, Visible and UV. Lasers, which are monochromatic and coherent beams of IR, Visible, or UV light in a highly collimated beam, will also be discussed.

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[1] See also *OHS BoK*: Physical Hazards: Ionising Radiation.

[2] See *OHS BoK:* Noise and Vibration.

[3] Ultrasound may be covered in a future update of the chapter on noise, depending on perceived need by OHS professionals.

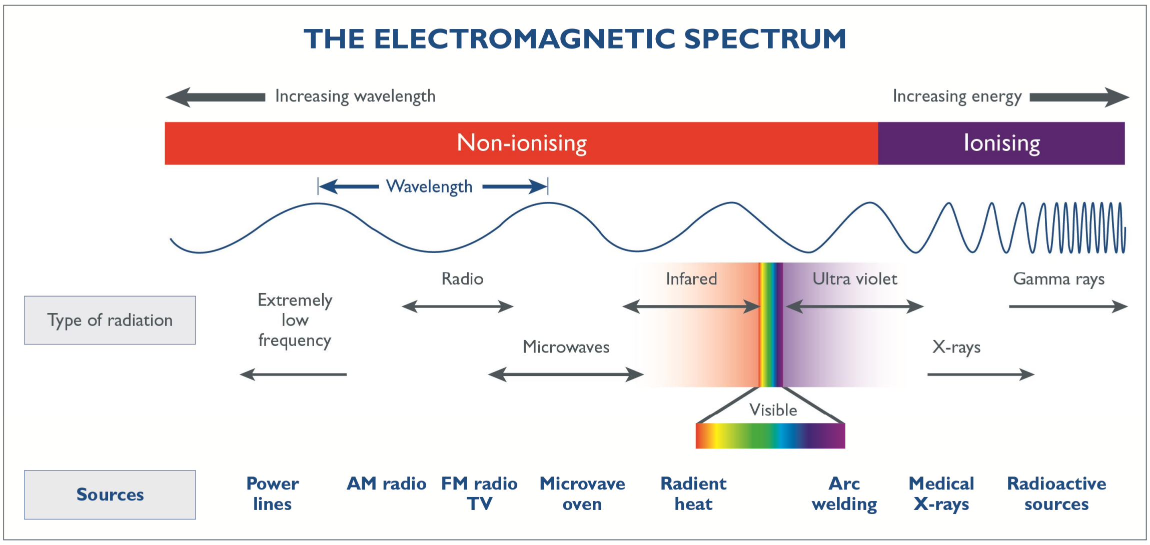

Figure 1: The electromagnetic spectrum (modified from ARPANSA, 2012)

2 Historical context

Human beings have always been exposed to most wavelengths of EMR from natural sources, principally the sun and stars. EMR is emitted from the stellar sources in the universe but the dominant effect on humans comes from our exposure to the sun, whose light contains significant IR, visible and UV wavelengths. Exposures to EMR also can occur from natural events such lightning. In nature, EMR from such sources, apart from UV and cosmic radiation, has been too diffuse to cause significant harm to living things. Within the last century, human beings have been able to provide concentrated sources of EMR that if not controlled, can cause significant harm to people.

In 1704 Sir Isaac Newton published *Opticks*, considered one of the greatest scientific treatises, dealing with the reflection and refraction of light. Newton showed through experiments that visible light was composed of waves of different lengths that could be separated out using a prism, and then recombined back into visible (white) light (Bronowski, 1976).

After Scottish physicist James Maxwell theorised the existence of radio waves in the 1860s, their generation was demonstrated by German physicist Heinrich Hertz in 1886 and the feasibility of communication via radio waves was proven by Italian inventor Guglielmo Marconi in 1895. In 1965, Penzias and Wilson from the Bell Laboratories identified the cosmic background MW associated with the "Big Bang" in the creation of the universe (Krauss & Scherrer, 2008).

3 Extent of the problem

Overall data on injuries arising from non-ionising EMR (apart from UV) is difficult to find, with overall effects of radiation (ie: ionising and non-ionising) being lumped together with heat, radiation and electricity by Safe Work Australia. Heat, radiation and electricity is the category with fewest compensation claims (Safe Work Australia, 2011a). Clearly the band with the most significant potential for injury is the UV, with some 380,000 new cases of skin cancer diagnosed each year (ARPANSA, 2006). The extent of the problem of UV radiation is further discussed in section 9.

4 Understanding non-ionising EMR

Although humans have long used radiation emitted in the form of light and heat, an understanding of its nature and units is essential for the OHS professional to understand relevant exposures and control strategies.

4.1 Units of measurement

The defining feature of any EMR is its frequency; the number of oscillations per second, measured in Hertz (Hz) in units of second^{-1}.

Once frequency has been identified, the wavelength (λ, measured in metres) and energy (E, measured in electron-volts) can be calculated using the following equations:

Wavelength (λ m) = 3×10^{8} (m/sec) / frequency (Hz s^{-1})
where 3×10^{8} m/sec = speed of light (in a vacuum)

Energy (E eV) = 4.136×10^{-15} (eVsec) x frequency (Hz s^{-1})
where 4.136×10^{-15} eVsec = Planck's Constant[4]

Hence it can be seen that the higher the frequency, the shorter the wavelength and the higher the energy. When the frequency is high enough (eg: X-rays or gamma rays), the waves are so energetic that they become ionising.[5]

The Power of an emitting source is measured in Watts.

4.2 The impact of non-ionising EMR on the body

EMR in the non-ionising range of the spectrum only has enough energy to be able to excite electrons to higher states and is insufficient to displace electrons from the atomic structure

[4] Plank's constant is a proportionality constant in physics linking the energy of a photon and the frequency of its associated electromagnetic wave, and identifies the size of a quantum of energy of the photon.

[5] See *OHS BoK* Physical Hazards: Ionising Radiation

(Ng, 2003). Therefore, the nature and extent of the biological effects of exposure to non-ionising EMR depend on factors such as:

> the energy of the incident radiation (which determines the penetration depth), the power density of the field or beam, source emission characteristics, duration of exposure, environmental conditions, and the spatial orientation and biological characteristics of the irradiated tissues. (Ng, 2003, p 4ï 5).

Generally speaking, the longer the wavelength, the less the likelihood that an interaction with tissue will occur; and the greater the power of the source, the greater the opportunity for tissue damage. The health effects of each EMR band are discussed in the relevant section below.

4.3 Legislation

Of all EMR use, only lasers are regulated within the model Workplace Health and Safety Regulations (Safe Work Australia, 2010) (WHSR s 5.1.45). Apparatus emitting very high levels of RF radiation (> levels set in RPS3[6]) are ócontrolled apparatusô under the *Australian Radiation Protection and Nuclear Safety Act* 1998.

Some appliances within the public health domain, such as solaria, are governed by legislation within each jurisdiction. However, these will not generally be within the realm of control by the OHS professional and legislation is not detailed here.

Numerous standards have been issued by Standards Australia and ARPANSA covering different EMR bands, and many of these will be discussed within the relevant sections below. As with other hazards, the general duty of care within the model Work Health and Safety Act applies to all EMR, and these standards published by ARPANSA and Standards Australia provide a benchmark when determining what is reasonably practicable in the control of EMR. Any assessment of reasonably practicable should also consider the Precautionary Principle[7] as in some technologies (eg: mobile phones) the epidemiology relating to health effects is still developing.[8]

5 Extra Low Frequency Radiation

5.1 Definition and use

Extra low frequency (ELF) generally refers to EMR with frequencies of 1 ï 3000 Hz. In Australia, alternating current electricity is supplied at 50 Hz, and therefore any EMR

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[6] See section 6.3

[7] For a detailed explanation of the Precautionary Principle see COMEST (World Commission on the Ethics of Scientific Knowledge and Technology. (2005). *The Precautionary Principle*. UNESCO, Paris France. Retrieved from http://unesdoc.unesco.org/images/0013/001395/139578e.pdf.

[8] See *OHS BoK* Control: Prevention and Intervention.

associated with power supplies will be at 50 Hz in the ELF band (ARPANSA, 2011a). Exposure to ELF is virtually unavoidable due to the reliance on electrically operated equipment in modern society.

Electricity generates both electric and magnetic fields. The strength of the electric field depends on the voltage (eg: 230 V for households, 400 V or higher in industry[9]) and is present in any electrically-live wire whether an appliance is being used or not. Magnetic fields are produced by flowing electric currents so a magnetic field is created around the lead and the appliance when it is operating; however when an electrical appliance is turned off there is no magnetic field. It is these magnetic fields which have given rise to concerns over a possible association with childhood cancer. The strength of magnetic fields is measured in microtesla (µT) or milligauss (mG), where 1 µT = 10 mG.

5.2 Health effects

The health effects (if any) of exposure to ELF will be dependent upon: the strength of the magnetic field at the source: the distance from the source: and the duration of exposure. Despite the very low levels normally encountered in everyday activities, exposure to ELFs remains a source of public debate. (See, for example, ARPANSA, 2011a; WHO, 2011.)

Concern with possible adverse health effects of ELF was initiated by studies in the 1970s in Denver on the association of childhood leukaemia with proximity to high voltage power lines (Werthiemer & Leeper, 1979). This triggered a significant research effort to elucidate this issue with the UK government commissioning Sir Richard Doll to investigate the association between ELF and cancer. In his 2001 report he wrote:

> Laboratory experiments have provided no good evidence that extremely low frequency electromagnetic fields are capable of producing cancer, nor do human epidemiological studies suggest that they cause cancer in general. There is, however, some epidemiological evidence that prolonged exposure to higher levels [more than 0.4 µT] of power frequency magnetic fields is associated with a small risk of leukaemia in children. In practice, such levels of exposure are seldom encountered by the general public in the UK. In the absence of clear evidence of a carcinogenic effect in adults, or of a plausible explanation from experiments on animals or isolated cells, the epidemiological evidence is currently not strong enough to justify a firm conclusion that such fields cause leukaemia in children. Unless, however, further research indicates that the finding is due to chance or some currently unrecognised artefact, the possibility remains that intense and prolonged exposures to magnetic fields can increase the risk of leukaemia in children (Doll, 2001, cited in ARPANSA, 2011a)

In 2002 The IARC classified ELF magnetic fields as a ñpossible human carcinogenò (IARC, 2002), which decision was upheld by the WHO in 2007 (WHO, 2007). However, ARPANSA concluded from the above data:

[9] See *OHS BoK* Physical Hazards: Electricity

> The scientific evidence does not firmly establish that exposure to 50 Hz electric and magnetic fields found around the home, the office or near powerlines is a hazard to human health. In view of the epidemiological studies, however, the possibility remains that intense and prolonged exposures to magnetic fields may increase the risk of leukaemia in children. (ARPANSA, 2011a).

5.3 Risk management

Arising from the debate on ELF magnetic fields, the National Health & Medical Research Council developed an interim guide on exposure to ELF fields, and which was subsequently taken over by ARPANSA. This guide, which is currently being reviewed by ARPANSA, sets out exposure limits for workers and the public for electric and magnetic ELF fields (ARPANSA, 1989). In terms of the critical magnetic fields, the guide sets continuous exposure to be not more than a root mean square flux density of 0.5 mT and short term exposures of two hours to be limited to 5 mT (ARPANSA 1989). These levels can be compared to measured levels beneath power lines (up to 10µT), or at the edge of an easement 40m from a power line as 1µT.

Control of ELF should utilise the Precautionary Principle and primarily focus on initial design of plant, positioning it away from locations that workers or the public may occupy for significant times. The magnitude of both electric and magnetic fields decreases rapidly with increasing distance from the source. Therefore the design and location of plant involving electrical apparatus should be such that that exposure is kept as low as reasonably practicable (ALARP) and consistent with the requirements of ARPANSA, 1989. For example, electric power companies locate power lines on easements where access by the public is limited.

In existing installations, electromagnetic fields can be stopped by a Faraday cage which is an enclosure constructed of conducting materials or a mesh of such material. Such an enclosure blocks out external static and non-static electric fields. Suits made from nomex and stainless steel threads are used by power line workers working in the immediate vicinity of live high voltage lines to avoid exposure to the electromagnetic fields.

Administrative controls in the form of Permits to Work and related procedures should apply to any work in the vicinity of high voltage electrical apparatus to avoid excessive exposure to magnetic fields, as well as contact with electricity[10].

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[10] See Safe Work Australia (2012) Draft Code of Practice, *Working in the Vicinity of Overhead and Underground Electric Lines*

6 Radio Frequency Radiation

6.1 Definition and use

Although radio frequency (RF) waves can be made by natural phenomena such as lightning or astronomical objects, OHS professionals are most likely to encounter artificially generated radio waves in radar and navigation systems, broadcasting, and communication and computer networks. Radio waves are also used in medical applications such as Magnetic Resonance Imaging (MRI) and industrial processes such as RF welding applications. (See ARPANSA, 2002; NRPB, 2001.)

Different frequencies of radio waves have different propagation characteristics in the Earth's atmosphere making different frequencies suitable for different purposes. Table 1 identifies the common names and uses for specific radio frequency bands (Doll, 2001, p6).

Table 1: Radio frequencies and applications

Frequency	Description	Typical Applications
30kHz	Very Low Frequency (VLF)	TVs/VDUs
300kHz	Low Frequency (LF)	AM radio
3MHz	Medium Frequency (MF)	Induction heaters
30MHz	High Frequency (HF)	RF heat sealers
300MHz	Very High Frequency (VHF)	FM radio
3GHz	Ultra High Frequency (UHF)	Mobile phones, TV broadcasts, microwave ovens
30GHz	Super High Frequency (SHF)	Radar, satellite links, MW communications
300GHz	Extra High Frequency (EHF)	Point-to-point links

RF heaters and sealers emit high energy RF between the frequencies of 300 kHz and 299 MH from two conductive plates. These plates are part of a press which, when closed, clamp two or more pieces of non-conductive material such as vinyl or plastic together. When the plates are energized, the material is fused. These devices are used as sealers, solders, fusers, moulders, fasteners, embossers, dryers or welders and result in a seal that is very strong and solvents are not required.

Radar and navigational aids are fixed sources of RF used to control, assist or provide information concerning traffic on land, at sea or in the air. The intensity of the radiation from these sources will depend on several factors including: the frequency; the characteristic of the source being used; the power transmitted by the source; the pulse width and repetition rate; and the distance from the source. Most instances of overexposure are likely to be incurred by airport workers standing near one of these sources while it is transmitting.

Microwaves are used in telecommunications, mobile phones and microwave ovens, and encompass the 300 MHz ï 300 GHz region of the electromagnetic spectrum (Ng, 2003). In the microwave oven, a magnetron is used to produce the microwaves at a frequency of 2.45 GHz. The microwaves then pass into the enclosed metal oven cavity where they are reflected around the oven walls and absorbed in food or drink placed in the oven. The microwaves penetrate the food or liquid and agitate the water molecules within, heating them. The microwave oven is constructed as a Faraday cage, ensuring that no microwaves can escape when functioning properly.

6.2 Health effects

At longer wavelengths, RF can induce alternating electric fields in bodies because of the water content of living tissue. The water molecule is a dipole ï with one side positively charged and the other negatively charged. An electric field induces the water molecule to attempt to rotate to align with the field. Because radiations are emitted with an *alternating* electric field, the water molecule changes directions with the rapid changes in electric field, which causes the molecule to vibrate. The vibration causes a friction-like dissipation of energy in the form of heat. Therefore, unlike localised heating caused by shorter wavelength radiations, longer wavelengths (such as microwaves and radio frequencies) can induce heating deep into tissue. At the low frequency end of the spectrum (ie: long wavelength) it is thought that magnetically-induced effects may occur that can manifest as vertigo or nausea (see, for example, WHO, 2011). Exposure to sufficiently high levels of RF can heat biological tissue and if the human body is unable to cope with the excessive heat, potentially cause tissue damage.

In relation to the longer wavelength RF, the UK National Radiological Protection Board has stated that:

> The experimental evidence reviewed strongly suggested that these fields do not harm genetic material and so would not normally be expected to initiate cancer. There was, however, a possibility that they might act as tumour promoters; that is, they might increase the growth of potentially malignant cells. The results of experimental studies, when taken together were, however, inconclusive. It could not be concluded that any effect of electromagnetic fields on cells and tissues could be regarded as potentially carcinogenic in humans. (NRPB, 2001, p. 5)

There is much interest in the potential effects of radiations related to transmissions from mobile phone base stations and from the handsets. At typical levels, mobile phone base station emissions are well below the allowable general public exposure limit of around 450 $\mu W/cm^2$ (frequency dependent) or some 1000 times below allowable exposure standards (ICNIRP, 2009). Mobile phone handsets radiate RF emissions close to the head and produce complex exposure patterns that are difficult to measure. ARPANSA (2002) specifies exposure limits (Specific Absorption Rate ï SAR) that regulate the rate at which the user absorbs energy from the handset. The SAR limit for mobile phone handsets in Australia is 2 W/kg of tissue (averaged over 10 grams). A SAR of 4 W/kg is associated with a 1°C rise in humans. In practice a digital phone will only cause a temperature rise of a fraction of a degree which is unlikely to be noticed compared with the normal daily variations in body temperature. All phones sold in Australia have to meet this ARPANSA standard.

In 2011, the International Agency for Research on Cancer (IARC) noted the following points in relation to mobile phone emissions:

- The epidemiological evidence, while still accumulating, is currently strong enough to support a 2B classification (possibly carcinogenic to humans);
- There is limited evidence among users of wireless telephones for glioma (tumor in glial cells in brain) and acoustic neuroma (benign tumor in canal between brain and ear);
- The highest risk only applies to those users who use mobile phones most intensely, and who have been using mobile phones for the longest time. The Odds Ratio of >1 were only found for highest decile users with exposures >7 years; and
- While newer 3G phones emit some 100 times less energy than older 2G phones, people are using mobile phones more. (IARC, 2011)

High intensity and long duration of mobile phone use may be associated with tinnitus (Hutter et al., 2010).

Research into the biological effects of chronic exposure to RF continues, and public interest in the possible health effects of mobile telephones, remains high (see, for example, Dubois, 2009). In October 2011, a Danish study reported that there was no link between the duration of mobile phone use and brain tumours (Frei, Poulsen, Johansen, Olsen, Steding-Jessen & Schüz, 2011).

6.3 Risk management

The dose limits for exposure to EMR are dependent upon the wavelength of radiation encountered and therefore its energy, whether it is incident upon a plane/flat surface and the strength of its associated electric and magnetic fields. Limits for RF have been published by ARPANSA in *Radiation Protection Standard 3 (RPS3) - Maximum Exposure Levels to Radiofrequency Fields - 3 kHz to 300 GHz* (ARPANSA 2002). Apparatus emitting levels higher than levels set in RPS3 are ócontrolled apparatusô under the

Australian Radiation Protection and Nuclear Safety Act 1998.[11] Cautionary signage for RF is shown in Figure 2.

Figure 2 Warning sign for radio-frequency non-ionising radiation

Measurement of RF fields and management of ócontrolled apparatusô is a specialist activity[12] with the role of the OHS professional being primarily at the design stage ï to ensure that the design of RF apparatus conforms to the ARPANSA Standard RPS3. Generally this means engineering controls which may include: shielding; waveguides; failsafe inter-locks; earthing of metallic objects; in-built leakage detectors; and alarms. Having achieved good design, processes are required to ensure routine maintenance of the apparatus to ensure the barriers to RF leakage do not degrade.

When well designed and properly operated, RF sealers should not produce high levels of RF in the vicinity of the operator. However, if the shields designed to protect the operator are not properly installed; are not made of the proper materials; or completely absent; then the levels of RF radiation to which the operator and other personnel in the area may be exposed can be many orders of magnitude higher than exposure limits allowable under RPS3. If shielding is needed and it is not possible to retrofit the heat sealer with shields, it may be possible to reduce operator exposure to a safe level by separating the operator and the device or by reducing the on-time of the RF radiation.

All microwave ovens have at least two safety interlock switches which stop the generation of microwaves immediately the door is opened. The Faraday cage design is such that the microwaves should be fully contained within the oven, but it is still possible for some leakage to occur around the doors of certain microwave ovens. ARPANSA notes that the microwave leakage at any point 50 mm or more from the external surface of the appliance shall not exceed 50 W/m^2. This applies to ovens designed for domestic applications, even

[11] See ARPANSA, *Regulatory Guide: How to determine whether an RF sources in a controlled apparatus,* Jan 2012, Retrieved from http://www.arpansa.gov.au/pubs/regulatory/guides/OS-LA-SUP-240N.pdf
[12] óControlled apparatusô should be under the management of a radiation safety officer, who has undergone specialist training in this area.

if used in a workplace. A microwave oven should only be used if an inspection confirms all of the following points:

- The surface of the door is not damaged,
- The door fits squarely and securely and opens and closes smoothly,
- The door hinges are in good condition,
- The oven is clean and in particular the door edges and interior surrounds are not covered with food or burnt material, and
- No corrosion is evident on the door, the door hinges or the oven interior. (ARPANSA, 2011b)

Physical barriers are required to control access to telecommunications or radar transmitters while they are operating while access for maintenance must be controlled through Permits to Work, as well as Lock Out-Tag Out procedures.

7. Infra Red Radiation

7.1 Definition and use

The Infra Red (IR) spectrum has been classified in ISO 20473 *Optics and photonics – Spectral bands (ISO, 2007)* as having the following sub-bands:[13]

- Near Infrared (NIR): 780 ï 3000 nm
- Middle Infrared (MIR): 3000 ï 50 000 nm
- Far Infrared (FIR): 50 000 ï 10^6 nm. (ISO, 2007)

IR radiation is most often encountered as an adventitious or unintended by-product of a process involving lighting or heating. A prime source of IR is the sun, but sources can include any combustion process, furnaces, glassmaking, welding, etc.

IR is used specifically in heating lamps and óblackô[14] room heaters, and has application in industrial processes involving drying and baking, heating and dehydration of food products. IR conveyor ovens are used for curing, preheating, drying, soldering, stress relieving and annealing. IR can also be used for welding of plastics. In this process, IR is often supplied by high-intensity quartz heat lamps, producing radiation with wavelengths around 1000 nm. When this radiation is applied to a polymer, melting occurs. In one mode

[13] For IR, Visible and UV light, it is more common to use the wavelength in nanometres (nm or 10^{-9}m) as the identifying feature instead of the frequency.

[14] A black body is theoretically an ideal radiation emitter. Black room heaters are electric heaters where the element is encased with a black external surface that emits IR at lower temperatures than the naked element would, thus making for a more comfortable environment.

of operation, the lamps are removed after melting has occurred, and the parts are forged together.

IR is also used for thermal imaging cameras which allow fire fighters to make faster searches for victims in structures, find hidden fires in walls, find hot appliances, and conduct search and rescue in wooden areas or water. They can also be used in *HazMat* application to identify liquid levels in containers.

7.2 Health effects

As absorption of IR radiation heats objects, it will clearly heat the human body. Heat stress through exposure to hot processes or objects is discussed elsewhere.[15] The eye is the organ most vulnerable to excessive IR exposure with the most vulnerable tissues being the cornea and aqueous humour, as the infrared radiation raises the overall temperature of the anterior eye. Long wavelength infrared rays also reach the retina and can cause permanent damage to the delicate photoreceptors ï for instance, through sun gazing.

Legge, in 1907, reported a ónewô UK legal occupational disease of óglass blowerös cataractô (Sichel, 1923). Glass blowers and welders are exposed to high levels of IR light at close range. Both direct absorption by the lens and indirect heating of the lens fibres through the absorption of the iris can cause the lining of the lens to peel back resulting in cataract formation and IR-induced opacities. Welding is discussed further in Section 9 on UV.

In general excessive exposure to the subcategories of IR can cause:

- Erythema   MIR and FIR
- Pigmentation   MIR and FIR
- Photokeratitis   MIR and FIR
- Cataracts   NIR (Highest energies)
- Retinal burn   NIR

Contact with hot surfaces can also result in burns which are discussed in *OHS BoK* Physical Hazards: Thermal Environment.

[15] See *OHS BoK* Physical Hazards: Thermal Environment.

7.3 Risk management

There is no designated regulatory standard for exposure to IR[16]. Control of IR is primarily at the design stage ï to ensure that the design of IR apparatus minimises the adventitious emission of IR. This is generally achieved through engineering controls such as shielding and failsafe inter-locks. Having achieved good design, there is a continuing need to ensure routine maintenance of the apparatus to ensure the barriers do not degrade. Access for maintenance to such apparatus must be controlled through Permits to Work as well as Lock Out-Tag Out procedures.

Where there are high levels of adventitious IR emissions that cannot be controlled by barriers (eg: when sampling from a furnace) then appropriate personal protective such as reflecting face-shields, glasses or other protective clothing including aprons, gloves and silvered coveralls are required. AS 4502.1 (SA, 2006) provides advice on selecting clothing to protect against radiant heat. [17]

8 Visible Light

8.1 Definition and use

Visible light is a very narrow range of EMR in the wavelength 380ï 750 nm that is broadly visible to the human eye (Ng, 2003). Humans have evolved in an environment of natural sunlight. Prior to the Industrial Revolution, lighting after sundown was provided by very ineffective lamps burning oil or similar materials. The introduction of gas lighting in the 19th century improved the situation somewhat. However, it was the invention and distribution of electricity and the development of the incandescent light bulb by Edison and Swan at the end of the 19th century that changed lighting in the home and industry. There are now many different types of light sources, including fluorescent and mini-fluorescent tubes, light emitting diodes, high and low pressure sodium and mercury bulbs, metal halide bulbs and so on. However, the spectral distribution of artificial lighting is different from sunlight, and this has productivity implications.

Accordingly, the issue with artificial lighting is generally not one related to overexposure, as with other EMR, but of:

- Inadequate lighting having safety implications (eg: increasing probability of tripping)

[16] However, there are Australian Standards on exposure from electrical appliances. See AS/NZS60335.2.27:2004 Household and similar electrical appliances ï Safety ï Particular requirements for skin exposure to ultraviolet and infrared radiation.

[17] See *OHS Bok* Physical Hazards: Thermal Environment for a discussion of barriers around hot processes to reduce heat radiation and avoid heat stress.

- Inappropriate distribution or type of lighting having safety and health implications (eg: glare increasing visual fatigue within office workers) which can exacerbate ergonomic design issues in workplaces.

In addition, the spectral distribution of artificial lighting is generally different from the solar spectrum against which humans have evolved. Each type of lamp will have a characteristic spectrum from the warm colours of an incandescent bulb, to the single colours of sodium (yellow) and mercury (blue) lamps. Fluorescent tubes, which dominate office environments, have colours which are determined by the particular phosphors on the inside of the tube. The UV light generated by the electrodes in the tube excites the phosphors which then transmit their light through the glass tube. The cheaper versions do not approximate the solar spectrum. Figure 3 identifies such a particular type of fluorescent tube (830, ôWarm Whiteö) with the spectrum emitted being very different from the solar spectrum (Reese et al, 2011).In processes where colour discrimination is important, the appropriate light source having the correct colour of ôwhiteö light needs to be chosen.

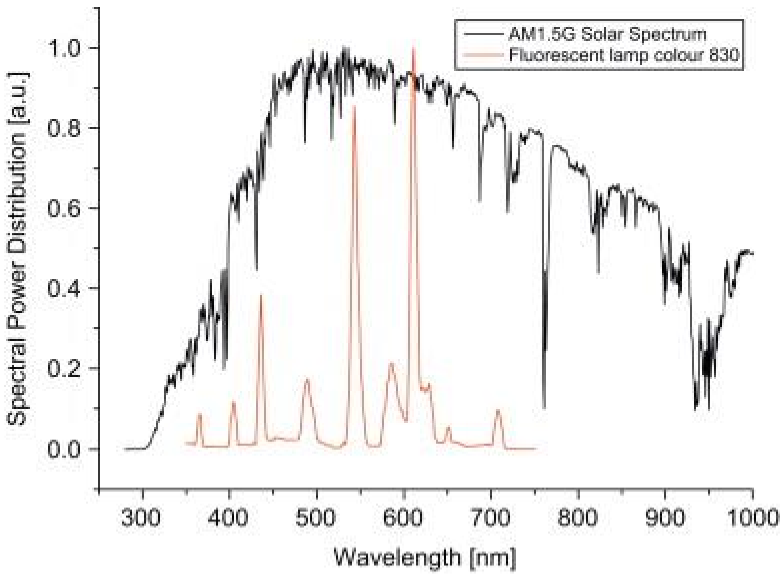

Figure 3: Comparison of the spectrum from the sun and a fluorescent tube (Reese et al., 2011)

While lighting design is a specialist area the OHS professional needs to understand the basics of lighting to be able to assess the adequacy of workplace lighting. Light sources emit radiation in the visible range. Some of that radiation will strike the working surface. This working surface might be the desk surface, or the footpath being walked on. The critical measure as far as the OHS professional is concerned is the quantum of light on the working surface, called *illuminance* and measured in Lux. Illuminance requirements within workplaces will vary according to the tasks that are carried out. For example, fine work such as watchmaking will require a very much higher illuminance than the general lighting within a warehouse or a car park. Levels are usually set to provide for safe and productive visual minima, and have been so defined in AS1680.1:*Interior lighting and workplace design – General principles and recommendations* (SA, 2006).

8.2 Health effects

Visible light can cause photoretinitis (ôblue-light hazardö) via photochemical alterations of molecules in the retina (Ng, 2003). However, the main health issue in relation to light is glare, which is a gross overloading of the adaptation process of the eye, brought about by over-exposure of the retina to light. Glare can be subdivided into:

- Absolute glare, where the source of light is so bright that the eye cannot possibly adapt to it;
- Relative glare, where there is excessive brightness contrasts between different parts of the visual field.

Working positions facing windows should be avoided as the most severe discomfort indoors can arise from windows when the sun is directly visible or when there are views of a bright overcast sky.

Excessive eye strain can have two main effects of tiring the eye and of adding to general fatigue (WorkSafe Victoria, 2006). Visual fatigue comprises all those symptoms that arise after excessive stress on any of the functions of the eye. The most important are straining the ciliary muscles by close visual work, and the effects of sharp contrasts on the retina.

Visual fatigue manifests itself as painful irritation of the eye, double vision, headaches, reduced powers of accommodation and reduced visual acuity. Work conditions that might bring about visual fatigue include fine work, reading poorly printed texts, inadequate lighting, and exposure to flickering light.

8.3 Risk management

Physiological requirements for artificial lighting include: a suitable level of illumination; spatial balance of surface illuminances; temporal uniformity of lighting; and avoidance of glare. As a general rule, discomfort glare from artificial lighting can be avoided by: the choice of luminaires (eg: light fittings recessed so that the luminous portion of the base projects less than 30mm vertically); their position; and by use of high reflectance surfaces for the ceiling and upper walls.

The effect of relative glare is greater the nearer the source of dazzle is to the direct line of sight, and the greater its area. A bright light above the line of sight is less dazzling than one below or to either side. The risk of dazzle is greater in a dim room since the retina is then at its most sensitive. Glare can be reduced in the office workplace by controlling natural light from windows using blinds or window tint; reducing the contrast between the foreground and background; and repositioning the work surface to reduce light falling onto the work surface (Bridger, 2009).

When working with computers, the factors causing increased incidence of visual complaints include: screen flicker (less of a problems with flat screens); excessive luminance contrast ratio between screen and environment; reflected glare on the screen; and poor readability (Kroemer & Grandjean, 1997)

High luminance sources (eg: sources of bright light) can be reflected from the screen to the operator, and are seen on the screen superimposed on the text. This can both reduce the contrast and be distracting if they occur outside the immediate task area. Sharply defined high luminance reflections can constitute misleading cues about the distance at which the eye should be focused. The most common sources of high luminance in a room are the sky seen through a window, and inappropriate or poorly positioned luminaires (Kroemer & Grandjean, 1997).

Lighting levels need to be matched with the type of tasks required and can vary from 40 lux (corridors, walkways) to 1600 lux for very fine and difficult jobs (watchmaking) (see SA, 2006, Table 3.1). For general lighting systems, uniformity of illuminance (minimum illuminance / average illuminance) within a room should be not less than 0.7 on a given plane within the measurement area. In some activities, only the working plane needs to have the required illuminance and this could be supplied using localised lighting such a desk lamp. SA, 2006 provides instruction on how to assess the overall lighting arrangements within a room.

In summary, good lighting design provides for the following issues:

- Buildings should be built so as to maximise the use of natural light
- All workers should where possible have access to a window at their workstation;
- Workers should be encouraged to take 'light breaks' and get out of artificially lit environments during their lunch periods
- Where artificial lighting must be used, preference should be given to use of light sources that simulate the spectral density of sunlight, eg ódaylightô fluorescent tubes (Kroemer & Grandjean, 1997).

Having achieved good lighting design, the OHS professional should ensure that proper maintenance of the lighting system keeps it to the appropriate standard. The following points should be noted:

- Luminaires (light fittings and associated equipment) should be regularly cleaned so the dust and detritus does not reduce the light emission which can result in reduced workplace illuminance
- If bulbs or tubes burn out, or commence to flicker towards the end of their life, they should be promptly replaced. Consideration should be given to replacing all lights within a work area at the one time, based on their projected average lifespan, so that the problems of dead or flickering tubes are minimised
- When work arrangements are changed, consideration needs to be given to changing the lighting design in the workplace. Such changes may require an increase in illuminance or repositioning of the luminaires to maintain the requirements of AS1680.1.

9 Ultraviolet Radiation

9.1 Definition and use

Ultra violet (UV) light is EMR with a wavelength in the range of 100ï 400 nm and is invisible to the human eye. While UV light is found naturally in sunlight, it also can be found in workplaces as adventitious emissions associated with electric arcs (eg: from arc welding). It can also be emitted from high intensity discharge lights (eg: mercury vapour lamps) where the external borasilicate glass cover is broken (see Ng, 2003; NRPB, 2001; Ontario Ministry of Labour, 2009). The high energy nature of UV is also utilised in biosafety cabinets to sterilise materials, and in germicidal lamps to disinfect water.

UV can be broken into the following sub-bands (ARPANSA, 2006):

- Near UV: 400-315 nm (UV-A)
- Middle UV: 315-280 nm (UV-B)
- Far UV: 280-100 nm (UV-C)

It should be noted that UV-C straddles the border between ionizing and non-ionizing radiation and the higher energies are ionizing. It is the most dangerous band in relation to sun exposure. However, the ozone layer absorbs UV-C and little radiation below 290 nm reaches the earthôs surface (ARPANSA 2006).

Of all the frequency bands of EMR, it can be argued that UV is the highest risk, with the highest number of workers exposed and with the highest potential consequence. The largest category is outdoor workers, particularly the following industries: construction, parks and gardens, lifeguards and rural workers (ARPANSA, 2006). Solar UV can reach the worker:

- Directly from the sun
- Scattered from the open sky
- Reflected from the environment.

The intensity of UV increases with increasing altitude, proximity to the equator, and when the sun is highest in the sky (noon) while clouds and shelter can reduce the exposure to UV.

9.2 Health effects

The UV spectrum has many effects, both beneficial and damaging, to human health. UV radiation has beneficial applications as it can be used for killing bacteria (useful in medical or dental practices) and it can be used in curing resins or inks. Exposure to sunlight is necessary to naturally develop vitamin D which is required for healthy bones. Most people probably achieve adequate vitamin D levels through the UV-B exposure they receive during typical day-to-day outdoor activities (Cancer Council, 2007).

Acute exposure to UV can result in "sunburn" and many arc welders are aware of the condition known as "arc-eye", a sensation of sand in the eyes caused by excessive eye exposure to UV. Chronic negative effects of exposure to UV radiation include skin cancers and cataracts. Also, evidence exists associating UV radiation with increased risk of infectious disease and reduced efficacy of vaccinations (Ng, 2003). UV radiation can also damage the lens of the eye.

Some specific health effects of the different UV bands are:

- UV-A Sun tan and pigmentation
- UV-B Skin erythema, eye effects of keratitis and cataracts
- UV-C Skin cancer.

A range of natural products, drugs and industrial chemicals can act as photosensitizes which increase the sensitivity of human skin to UV, including coal tar products, some printing inks and ibuprofen (ARPANSA, 2006).

Although UV-C is largely filtered by the ozone layer, the current evidence is that both UV-A and UV-B are contributing factors to melanoma and non-melanomic skin cancers (Cancer Council Australia, 2005). Australia has the highest rate of skin cancer in the world, with some 1700 Australians dying from these cancers each year (Safe Work Australia, 2010b). Outdoor work is estimated to cause some 200 melanomas and 34000 non-melanoma skin cancers each year. Over the period 1999-2004, the rate of compensable skin cancer claims per million employees more than doubled (Safe Work Australia, 2010b). The industries with highest percentage of employees exposed to sunlight are

Agriculture/Forestry/Fishing (75% with cancer Odds Ratio of 18.3) and Construction (60% with cancer Odds Ratio of 8.8) (Safe Work Australia, 2010b).

9.3 Risk management

ARPANSA has set out recommended standards for exposure to UV in *Radiation Protection Standard for Occupational Exposure to Ultraviolet Radiation* (RPS12) (ARPANSA, 2006). The Standard sets out to protect workers by limiting the occupational exposure to ultraviolet radiation from artificial sources in the workplace, and setting requirements for minimising a personõs exposure to uncontrollable sources of UV, such as the sun. However, given the variability in exposures to solar UV due to highly variable ambient solar UV levels as well as behavioural effects and different exposure geometry, strict application of the exposure limits for outdoor work may not be reasonably practicable and limiting UV exposures to as low as reasonably practicable is the most effective approach (ARPANSA, 2006). The control limits vary with wavelength and measurement is a matter for specialist expertise. Vecchia, Hieranen, Stuck, van Deventer & Niul., (2007) outline generic ways of protecting against UV exposure and which are discussed in the following two sections addressing apparatus producing UV and outdoor work.

9.3.1 UV producing apparatus

As in many of the other forms of EMR, the role of the OHS professional in controlling radiation risk associated with UV-producing apparatus focuses on ensuring that the design of the equipment complies with RPS12 (ARPANSA, 2006) , and that appropriate maintenance is in place to ensure that the controls are maintained. A Safety Alert issued by the Queensland Department of Natural Resources highlights how excessive exposure to UV can occur and the impact. The case resulted in 5 lost time injuries with 9 days lost time when workers on a mine plant were exposed to UV from a 400W mercury vapour lamp situated directly above the work area. The outer envelope of the lamp had broken, but the lamp continued to discharge. Workers were treated for skin burns and eye flash burns. Prior to this incident, the lamp had regularly failed about once per month due to mechanical impact. The lamp was inappropriately protected, and if the location was such that impact was likely, then an alternative source of light, eg: a sodium lamp, should have been utilised. (Safety Alert 81 Qld Dept Natural Resources and Mines 18/7/02)

Solaria can emit levels of UV up to 5 times as strong as the summer noon sun (eg: UV index up to 60). A solarium tan is induced through concentrated exposure to high levels of UV. Solaria that advertise 'mini' or 'high performance' tans that colour skin in less than 10 minutes do this by exposing clients to extreme levels of UV radiation. AS/NZS 2635: *Solaria for Cosmetic Purposes* (SA/SNZ, 2006) specifies exposure times, and prohibits people younger than 18 years and of Skin Type 1 (Very fair skin tone, blond or redhead, freckles, burns easily, never tans)[18] being exposed. Some jurisdictions have other prohibitions on solaria.

Welding can emit IR, Visible and UV radiation from arcs which can affect not only the welder, but also anyone who is accidently exposed to the unprotected arc. The model Code of Practice on Welding and Allied Processes identifies the following control procedures to protect from radiation from this source:

- Install non-flammable screens and partitions
- Use signs to warn that welding is occurring and that entry into the work area is not permitted unless personal protective equipment is worn and
- Provide personal protective equipment including filter shades for goggles and face shields to protect the eyes from radiation. Gloves and other protective clothing should be worn to cover exposed skin. (Safe Work Australia 2011c, p10)

9.3.2 Outdoor Work

ARPANSA recommends the following control measures, in priority order, that could be implemented for outdoor work (elimination and substitution are not considered practicable):

- Engineering Controls: physical changes to the workplace or work environment e.g. putting up shade-cloth to protect workers from the sun.
- Administrative Controls: actions or behaviours employers and employees can take to reduce to their exposure e.g. do outdoor jobs/tasks earlier in the morning or later in the afternoon (when levels of solar UV are less intense).
- Personal Protective Equipment: equipment that employees wear to protect against UV from the sun e.g. sun-protection clothing that covers as much skin as possible, hats, sunglasses, and sunscreen. (ARPANSA, 2006)

The concept of Ultraviolet Protection Factor (UPF) is important in discussing engineering controls and protective clothing. UPF is similar in concept to the more familiar Sun Protection Factor for sunscreens (SPF). The UPF rating indicates how effective a material is at blocking out solar ultraviolet radiation with testing performed according to SA/NZS4399: *Sun protective clothing – Evaluation and classification* (SA/SNZ, 1996). UPF ratings range from 15 to 50 with higher ratings indicating more effective UV blocking and therefore better protection.

[18] For definition of skin types see Fitzpatrick Skin Type Chart, http://www.arpansa.gov.au/pubs/RadiationProtection/FitzpatrickSkinType.pdf

Engineering Controls

The work layout should provide shade or other measures to reduce exposure to UV. Shade cloth acts as a physical barrier to incident solar UV and transmits as much UV as visible light. The higher the visibility through the shade cloth (e.g. the coarser the weave), the more UV can get through. If the shade cloth is rated at 90%, it absorbs 90% (and transmits 10%) and has a UPF of 10. Awnings and other solid barriers have the highest UPF. However, it should be remembered that UV can still be reflected from the ground or other surfaces so can still affect people who are in the shade. There should be a balance between the need for the highest practicable UPF with ease of use, particularly in mobile situations. A similar situation occurs in window glass for vehicles and buildings. There are many different types of glass and most are indistinguishable to the human eye, but they provide very different amounts of protection against solar UV. The UPF for glass measures the decrease in UV light transmitted. A UPF of 50 means there is a 50-fold reduction in the amount of UV transmitted. Tinting of the glass can increase UPF to 50+ (ARPANSA, 2006)

Administrative Controls

The risk of UV for outdoor workers in a particular location can be estimated through the UV Index. The Bureau of Meteorology forecasts and publishes UV levels for public use in the news media and on the Bureau website.[19] The UV Index is a number relating to how much solar UV reaches the ground, based on the potential for skin injury. The reported value is calculated from the daily maximum UV averaged over 30 minutes. One UV Index unit represents 25 mW/m^2 of UV. On a clear sky day, the maximum UV level occurs at noon. If there is substantial cloud cover during this time, the maximum may occur at another time. The UV Index map for Australia, noon on March 12, 2012 is given in Figure 4 as an example of the problems associated with outdoor work in the Australian summer. It shows that essentially the whole of mainland Australia as having Very High or Extreme levels of UV Index at noon on that day (UV Index >8). This reinforces the approach of, where possible, scheduling work in the morning, or afternoon, away from the two hours each side of the noonday sun.

[19] http://www.bom.gov.au/australia/charts/UV.shtml

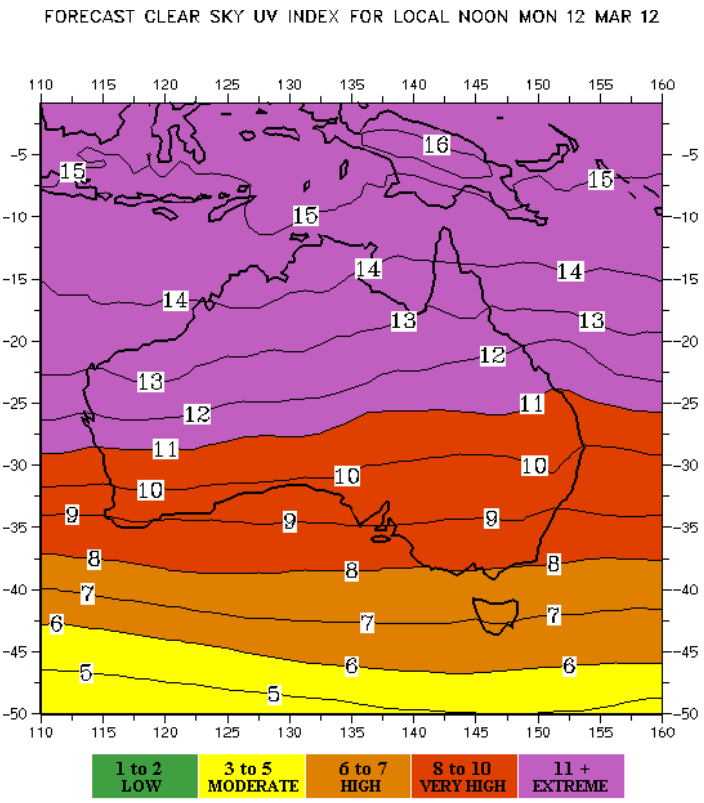

Figure 4: UV Index, Australia, noon 12/3/2012, Bureau of Meteorology (retrieved from http://www.bom.gov.au/australia/charts/UV.shtml)

The World Health Organisation (WHO) recommends use of sun protection measures when the UV Index reaches 3 or above to avoid skin damage and skin cancer. For untanned, unprotected skin, exposure to the summer sun 10amï 2pm:

- 12 mins can result in mild sunburn
- 30 mins can result in appreciable discomfort
- 60 mins can result in peeling and blistering
- 120 mins can result in permanent skin damage (Safe Work Australia, 2008, p9).

Personal Protective Equipment

Given the real practicable limitations of engineering and administrative controls for outdoor work, a very high emphasis is placed on personal protective equipment, including sunscreen for protecting outdoor workers. This section looks at the UPF associated with clothing, and appropriate selection and use of sunscreens.

The factors which affect the UPF of clothing include the following:

- Composition of fabric: some fibres absorb UV more than others

- Weave density: the higher the weave, the higher the protection
- Colour: many dyes absorb UV, in general, darker colours absorb more UV
- Tension: stretching a fabric will normally cause a decrease in the UPF rating
- Moisture content: many fabrics have lower UPF ratings when wet
- Design: garments that are sensibly designed for sun protection can make a large difference to UV exposure. A shirt with long sleeves and a large collar offers more protection than a short-sleeve shirt without a collar. Loose fitting garments give better protection than garments that are worn close to the skin and also may be more comfortable to wear on hot days. A legionnaire style cap with a flap protects the ears and back of the neck. A broad-brimmed hat shades the face and neck (For example, see, Safe Work Australia, 2008, section 4.)

Sunglasses eliminate solar UV, in particular the more-damaging UV-B radiation. Good quality sunglasses (particularly, the ówraparoundô type) provide the eyes with substantial protection against solar UV. AS/NZS 1067: *Sunglasses and Fashion Spectacles* (SA/SNZ, 2003), sets limits on the transmittance of fashion spectacles, general purpose sunglasses and specific purpose sunglasses. General purpose sunglasses are intended to reduce sun glare in ordinary circumstances (including driving in daylight) and offer good protection against solar UV.

Specific purpose sunglasses are intended for situations where general purpose sunglasses may not provide adequate protection, due to the presence of higher levels of solar UV, for example, on snowfields. Sunglasses that comply with the requirements of AS/NZS 1067 should be labelled as such. Those labelled ŒEPF 10ô (Eye Protection Factor rating 10) actually exceed the requirements of AS/NZS 1067 and thus provide even greater protection. Sunglasses that are to be worn while driving must also comply with the coloration limits of AS/NZS 1067. Colours, in particular traffic signals, will then still be recognisable when viewed through the lens.

Sunscreens are always useful in summer and are an important adjunct to hats and clothing, and should be applied to areas not otherwise protected. Sunscreens should be at least SPF 30, and applied to clean, dry skin 20 minutes before going out into the sun. If removed through washing, they need to be reapplied, but reapplication only keeps up the protection of the first application, and it doesn't provide extra protection (Cancer Council Australia, 2005).

The Sun Protection Factor as defined in AS/NZS 2604.1998 *Sunscreen Products – Evaluation and classification* (SA/SNZ, 1998) identifies the extended time of exposure to sunlight required to produce erythema or redness, compared to not applying sunscreen. Depending on skin type and the UV Index, erythema can occur in around 12 minutes with untanned, unprotected skin (Safe Work Australia, 2008). A SPF30 sunscreen properly applied provides thirty times this time before erythema occurs (30x12=360 minutes or 6 hours). However the protection is not absolute and some UV does get through. For example, an SPF30+ sunscreen, under laboratory conditions allows 3% of the UV to be transmitted through to the skin. This adds to the lifetime total UV exposure and increases the risk of skin cancer. Unfortunately, Australians generally apply too little sunscreen compared to that required to achieve the protection given in AS/NZS 2604 when tested in a laboratory, which is approximately a teaspoon of sunscreen per limb (Cancer Council Australia 2005).

10 Lasers

10.1 Definition and use

Laser (an acronym for Light Amplification by Stimulated Emission of Radiation) devices utilise collimated (low divergence) beams of intense monochromatic, coherent light in the UV, Visible or IR wavelengths (see, for example, University of Texas, 2009). Lasers are classified according to the wavelength of light generated at their maximum power output. Laser light is generally non-ionising.

Lasers are classed according to their safety (see AS/NZS IEC 60825.1:2011 *Safety of laser products*) as follows:

- **Class 1** ï Safe under reasonably foreseeable conditions, including use of optical instruments for intrabeam viewing (eye is exposed to the direct or specularly reflected laser beam).
- **Class 1M** (Magnifier) ï λ in range 302.5 ï 4000nm, safe under foreseeable conditions, but may be hazardous if user employs optics within the beam.
- **Class 2** ï λ in range 400 ï 700nm where normal aversion response (blinking) offers adequate protection.
- **Class 2M** (Magnifier) ï as for 2 but viewing of output may be more hazardous if user employs optics within the beam
- **Class 3R** (Restricted) ï λ in range 302.5 ï 10^6 nm where direct intrabeam viewing is potentially hazardous but risk is lower than 3B
- **Class 3B** ï normally hazardous when intrabeam exposure occurs. Viewing diffuse reflections is normally safe
- **Class 4** ï lasers that are capable of producing hazardous diffuse reflections. They may cause skin injuries and could also constitute a fire hazard. Use requires extreme precaution. (AS/NZS IEC 60825.1:2011 Safety of laser products)

Lasers are used for a variety of purposes in a range of industries. In construction lasers are used in surveying, levelling and alignment activities. Gas-assisted laser fusion cutting is performed by concentrating the light from a laser onto a surface so that the material melts. The melted material is then removed by flowing gas. Oxygen can also be used to assist in the reaction. Apart from metals, laser fusion cutting is also used for glass and ceramics, wood, cloth and plastics, and is suited for high speed automation and is able to cope with complex shapes. In surgery, a laser beam can cauterize a wound, repair damaged tissue, or destroy cells under the beam, allowing for cutting through tissue without damaging neighbouring cells. Lasers have been used in place of surgical cutting instruments in various surgeries, including eye surgery, gynaecological procedures, and removal of skin marks and excising small tumours. Lasers are also used in barcode readers, pointers, and a wide range of consumer and industrial applications including CD/DVD players and analytical devices.

Some laser colours / wavelengths are given below:

UV
- Argon Fluoride 193nm
- Krypton Flouride 248nm
- Xenon Chloride 308nm
- Nitrogen 337nm

Visible
- Argon (Blue) 488nm
- Argon (Green) 514nm
- Helium-Neon (Green) 543nm (Civil Engineering, bar code, particle size)
- Helium-Neon (Red) 633nm
- Rhodamine 6G dye (tunable) 570-650nm
- Ruby (red) 694nm

Infra red
- Neodymium-YAG (yttrium-aluminium-garnet) 1064nm (printing, microwelding, diamond drilling)
- Carbon Dioxide 10600 nm (profile cutting, medical).

10.2 Health effects

The risks from lasers vary with the wavelength, intensity and duration of the output or length of exposure. Except for Class 4 lasers, laser radiation is essentially optical with relatively shallow penetration. The principal risk is normally to the eyes, although body burns may also occur at high power. The risk may be either by directly viewing the beam, or seeing a reflected beam off a mirrored (specular) surface.

10.3 Legislation

Lasers are defined as ‘plant’ and controlled under the model Work Health and Safety Regulations (Safe Work Australia, 2010) (WHSR s 5.1.45) which addresses safe installation, use and instruction on lasers. The regulation is directed at avoiding accidental irradiation of the operator or any person, particularly by viewing of the direct beam or any reflection. There are regulatory requirements for training of operators and Class 3B and 4 lasers are prohibited from use in the building or construction industries.

10.4 Risk management

Useful references on laser safety include ACGIH, 1990 and AS/NZS IEC 60825.1:2011.

The warning sign for lasers is given in Figure 5.

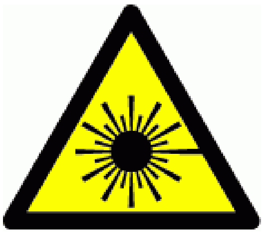

Figure 5: Laser radiation warning signs

Laser control measures vary depending on the type of laser being used and the manner of its use with the specific precautions for each class being:

- Class 1 ï none ï provided Class 1 level maintained
- Class 2 - Avoid staring into the beam (ie: deliberate viewing), pointing the beam at other people, or directing the beam into areas where other people may be present
- Class 3 - Prevent eye exposure to the beam. Guard against unexpected specular reflections (ie: those arising from shiny, mirror-like surfaces)
- Class 4 - Prevent eye and skin exposure to the beam, and to diffuse reflections (scattering) of the beam. Protect against beam interaction on flammable or other materials that could cause fire or fume. (SA/SNZ IEC,2011)

Further generic engineering and administrative controls for Class 3 and 4 lasers are:

- Security of access
- Interlocks, shields, beam stops, attenuators, etc. Where practicable, laser beams should be located well above or below eye level and terminated at the end of the useful light path. The occurrence of hazardous reflection risks should be identified
- Systems of work and their operation to ensure that it is not possible for a person to stare directly into the beam or through optical instruments which have not been fitted with suitable filters to protect the viewer. Whenever practicable laser beam alignment should be done remotely.
- High powered lasers should be under the control of a trained Laser Safety Officer with installation, adjustment and operation of laser products only carried out by employees approved by the Laser Safety Officer
- Areas where high powered laser products are used and to which there is access by untrained people (such as the public) should be clearly labelling / signposted

- Training and certification of laser operators
- PPE (for skin and eyes)
- Secure storage of laser products when not in use.

Protective laser eyewear should be an adjunct to engineering and administrative controls. Eye protection generally consists of filter plates which selectively attenuate at specific laser wavelengths but transmit as much visible light as possible. Such protective eyewear is available for a range of common lasers.[20].

11 Implications for practice

The implications for the generalist OHS professional in relation to identification and control of non-ionising EMR will largely depend on the industry in which they work. However, regardless of the industry, it is imperative that the OHS professional understands the health effects of EMR, and the applicable standards covering the exposure to different EMR frequency bands. They should be able to utilise this information at the design stage of relevant apparatus and tasks, and so develop appropriate control strategies including engineering controls, safe work procedures and appropriate personal protective equipment.

In cases where the epidemiology is still developing, the OHS professional needs to maintain awareness of the relevant research and be able to differentiate real or probable effects from emotive claims that are without foundation.[21] In addition, the OHS professional needs to be able to provide valid information to managers, designers and the workforce as needed. Where there is doubt on health effects, the Precautionary Principle should be applied in developing control measures.[22]

In most cases, the actual measurement of EMR power and frequency / wavelength, or the design of engineering safeguards for EMR emitting equipment, is a specialist area requiring specifically trained occupational hygienists, physicists, or engineers. In relation to testing of workplace lighting, the generalist OHS professional may liaise with certified occupational ergonomists or hygienists for this purpose.

Exposure to ELF will relate largely to workers within the power industry (generation, transmission or distribution) or bulk users of electricity such as aluminium smelters. Depending on the jurisdiction, these organisations may be subject to legislation such as the *Electrical Safety (Management) Regulations* 2009 (Vic) which require the organisation to have a Safety Management System (SMS) covering the safe operation of high voltage apparatus. Such an SMS should include appropriate controls for exposure to ELF.

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[20] For example, see, http://www.roithner-laser.com/safety.html or http://www.laserglasses.com.au/?gclid=CIT3j6mL6K4CFUwmpAodsHD1jg
[21] See *OHS BoK:* Practice: Critical Consumer of Research.
[22] See *OHS BoK*: Control: Prevention and Intervention.

In manufacturing industries involving the use of RF or IR heaters or apparatus, or high powered laser cutting apparatus; or telecommunications involving RF or MW transmitters / receivers; or aviation or other industries utilising radar; and organisations servicing RF, MW or IR producing apparatus; the use of a radiation safety officer is advised. The role of the generalist OHS professional should be at the design and installation stage to ensure that the relevant exposure standards are achieved, and to ensure appropriate maintenance schedules are implemented so that the designed barriers remain effective. Development of procedures and training in safe work will also be required.

Most generalist OHS professionals will be involved with exposure to Visible and UV light. UV light will be encountered particularly in activities such as welding, and in outdoor work. While some engineering controls may be applicable to controlling these exposures, the prime method of controlling exposure, particularly in relation to outdoor work will be through administrative controls and personal protective equipment, including sunscreens. The role of the supervisor in training and supervising staff to follow procedures and utilise protective equipment will be critical, and the OHS professional needs to pay special attention to worker needs including adequate and comfortable hats and clothing with appropriate UPF providing appropriate cover for outdoor workers. As, traditionally, people have not applied sunscreen appropriately to achieve the stated sun protection factors possible in laboratory testing and claimed by the sunscreen manufacturers, workers need to be trained in the appropriate application of sunscreen to safeguard against future skin disease.

12 Summary

Non-ionising EMR covers a number of frequency bands with the health effects and controls being different for each of the frequency bands. As the frequency increases (or the wavelength shortens) the EMR becomes more energetic so that it achieves ionising potential within the UV band. Commensurate with the differing health effects, there are relevant exposure standards that have been promulgated by ARPANSA and Standards Australia, although actual measurement of EMR is a specialised activity. Occupational and public health legislation may also apply to apparatus producing non-ionising EMR.

The role of the OHS professional is to remain up-to-date in understanding the effects and principles of non-ionising EMR safety and to ensure that this is applied at the design, implementation and maintenance stages of the equipmentôs life cycle. OHS professionals are likely to be involved in control of visible light within the built workplace, and control of outdoor work requiring development of suitable design arrangements, administrative controls and selection and use of personal protective equipment and sunscreens.

13 Additional Sources of Information

The ARPANSA website, www.arpansa.gov.au, provides a wide range of information related to non-ionising EMR. Worksafe regulators in each jurisdiction can also be a useful source of information.

14 References

American Conference of Governmental Industrial Hygienists (ACGIH), (1990). *A Guide for Control of Laser Hazards*, 4th ed., ACGIH Inc., Cincinnati, Ohio

ARPANSA (Australian Radiation Protection and Nuclear Safety Agency). (1989). *Interim Guidelines on Limits of exposure to 50/60 Hz electric and magnetic fields* (Radiation Health Series No. 30). Canberra, ACT: Commonwealth of Australia. Retrieved from http://www.arpansa.gov.au/pubs/rhs/rhs38.pdf.

ARPANSA (Australian Radiation Protection and Nuclear Safety Agency). (2002). *Radiation Protection Standard: Maximum Exposure Levels to Radiofrequency Fields – 3 kHz to 300 GHz* (Radiation Protection Series No. 3). Canberra, ACT: Commonwealth of Australia. Retrieved from http://www.arpansa.gov.au/pubs/rps/rps3.pdf.

ARPANSA (Australian Radiation Protection and Nuclear Safety Agency). (2006). *Occupational Exposure to Ultraviolet Radiation* (Radiation Protection Series No. 12). Canberra, ACT: Commonwealth of Australia. Retrieved from http://www.arpansa.gov.au/pubs/rps/rps12.pdf.

ARPANSA (Australian Radiation Protection and Nuclear Safety Agency). (2011a). *Electricity and Health,* Canberra, ACT: Commonwealth of Australia. Retrieved from http://www.arpansa.gov.au/radiationprotection/factsheets/is_electricity.cfm.

ARPANSA (Australian Radiation Protection and Nuclear Safety Agency). (2011b). *Radiation Emissions from Microwave Ovens*, Canberra, ACT: Commonwealth of Australia. Retrieved from http://www.arpansa.gov.au/pubs/factsheets/012is_microwave.pdf.

ARPANSA (Australian Radiation Protection and Nuclear Safety Agency). (2012). *Radiation basics,* Canberra, ACT: Commonwealth of Australia. Retrieved from http://www.arpansa.gov.au/radiationprotection/basics/ion_nonion.cfm.

Bridger, R., 2009. *Introduction to Ergonomics,* 3rd Ed, CRC Press, Boca Raton, Florida.

Bronowski, J., 1976. *The Ascent of Man,* Book Club Associates, London.

Cancer Council Australia. (2005). *Position Statement: Use of SPF30+ sunscreens,* Retrieved from http://www.cancer.org.au/File/PolicyPublications/Position_statements/PS-Use_of_SPF30_sunscreens_June_2005.pdf.

Cancer Council Australia. (2007). *Position Statement: Risks and Benefits of Sun Exposure,* Retrieved from http://www.cancer.org.au//File/PolicyPublications/PSRisksBenefitsSunExposure03May07.pdf .

CDC (Centres for Disease Control and Prevention). (2006). Radiation dictionary. Retrieved from http://www.bt.cdc.gov/radiation/glossart.asp.

Doll R., (2001). *ELF Electromagnetic Fields and the Risk of Cancer*, National Radiological Protection Board, 2001. Retrieved from www.hpa.org.uk/web/HPAwebFile/HPAweb_C/1194947420620.

Dubois, F. (2009). Whatôs to fear about mobile phones? *research*eu*, *61*. Retrieved from http://ec.europa.eu/research/research-eu/61/article_6138_en.html

Frei, P., Poulsen, A. H., Johansen, C., Olsen, J. H., Steding-Jessen, M., & Schüz, J. (2011). Use of mobile phones and risk of brain tumours: Update of Danish cohort study. *British Medical Journal*, *343.* Retrieved from http://www.bmj.com/content/343/bmj.d6387?tab=responses.

Government of Western Australia. (2009). Laser hazards. Retrieved from http://www.commerce.wa.gov.au/worksafe/content/safety_topics/Plant_and_machines/Additional_information/Laser_hazards.html.

Hutter, H., Moshammer, H., Wallner, P., Cartellieri, M., Denk-Linnert, D., Katzinger, M., Ehrenberger, K., Kundi M., (2010). Tinnitus and mobile phone use, *Occupational and Environmental Medicine* (on-line), doi:10.1136/oem.2009.048116.

IARC (International Agency for Research on Cancer). (2002). IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, v80, *Non-Ionising Radiation, Part 1: Static and Extremely Low-Frequency (ELF) Electric and magnetic Fields.* Retrieved from monographs.iarc.fr/ENG/Monographs/vol80/mono80.pdf.

IARC (International Agency for Research on Cancer). (2011). Carcinogenicity of radiofrequency electromagnetic fields, *The Lancet Oncology*, 12, 624-626.

ICNIRP (International Commission for Non-ionising Radiation Protection). (2002). Statement on the general approach to protection against non-ionising radiation protection, *Health Physics,* 82(4), 540-548

ICNIRP (International Commission for Non-ionising Radiation Protection). (2009). Statement on the Guidelines limiting exposure to time-varying electrical, magnetic and electromagnetic fields, *Health Physics,* 97(3), 257-258

ISO(International Standards Organisation). (2007). ISO 20473:*Optics and photonics – Spectral bands*

Krauss, L., & Scherrer, R., (2008), The End of Cosmology?, *Scientific American,* March 2008, 34-41

Kroemer, K., & Grandjean, E., (1997). *Fitting the Task to the Human*, Taylor & Francis, London.

Ng, K.-H. (2003). Non-ionizing radiation ï sources, biological effects, emissions and exposures. In *Proceedings of the International Conference on Non-Ionizing Radiation at UNITEN.* Retrieved from http://www.who.int/peh-emf/meetings/archive/en/keynote3ng.pdf

NRPB (National Radiological Protection Board). (2001). *ELF Electromagnetic Fields and the Risk of Cancer: Report of an Advisory Group on Non-Ionising Radiation*. Retrieved from http://www.hpa.org.uk/web/HPAweb&HPAwebStandard/HPAweb_C/1254510570928

Ontario Ministry of Labour. (2009). *Ultraviolet Radiation in the Workplace.* Retrieved from http://www.labour.gov.on.ca/english/hs/pubs/uvradiation/

Reese, M., Gevorgyan, S., Jørgensen,M., Bundgaard,E., Kurtz, S., Ginley, D., Olson, D., Lloyd, M., Morvillo, P., Katz, E., Elschner, A., Haillant, O., Currier, T., Shrotriya, V., Hermenau, M., Riede, M., Kirov, K., Trimmel, G., Rath, T., Inganäs, O., Zhang, F., Andersson, M., Tvingstedt, K., Lira-Cantu, M., Laird, D., McGuiness, C., Gowrisanker, S., Pannone, M., Xiao, M., Hauch, J., Steim, R., DeLongchamp, D., Rösch, R., Hoppe, H., Espinosa, N., Urbina, A., Yaman-Uzunoglu, G., Bonekamp, J., van Breemen, A., Girotto, C., Voroshazi, E., Krebs, F., (2011). Consensus stability testing protocols for organic photovoltaic materials and devices, *Solar Energy Materials and Solar Cells*, 95(5), 1253-1267, 10.1016/j.solmat.2011.01.036. Retrieved from http://www.sciencedirect.com/science/article/pii/S092702481100050X

Safe Work Australia, (2008). Guidance Note *Protection of Workers from UV Radiation in Sunlight.* Canberra, ACT. Safe Work Australia. Retrieved from http://safeworkaustralia.gov.au/AboutSafeWorkAustralia/WhatWeDo/Publications/Documents/306/GuidanceNote_ProtectionOfWorkers_UltravioletRadiationInSunlight_2008_RTF.rtf

Safe Work Australia. (2010b). *Work Health and Safety Regulations* (Draft). Canberra, ACT: Safe Work Australia.

Safe Work Australia, (2011a). *Key Work Health & Safety Statistics,* Retrieved from http://www.safeworkaustralia.gov.au/AboutSafeWorkAustralia/WhatWeDo/Publications/Documents/567/KeyWHSStatistics2011.pdf

Safe Work Australia, (2011b). *National Hazard Exposure Worker Surveillance: Exposure to direct sunlight and the provision of sun exposure controls in Australian workplaces,* Retrieved from http://www.safeworkaustralia.gov.au/AboutSafeWorkAustralia/WhatWeDo/Publications/Documents/310/NationalHazardExposureWorkerSurveillance_Exposure_DirectSunlight_Provision_SunExposureControls_AustralianWorkplaces_2010_PDF.pdf

Safe Work Australia, (2011c). *Model Code of Practice on Welding and Allied Processes. .* Canberra, ACT. Safe Work Australia.

SA (Standards Australia). (2006) AS1680.1: *Interior lighting and workplace design – General principles and recommendations.* Sydney: Standards Australia/Standards.

SA (Standards Australia). (2006). AS4502.1: *Methods for evaluating clothing for protection against heat and fire - Evaluation of thermal behaviour of materials and material assemblies when exposed to a source of radiant heat.* Sydney, Australia Standards Australia;

SA/SNZ (Standards Australia/Standards New Zealand). (1996). AS/NZS 4399:*Sun protective clothing - Evaluation and classification*. Sydney and Wellington: Standards Australia/Standards New Zealand.

SA/SNZ (Standards Australia/Standards New Zealand). (2003). AS/NZS 1067: *Sunglasses and Fashion Spectacles.* Sydney and Wellington: Standards Australia/Standards New Zealand.

SA/SNZ (Standards Australia/Standards New Zealand). (2004) AS/NZS 2243.5: *Safety in Laboratories Part 5: Non-ionising radiations – Electromagnetic, sound and ultrasound.* Sydney and Wellington: Standards Australia/Standards New Zealand.

SA/SNZ(Standards Australia/Standards New Zealand). (2008). AS/NZS 2635: *Solaria for Cosmetic Purposes.* Sydney and Wellington: Standards Australia/Standards New Zealand.

SA/SNZ/IEC (Australia/Standards New Zealand/International Electrotechnical Commission).(2011). AS/NZS IEC 60825.1: *Safety of laser products – Equipment classification, requirements and user's guide.* . Sydney and Wellington: Standards Australia/Standards New Zealand.

Sichel, A., (1923). So Called Glass-Workers Cataract Occurring in other Occupations, *British Journal of Opthalmology*, April 1923, 161-167. Retrieved from http://www.ncbi.nlm.nih.gov%2Fpmc%2Farticles%2FPMC513630%2Fpdf%2Fbrjopthal00948-0001.pdf&ei=XApcT-y-OaquiAf8udG9DQ&usg=AFQjCNHDkOo2nojS-OxEP4UWvjDgvyhthw&sig2=xcCVHuIsfX7pqlJRYEQZFA&cad=rja

University of Texas. (2009). Laser safety. Retrieved from http://www.utexas.edu/safety/ehs/lasers/Laser%20Safety%20Handbook-tnt.pdf

Wertheimer, N., & Leeper, E. (1979). Electrical Wiring Configuration and Childhood Cancer. *American Journal of Epidemiology*, 109(3), 273-284

WHO (World Health Organization). 2007. *Extremely Low Frequency Fields, Environmental Health Criteria Monograph No. 238.* Retrieved from http://www.who.int/entity/peh-emf/publications/Complet_DEC_2007.pdf

WHO (World Health Organization). (2011). Electromagnetic fields. Retrieved from http://www.who.int/peh-emf/about/WhatisEMF/en/index.html

WorkSafe Victoria, 2006. *Officewise - A guide to health and safety in the office*, Melbourne

Vecchia, P., Hietanen, Stuck, B. E., van Deventer, E., & Niu, S. (2007). *Protecting Workers from Ultraviolet Radiation.* International Commission on Non-Ionizing Radiation Protection. Retrieved from http://www.icnirp.de/documents/UVWorkers.pdf