Association of University Radiation Protection Officers

AURPO Guidance Note on Use of Non - Ionising Radiations in Research and Teaching 2013 Edition

AURPO Guidance Note No. 8

These notes were prepared by the AURPO Scientific & Technical Committee

CONTENTS

page

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Introduction

Radiation is the process of emitting energy as waves or particles. Radiation may be emitted from a variety of sources. The human body can absorb radiation and in some cases the effects are adverse. The severity of effects depends on a number of factors.

Ionising radiation (IR) is radiation which produces ionisation in matter; ionising electromagnetic radiation, has enough energy to make a neutral atom or molecule acquire or lose an electric charge resulting in the production of positively and negatively charged ions – hence the term ionising radiation. Non-ionising radiation (NIR) does not have enough energy to produce ionisation in matter.

Radio waves, light and gamma rays are all part of the electro-magnetic spectrum. They are all oscillating fields with two components, an electric field (E) and a magnetic field (H). They do not require any medium to transmit them and travel through space (vacuum) at the speed of light. The frequency of the oscillations is inversely proportional to the wavelength such that:

$$\mathbf{c = f\lambda}$$

where c = velocity of wave (3×10^8 ms^{-1} in free space), f = frequency and λ = wavelength (m). The energy associated with electromagnetic radiation comes in packets or quanta and is proportional to the frequency of the radiation such that:

$$\mathbf{E = h\,f}$$

where E = photon energy, f = frequency of the wave and h = Planck's constant.
Under these circumstances electric and magnetic fields propagate normal to each other and to the direction of propagation, i.e. transverse electromagnetic waves.

Electromagnetic radiation can be subdivided dependent on either its frequency or wavelength. For practical purposes the non-ionising radiations spectrum is divided into '**optical radiations**' covering UV, visible and infra-red, and '**electromagnetic fields**' covering time varying fields and static fields. This standard treatment is used by regulatory and advisory bodies.

Ultraviolet (UV) is on the boundary of ionising and non-ionising radiations. Very short vacuum UV is ionising and by convention non-ionising radiations are those having a wavelength longer than 100 nm as this equates to an energy of 12.4 eV which is sufficient to create ionisation.

As can be seen in Figure 1, non-ionising radiations form the major part of the electro-magnetic spectrum.

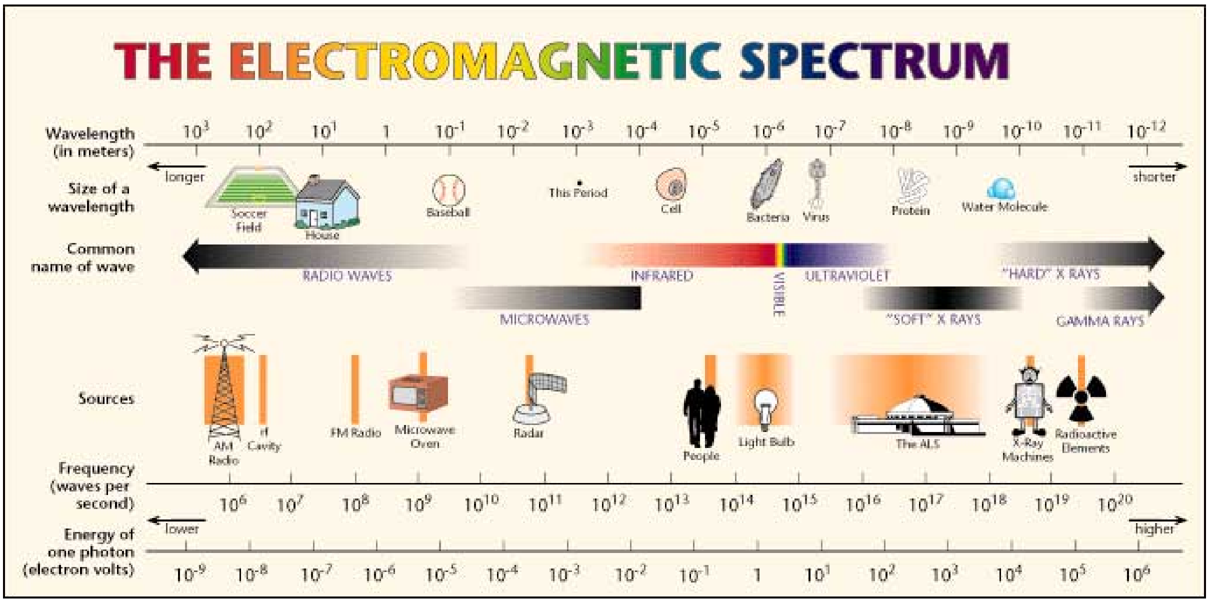
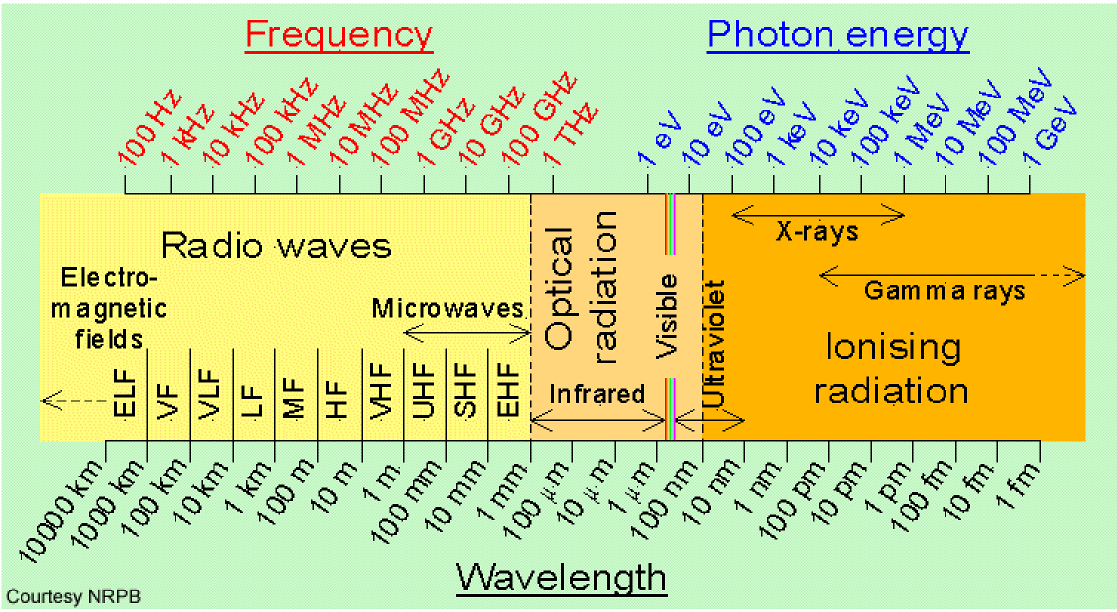


Figure 1. The Electromagnetic Spectrum

From the spectrum's wavelengths (Table 1), it can be seen that non-ionising radiation starts in the UV, continues through the 'optical wavelengths' (UV, visible and infrared) and then continues down with ever increasing wavelength through the electromagnetic fields of: microwaves; radiowaves (RF); extremely low frequencies (ELF) until static fields are reached.



λ>100 km	**100 km - 1m**	**1 m – 1 mm**	**1 mm -760 nm**	**760 – 380 nm**	**380 – 10 nm**	**λ<10 nm**
ELF	**RF**	**MICROWAVE**	**INFRA-RED**	**VISIBLE**	**UV**	**X-RAYS**

Table 1. Frequencies and Wavelengths of the different parts of the spectrum

The International Commission on Non-Ionizing Radiation Protection (ICNIRP), http://www.icnirp.org/, issues guidelines for exposure limits and these are implemented into European Union (EU) law by the European Commission (EC) under the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents directives (i.e. 'Physical Agents Directives'). There are Physical Agents Directives for both 'Artificial Optical Radiation' and for 'Electromagnetic Fields' and the Health and Safety Executive (HSE) have produced online guidance to assist employers in this field - http://www.hse.gov.uk/radiation/nonionising/index.htm

This guidance covers 'Artificial Optical Radiation' and 'Electromagnetic Fields' separately and further subdivides the guidance to match (and link into) guidance provided for different types of source in Table 2.

1. Artificial Optical Radiation	❖ Lasers ❖ Non-laser broadband sources (including light emitting diodes, LEDs) ❖ Ultraviolet (UV) ❖ Infrared (IR) ❖ Bright lights
2. Electromagnetic Fields (EMF)	❖ Microwaves and Radiofrequency (RF) ❖ Extremely low frequencies (ELF) ❖ Sub ELF – static and magnetic fields (inc NMR)

Table 2. Sources of non-ionising radiation

1. Optical Radiation

It should be noted that natural radiation from the sun is not covered by the EU Physical Agents Directive or by national legislation. Common sense should guide us for natural sources so as to avoid excessive exposure, in particular to UV radiation. A good guide to this can be found on the Public Health England website –

www.hpa.org.uk/Topics/Radiation/UnderstandingRadiation/AtAGlance/Flash_Sunsense/

In addition, the HSE has Publications that give advice on exposure to the sun:

- Keep Your Top On The Health Departments of England, Scotland and Wales have endorsed this advice on the health risks from working in the sun.
- Sun protection: advice for employers of outdoor workers (INDG337, 04/01). This gives advice to employers on reducing the health risks to their employees when they are working outside in the sun.

So, apart from the general duties with regard to health and safety in the Health and Safety at Work etc Act 1974, the specific regulations above dealing with optical radiations are confined to artificial sources.

The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995, RIDDOR, lists “Loss of sight (temporary or permanent)” as a reportable major injury.

1.1 The Control of Artificial Optical Radiation at Work Regulations

The Control of Artificial Optical Radiation at Work Regulations 2010, SI No. 1140 were implemented into UK law in April 2010; they enacted the Artificial Optical Radiations Directive 2006/25/EC.

Artificial Optical Radiation (AOR) is defined as radiation in the wavelength range from 100 nm - 1 mm; anything less than 100nm is ionising UV and greater than 1mm is microwave radiation. The Health Protection Agency[1] (HPA-RPD) assisted the EU by providing a very extensive and useful non-binding guide (161 pages!) on AOR to accompany the Directive, Non-binding guide to good practice for implementing Directive 2006/25/EC.

The HSE produced a shorter 8 page guide Guidance for Employers on the Control of Artificial Optical Radiation at Work Regulations (AOR) 2010. The guidance was prepared to help employers to decide what they needed to do to protect workers and comply with the Regulations.

All hazardous sources should already have been identified by risk assessments under the Management of Health and Safety at Work Regulations 1999.

[1] Formerly the National Radiological Protection Board (NRPB), the Health Protection Agency (HPA) became part of Public Health England (PHE) from 1 April 2013.

1.1.1 Health Effects of Exposure to Optical Radiation

Optical radiation has a limited penetration into the human body and the effects are generally limited to the skin and eyes as shown in Figures 2 and 3.

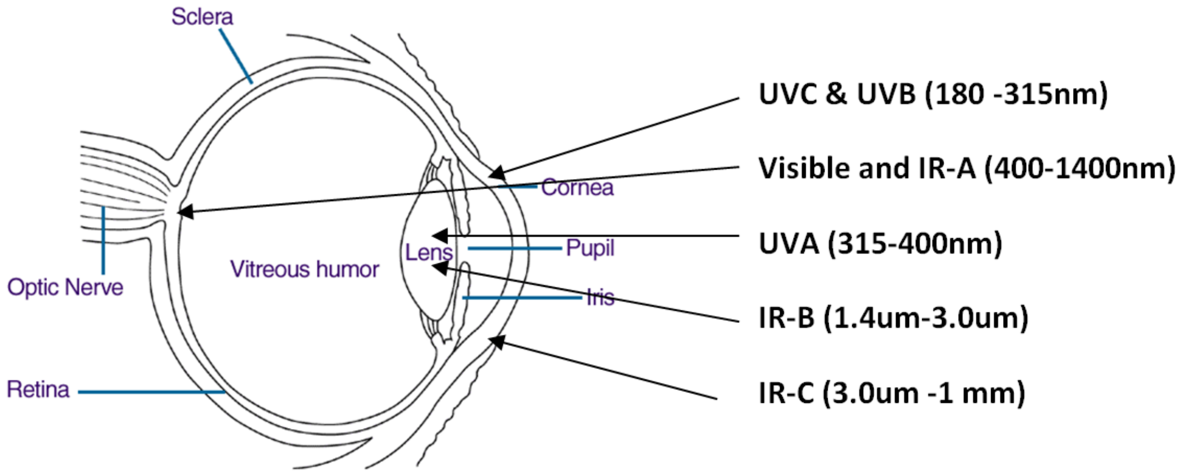


Figure 2. Penetration of optical radiation into the eye

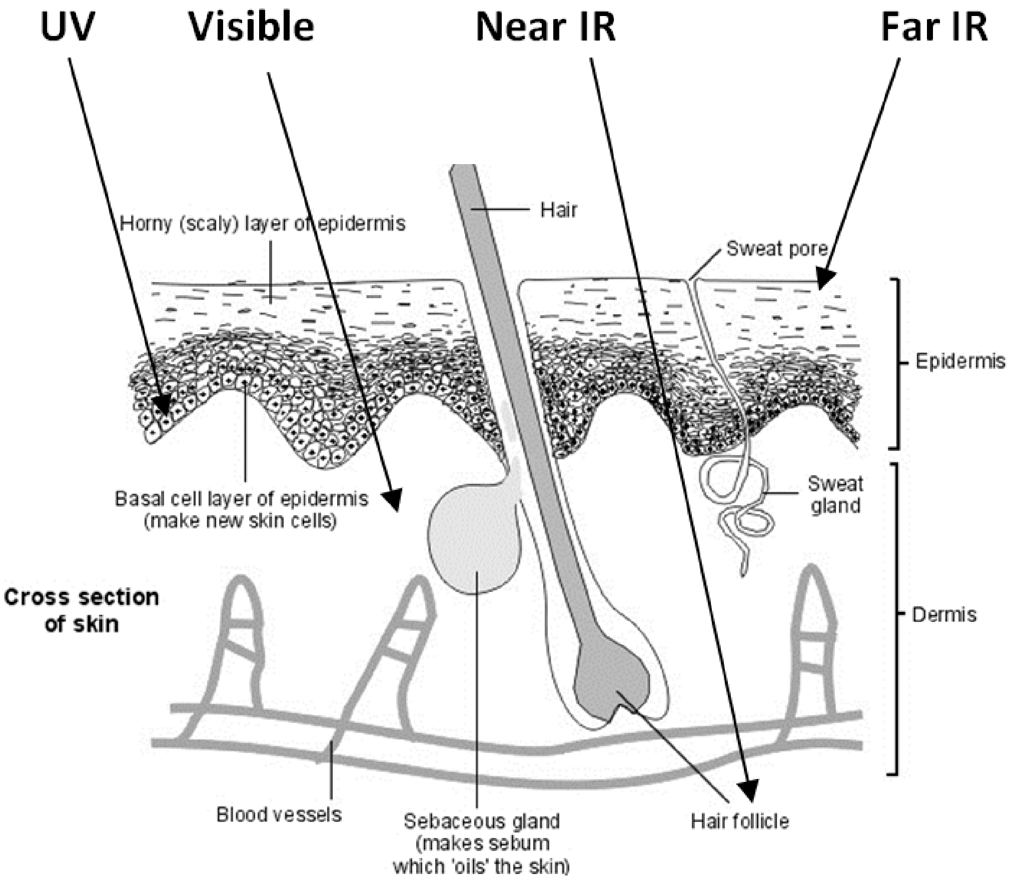


Figure 3. Penetration of laser radiation into the skin

This penetration into the skin or eye deposits energy leading to a number of different types of biological effect which can have a harmful effect.

Photochemical effects result from chemical reactions in the body initiated by the absorption of photons; for each type of reaction there is a threshold photon energy or wavelength below which the effect will not take place. Photochemical effects are predominant in the ultraviolet and blue/green visible regions. A positive effect is vitamin D synthesis and vision.

Thermal (heating) effects become dominant as the wavelength increase and the photon energy decreases; molecular bonds of proteins and enzymes are disrupted. The amount of damage depends on magnitude and duration of the temperature rise.

The biological effects on the eye and skin are tabulated below in Table 3.

λ (nm)	**Region**	**Effects on eye**	**Effects on skin**
100 - 280	UVC	photokeratitis*, photoconjunctivitis*	erythema, skin cancer
280 - 315	UVB	photokeratitis, photoconjunctivitis, cataracts	erythema, elastosis (photageing), skin cancer
315 - 400	UVA	photokeratitis, photoconjunctivitis, cataracts, photoretinal damage	erythema, elastosis (photoageing), immediate pigment darkening, skin cancer
380 - 780	Visible	photoretinal damage, (Blue Light Hazard), retinal burn	burn
780 - 1400	IRA	cataracts, retinal burn	burn
1400 - 3000	IRB	cataracts	burn
3000 - 10^6	IRC	corneal burn	burn

Table 3 Effects on Eye and Skin *(Table taken from Non-Binding Guide to AORD)*

*Photoconjunctivitis is inflammation of the outermost layer of the eye and inner surface of the eyelids. Photokeratitis is more severe and is like sunburn of the cornea and can take several hours to materialise; it will give a gritty feeling in the eye and increased tear production.

Further information on UV health effects can be found on WHO website at - http://www.who.int/uv/health/en/

1.2 Lasers

Lasers are already dealt with under the requirements of the BS EN 60825 series and AURPO have already produced separate guidance for work in this area, GUIDANCE ON THE SAFE USE OF LASERS IN EDUCATION AND RESEARCH, AURPO Guidance Note No. 7, 2012 Revised Edition.

1.3 Non-laser Broadband Sources (including Light Emitting Diodes, LEDs)

The vast majority of other light sources are known to be safe. Only those sources likely to cause harm need to be identified and appropriate measures taken. These are most likely to be sources of invisible optical radiation (UV and IR) where safety is not necessarily afforded by the aversion response.

The safety classification of non-coherent (not laser) sources is defined in BS EN 62471 and **is** based upon maximum accessible emission levels. **Note** there are two parts to the **'**Photobiological Safety of Lamps and Lamp Systems**'**, Part 1 is **BS EN 62471:2008** ***Photobiological safety of lamps and lamp systems*** and Part 2: **IEC/TR 62471-2:2009** Guidance on manufacturing requirements relating to non-laser optical radiation safety. Both parts of this standard will need to be looked at to fully understand the requirements of the regulations.

Four risk groups have been identified by BS EN 62471 with only the highest risk group presenting a significant risk of harm.

1.3.1 Risk Groups

1. Exempt	- no photobiological hazard under foreseeable conditions. e.g. domestic and office lighting, computer monitors, equipment displays and indicator lamps.
2. Risk Group 1	- low risk, limited by normal behavioural limitations on exposure. Safe for most applications – requires prolonged direct ocular exposure to cause discomfort/harm. Some bright light sources such as a torch may fall into this category.
3. Risk Group 2	- moderate risk, but risk limited by aversion response to very bright light sources or thermal discomfort. Such aversion responses may not always be applicable, especially to sources of invisible optical radiation[2].
4. Risk Group 3	- high risk, may pose a risk of harm even from a brief exposure. Training and safety control measures required for any source falling into this risk category. Written schemes of work required to include contingency plans for accidents or incidents.

It can clearly be seen that there is a parallel with laser safety here in that a Class 2 laser emits only visible laser radiation and safety is afforded by the aversion response as is Risk Group 2. A Class 3B laser presents an eye hazard as does Risk Group 3. Some Risk Group 3 sources will also present a skin hazard but are not necessarily as serious a hazard as a Class 4 laser.

The HSE in their guidance have focussed on potentially hazardous sources but have also identified those sources that do not pose a hazard so that time and effort is not wasted on these. The EC non-binding guide gives a more extensive review of optical sources. These guides, previously referenced, should be referred to if in any doubt.

An even briefer review is given in the HSE guidance note.

[2] Be wary of situations in which: people may be staring at a light source; sources of invisible optical radiation where the aversion response is not effective; situations where young people may be involved or where people involved may be under the influence of drugs or alcohol.

1.3.2 HSE Identified potential hazardous light sources

- Metal working-welding and plasma cutting
- Pharmaceutical and research – UV fluorescence and sterilisation systems
- Hot industries with furnaces
- Printing- UV curing processes
- Motor vehicle repairs – UV curing processes
- Medical and cosmetic treatments

1.3.3 HSE Identified safe light sources

- All forms of ceiling mounted lighting in offices
- Compact fluorescent lamps and tungsten halogen lamps >60cm from user
- All forms of task lighting (includes desk lamps etc)
- Photocopiers
- Computer type displays
- Photographic flashlamps
- Gas-fired overhead heaters
- Vehicle lights other than headlights

1.3.4 HSE Identified light sources where aversion response should ensure safety but staring at these sources for long periods or being in close proximity could be a problem

- High pressure mercury floodlights
- Desktop projectors
- Interactive whiteboards
- Vehicle headlights
- Medical theatre and task lights including foetal transilluminators and x-ray viewing boxes
- UV insect traps
- Spotlights, effect lighting and flashlamps used in entertainment

The above lists are not exhaustive but give a good guide as to what to look out for. Precautions and PPE should already be in place for all the identified hazardous situations e.g. welders goggles - visors and gloves for welding (adventitious UV) and hot metal work; visors for UV work .

1.3.5 What should we currently be doing?

There should be a policy in place that identifies who is going to be responsible for overseeing the requirements of AOR Regs 2010. This may be the Safety Officer or Laser Safety Officer or some other person depending on local circumstances. The important thing is that somebody is identified in every user department who will take on board the job of identifying whether any Risk Group 2 or 3 sources are used and ensure that they are used in a safe manner. The first thing to consider is whether the Risk Group 2 or 3 sources are really needed and whether safer alternatives could be used e.g. non-UV transilluminators or UVA sources instead of UVB ones.

Assuming that elimination or a safer alternative cannot be found then the following control measures need to be considered:-

- Preventing or controlling access by engineering controls and design features of equipment to limit exposure, e.g. interlocked screening.
- Restricting access to hazardous areas to trained, authorised personnel only.
- Increase distance between staff and the harmful source.
- Ensure safe systems of work are in place and that workers involved have received suitable and sufficient information and training.
- Have documented risk assessments for Risk Group 3 sources and possibly Risk Group 2 sources – these should have been included in existing workplace risk assessments.
- Have a procedure for effectively dealing with accidents.
- Issue Personal Protective Equipment (PPE), e.g. goggles or face visors.

PPE should be regarded as a last line of defence and only adopted after a full safety evaluation has been carried out and other means of affording protection have been considered. Its use should not be regarded as a convenient alternative to proper engineering controls or thorough hazard assessments.

1.3.6 Maximum Permissible Exposure Levels/ Exposure Limit Values

The following hazardous wavelength bands have been identified for broadband sources:-

- Actinic UV hazard
- Eye UVA hazard
- Retinal Blue Light hazard
- Retinal thermal hazard
- Infrared radiation hazard

Maximum permissible exposure levels (MPEs) or exposure limit values (ELVs) as they are now called in the regulations have been established by ICNIRP and American Conference of Government Industrial Hygienists (ACGIH) and it is these values that have been used in the relevant standards and regulations. Table 1.1 from the AOR Directive shows which limits apply as a function of wavelength, time and target organ. For some wavelength regions there is a simple exposure limit for any wavelength within that region e.g. for UVA the ELV is 10^4 J/m^2. If the irradiance at a given location is known, then the maximum exposure duration at that location can be calculated. The worst-case exposure duration is considered to be 8 hours for the workplace. Therefore, if the irradiance is less than 10^4 J/m^2 divided by 30,000 s (approximately 8 h), or 0.33 W/m^2, it will not be possible to exceed the ELV. For the UV actinic hazard and for the Blue Light Hazard, however, the hazard varies with the wavelength making assessments more difficult unless one has a weighted response filter for the hazard region. With the right detector, filter and radiometer combination a direct hazard reading can be taken in effective watts (W_{eff}).

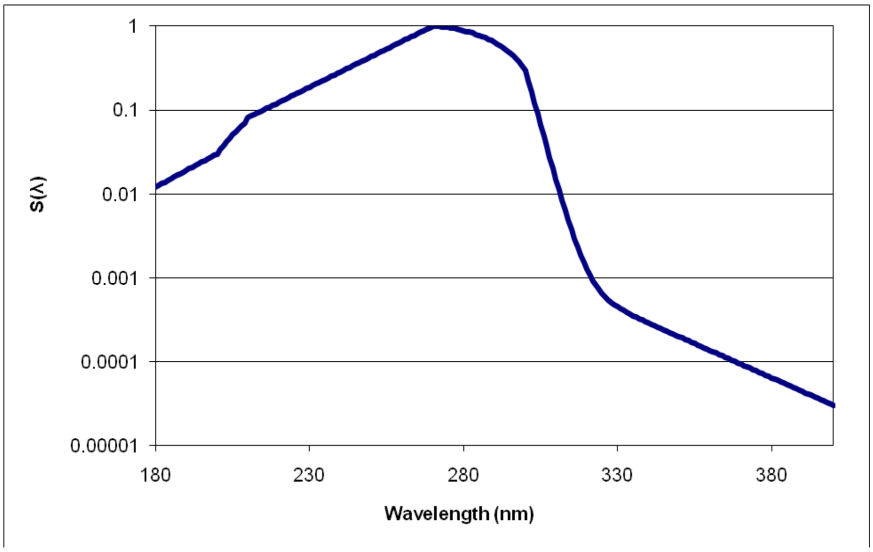


Figure 4. Spectral Weighting function for actinic UV {S(λ)}

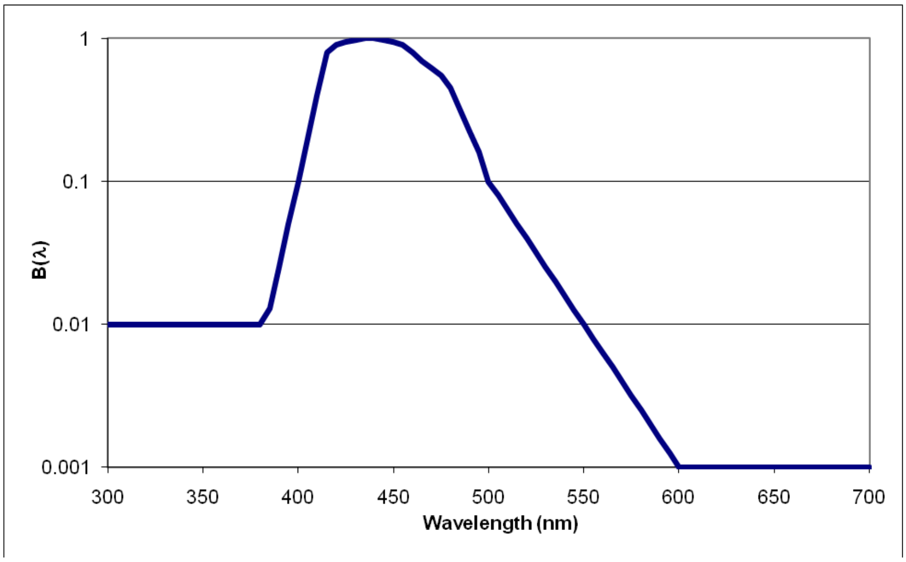


Figure 5. Spectral Weighting function for Blue Light Hazard {B(λ)}

The weighted response filters let all of the 'light' through at the most hazardous wavelengths and then an amount proportionate to the effectiveness of the wavelength at all other wavelengths. However, these instruments have limitations and can only be relied upon if the exposure level is close to decision levels, such as the ELV, if they have been calibrated using a source with a similar emission spectrum to the source under investigation.

W_{eff}/cm^2	$\mu W_{eff}/cm^2$	MPE
1×10^{-7}	0.1	8 hours
8×10^{-7}	0.8	1 hour
5×10^{-6}	5	10 min
5×10^{-5}	50	1 min
3×10^{-4}	300	10 sec
3×10^{-3}	$3mW/cm^2$	1 sec

Table 4. UVB/C Maximum Permissible Exposures (MPE) in Working Day (ACGIH)

(MPE is equivalent to 3000 $\mu W_{eff}/cm^2$ in an 8 hour day. Divide this by instantaneous reading in $\mu W_{eff}/cm^2$ to get maximum permitted exposure time in seconds per day.)

1.3.7 Measurements

Guidance from the HSE and the Non-Binding Guide indicate that the taking of measurements as part of the risk assessment may not always be necessary. Sometimes the hazard is obvious and the precautions to be taken well established. A lot depends however on the information that has been provided by the manufacturer in relation to lamp output. With good data, calculations can be made to establish safe working distances and the relative hazard at normal working positions. For new products this should improve as manufacturers start to use PD IEC/TR 62471-2:2009 but for old products the user is often left in the dark, e.g. many users are unsure as to the wavelength of their transilluminators (see 1.3.9). Prospective purchasers should ask manufacturers/suppliers for the relevant information and, if this is not forthcoming, alternative products should be sought.

There may be times then when measurements need to be taken and this will necessitate the use of some expensive equipment that might not be readily available. PD IEC/TR 62471-2:2009 recommends that a monochrometer with integrating sphere should be used to measure lamp output, but this guidance is intended for manufacturers performing measurements on an optical bench. Practical measurements taken in the workplace require something more portable such as a radiometer with a range of detector heads (see Fig 6) that correspond to the different wavelength bands. Sometimes additional weighted response filters can be used to give a direct hazard reading e.g. for UV and for Blue Light Hazard.

Figure 6. Solid State Radiometer with detectors

1.3.8 Safety signs and labels

Warning signs shall comply with the Health & Safety (Safety Signs and Signals) Regulations 1996. BS ISO 3864-1:2011, *Graphical symbols. Safety colours and safety signs. Design principles for safety signs and safety markings* was published in September 2011. Warning signs and mandatory notices (as shown in Figure 7) are best displayed in close proximity to equipment/areas where access to hazardous levels of (in this example) UV is possible.

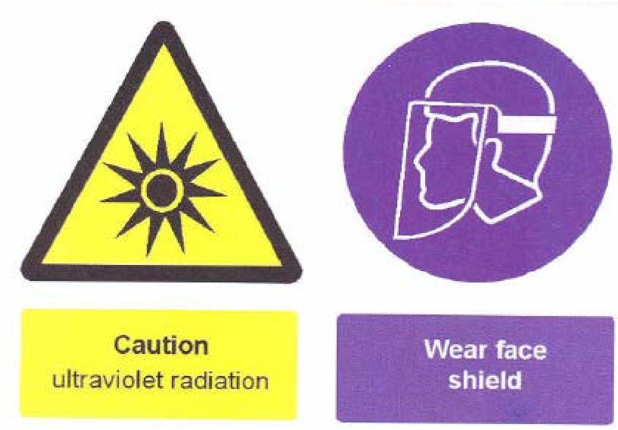


Figure 7. Example signs (taken from 9.5.3 of non-binding guide)

Users may wish to design their own labels that are more appropriate to the equipment being used and the hazard it presents. Examples are given in Figure 8 for a UV germicidal cabinet and in Figure 9 for a transilluminator. It is just black on yellow warning labels that have been used here (consistent with laser supplementary labels) although one could argue that the instructions accompanying the warning notice should be in the form of a blue and white mandatory sign.

CAUTION ULTRAVIOLET RADIATION

- Switch off UV before opening sash
- Hazardous UVC radiation could be present
- Less than 30 sec exposure could exceed the MPE for the skin.

Figure 8. Example Germicidal Cabinet Warning Label

CAUTION ULTRAVIOLET RADIATION

1. Work must always be carried out behind a screen or a full face visor must be worn
2. Operators should also ensure that their hands and forearms are always covered.
3. To protect other people in the vicinity there should be screens to the rear and sides of the transilluminator.

NB UVB from transilluminator is hazardous up to 2m away.

Figure 9. Example UVB Transilluminator Warning Label

Hazard	RG 1	RG2	RG3
Actinic UV/UVA (200nm - 400nm)	UV emitted from this product	CAUTION UV emitted from this product	WARNING UV emitted from this product
Retinal Blue Light or thermal hazard (300nm -780nm)	n/a	CAUTION Possibly hazardous optical radiation emitted from this product	WARNING Possibly hazardous optical radiation emitted from this product
Retinal thermal weak visual stimulus. (780nm – 1400nm)	WARNING IR emitted from this product	WARNING IR emitted from this product	WARNING IR emitted from this product
IR – eye (780nm - 3000nm)	IR emitted from this product	CAUTION IR emitted from this product	WARNING IR emitted from this product

Table 5. Manufacturer's Hazard related risk group labelling

PD IEC/TR 62471-2:2009 recommends labelling which manufacturers should provide with lamps and lamp systems. It is recommended that manufacturers should label the housing of the lamps (if practicable) with the Risk Group and appropriate warnings as indicated in Table 5 above. The label should be black on yellow as shown in Figure 10 below. If it is not practical to affix such a label one should be clearly shown in the user manual. NB this is a manufacturers' requirement and users may wish to highlight the particular hazard more as in Figures 8 & 9 rather than the Risk Group which will have limited meaning for users.

RISK GROUP 3

WARNING IR emitted from this product.

Do not look at operating lamp

CAUTION UV emitted from this product.

Eye or skin irritation may result from exposure. Use appropriate shielding.

Figure 10. Example Label: IR hazard is RG3 and UV hazard is RG2.
NB there is also warning text that has been added.

1.3.9 Information, Instruction and Training

Information, instruction and training is required when a risk assessment indicates that exposure in excess of any ELV is reasonable foreseeable.

Training should include:-

- What is being done to minimise exposure
- Who is managing the risks
- What are the ELVs
- Findings of risk assessment, measurements taken
- Reporting of any adverse effects
- Health surveillance

- Safe working practices
- Use of PPE

1.3.10 Health surveillance and medical examinations

The requirement, under Regulation 6 of AOR Regs 2010, for health surveillance and medical examinations only applies in situations where employees have been exposed to AOR in excess of ELVs or individuals have an identifiable disease or condition that makes them particularly susceptible to artificial optical radiation. The risk assessment should identify people at particular risk, and anyone with an existing condition that may be affected by work with UV or lasers (e.g. particular photosensitivity to UV) should be referred for medical advice.

There is no statutory requirement under the Control of Artificial Optical Radiation at Work Regulations 2010 (AOR) for routine medical surveillance for the eye. However, appropriate medical supervision is required if someone is exposed to optical radiation in excess of the MPE (termed the Exposure Limit Value in the Regulations).

Medical examination of overexposed persons or persons at risk should be carried out by a doctor or other suitably qualified person. This medical practitioner should also be able to advise on any future health surveillance that may be required.

A health record is only required for an exposed employee.

1.3.11 Things to watch out for

In the university and research sector, UV sterilisation and induced fluorescence equipment are the items that are most likely to have outputs well in excess of MPEs/ELVs and accidental overexposures with this type of equipment have been reported, e.g.

- Burns to face, neck and wrists through inadequate PPE with transilluminators
- Photokeratitis/conjunctivitis through inadequate screening/PPE with transilluminators
- Burns to skin and photokeratitis/conjunctivitis through inadequate screening/carelessness with germicidal lamps

A survey undertaken at one university highlighted a number of things to watch out for associated with the use of germicidal lamps, transilluminators and mineral lights.

1.3.11.1 Biological Safety Cabinets

Biological Safety Cabinets (BSC) are often fitted with UVC germicidal lamps. All modern ones should have interlocked front covers or sashes to prevent accidental exposure when a cover is removed or sash raised. Be careful though because not all do and many older BSCs do not and their warning notices (if present) are often poorly sited, hard to read and give inadequate warning as can be seen in the example below from Nuaire (Figure 11).

With the sash raised on one of these Nuaire cabinets the effective UV irradiance just outside the cabinet is approximately 110 $\mu W_{eff}/cm^2$ or 1.1 W_{eff}/m^2 (25 second maximum permissible exposure duration) and this is Risk Group 3. A similar Heraeus germicidal cabinet with a non-interlocked front cover was found to give a effective UV irradiance of approximately 50μW$_{eff}$ /cm^2 outside the cabinet (56 second maximum permissible exposure duration) and this is also Risk Group 3.

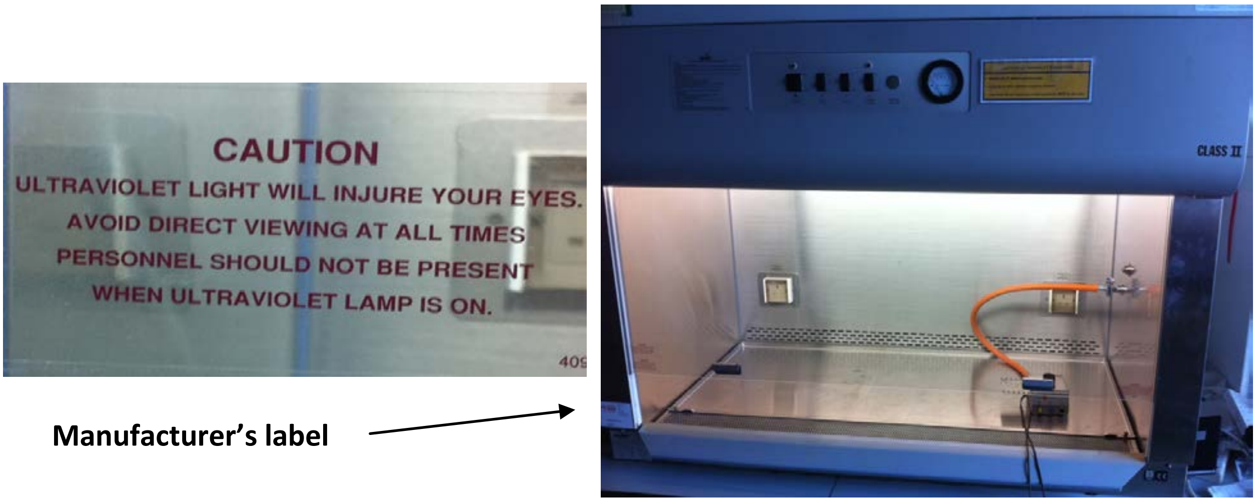


Figure 11. Example of Nuaire Class 2 Biological Safety Cabinet

1.3.11.2 Transilluminators

Transilluminators can operate in the visible, UVA or UVB spectral regions and whenever possible the safest option should be sought when buying new equipment. When assessing existing equipment it has been found that users are often unsure as to the wavelength emitted by their transilluminator and devices are often marked up incorrectly by the user e.g. precautions taken for UVB emissions when the transilluminator only emits UVA and is a Risk Group 1 device.

Typical UVB transilluminators do emit high levels of UVB with a weighted output at 10 cm from the surface of the order of 1500 μW$_{eff}$/cm^2 or 15 W$_{eff}$/m^2 (just 2 seconds for the MPE to be exceeded). With the MPE reached in such a short period of time it is easy to see how users can burn their wrists if they do not ensure that their skin is well covered. These are hazardous Risk Group 3 devices and require warning signs, PPE, training and inclusion in a risk assessment. Again watch out for poor warning signs from manufacturers. A UVB 'Syngene' transilluminator was found which had a warning sign stating that, 'we recommend to wear UV protection goggles or face shield'. Anyone who just wore goggles for any length of time could get severe sunburn to the face.

Many transilluminators are now housed in cabinets and although these generally have interlocked covers, the interlocks are easy to bypass and are often bypassed by users who need to cut out gels with the UV light on. In these circumstances the same precautions as for freestanding transilluminators need to be taken. The 'Bio-Rad' cabinet (see Figures 12 & 13) comes with a protective screen that can be fitted when work needs to be done with the interlocks over-ridden.

Figure 12. Bio-Rad Transilluminator Cabinet **Figure 13. With 'Safety Screen' in place**

Unfortunately in this case the manufacturer has only used ordinary Perspex for the screen rather than UV opaque Perspex so that some of the hazardous UV gets through. Tests showed that transmission through the screen was 18 $\mu W_{eff}/cm^2$ or 0.18 W_{eff}/m^2 (3 minutes for MPE to be exceeded) so that this still needs to be treated as Hazardous Risk Group 3 with appropriate warning, training, etc.

Care also needs to be taken in the use of protective gloves. Most provide good protection from UV but some thin plastic ones will let UV through. Studies have been undertaken that look at transmission properties of gloves, see -

http://www.ncbi.nlm.nih.gov/pubmed/15238329
http://rpd.oxfordjournals.org/content/121/3/265.abstract

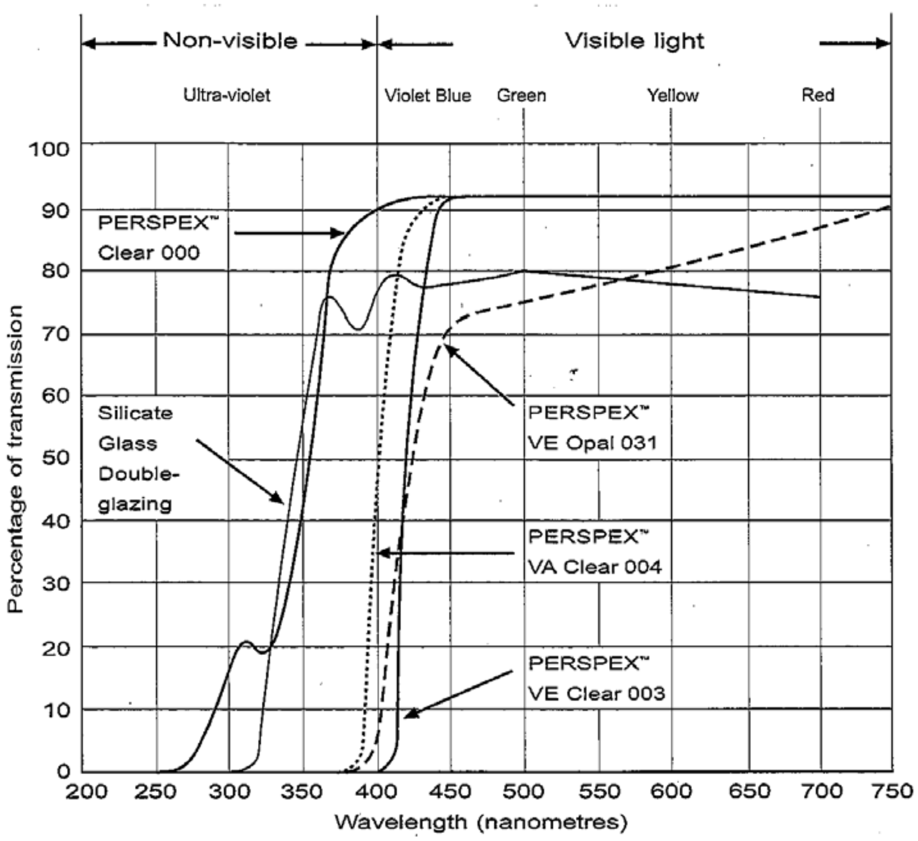


Figure 14. Spectral transmittance of 3mm Perspex™ XT extruded sheets[3]

[3] Figure 14: Clear Perspex VE is designed to cut out all UV but is less resistant to degradation than Perspex VA which lets some UV above 375 nm through. Ordinary Perspex will let 20% UVB through at just over 300nm.

1.3.11.3 Handheld UVC mineral lights

Handheld UVC mineral lights are often used as the name would suggest but they are hazardous Risk Group 3 devices where the MPE for unprotected skin is often less than 30 seconds close to. The full requirements for Risk Group 3 are therefore required.

Figure 15. Example of UVC Mineral light with viewing box

However they can be supplied with viewing boxes (Figure 15) that make them safe to use without further precautions. Some users make up their own viewing boxes that serve the same purpose. Users need to be reminded though that it is not just their eyes that they have to protect but they need to guard against skin exposure as well.

2. Electromagnetic Fields (EMF)

Electro-magnetic fields (EMFs) arise naturally e.g. electric fields generated in thunderstorms and magnetic fields generated from the earth's core. They also arise through human activity e.g. electric and magnetic fields generated whenever electrical energy is used and from radiofrequency emitting devices. Typical background exposure will occur in our daily lives from electrical appliances in our homes and also in the world at large from radio, TV, telecommunication broadcasting masts and from security detection devices. However, the electric and magnetic fields produced by the UK electricity supply are within scientific safety guidelines and radio waves emitted from mobile phones sold in the UK are below current international guidelines. We are concerned here just with artificial sources used in a university teaching and research context.

As mentioned in the Introduction, electromagnetic waves are oscillating fields with two components, an electric field (E) and magnetic field (H). The relationship between these components can be complex or indeed quite simple depending on the frequency and distance from the source. A number of different field regions exist. The further away from the source the emf is the more it behaves like a plane wave and in this region there is a simple relationship between E and H. This region is the **far-field.**

In general, the impedance (z) of an electromagnetic wave is a function of the medium in which the wave is travelling and is defined by :-

$$\mathbf{z = \sqrt{(\mu / \varepsilon)} = E / H}$$

where z is the impedance of the medium (Ω), μ is the permeability of the medium (henry/m), ε is the permittivity of the medium (farad/m), E is the electric field strength (V/m) and H is the magnetic field strength (A/m).

Under far-field conditions the impedance of free space is given by :-

$$\mathbf{z_0 = \sqrt{(\mu_0 / \varepsilon_0)}} \qquad \varepsilon_0 = \text{ permittivity of free space (} 8.854 \times 10^{-12} \text{ F m}^{-1}\text{)}$$

$$\mathbf{= 377\ \Omega} \qquad \mu_0 = \text{ permeability of free space (} 4\pi \times 10^{-7} \text{ H m}^{-1}\text{)}$$

The Poynting vector, S, represents the directional energy flux density of the wave and is given by:-

$$\mathbf{S = E \times H = E^2 / z_0 = H^2 z_0}$$

Under **far-field** conditions S decreases inversely as the square of the distance from the source. However as the source is approached this relationship becomes increasingly less valid and at distances closer than $D^2 / 2\lambda$, where D is the maximum aperture of the source, the relative phases and amplitudes give rise to a complex field distribution and this region is known as the **radiating near field** or **interference near field**. The above relationships between E and H no longer hold true and electric and magnetic field strengths must be measured separately in order to determine field strengths. At distances within $\lambda/2\pi$ of the source, reactive stored energy fields predominate which do not radiate into space but do react with objects and people. This region is known as the **reactive near field region** and again the relationships between E and H no longer holds true and exposure resulting from the source must be determined by separate the separate measurements of electric field strength (E) and magnetic field strength (H).

Measurement of electromagnetic fields is a specialised task. Monitoring instruments are available and these, like ionising radiation instruments, are specific to various regions of the spectrum. When measuring fields we need to know the characteristics of the field being measured, namely the frequency and location of the source. In any region, except the far field, it may be necessary to measure the E and H fields separately. In most cases it will only be necessary to measure one as the other may not have a dominant effect.

The ways in which people can be exposed to electromagnetic fields and the physical interactions and potentially harmful effects that may ensue vary with frequency (and wavelength). Many of the detrimental effects occur as a result of the direct absorption of energy by the human body; the degree depends on a number of factors including the orientation of the electric field, the shape and size of the body, the electrical properties of the tissues and the frequency.

EMF with wavelengths which are shorter than a few centimetres have only limited penetration into the human body; the effects are generally limited to the surface of the body, the skin and the eyes. Penetration is greatest at longer wavelengths (lower frequencies); meaning that energy may then be deposited in deeper tissues and organs.

The body acts as a resonant antenna in certain circumstances and maximum energy absorption occurs when the electric field is polarised parallel to the long axis of the body. The frequency at which resonance occurs depends on the height of the erect body and occurs when this is about 0.4λ (or at about 40 MHz).

At lower frequencies, the predominant interaction is the heating effect of induced currents in the body; these are much more likely in a narrow part of the body such as the neck, wrists or ankles. The degree to which this occurs is dependent on the rate of deposition of the energy per unit body weight, i.e. the specific absorption rate (SAR), in units of Wkg^{-1} and thermoregulation.

The Physical Agents Electromagnetic Fields Directive (June 2013) sets out the minimum health and safety requirements regarding the exposure of workers to electromagnetic fields. Member states have been given 3 years, up to 1st July 2016, to transpose the Directive into national law. UK legislation is being developed and practical guides will be made available to assist in complying with the European directive and national legislation. The European Directive covers well-established health links between short term biophysical effects and exposure to electromagnetic fields, but does *not* include the risks resulting from live conductors or any suggested non-established long term effects. The Directive is similar in format to the artificial optical radiation Directive, setting out exposure limit values and action levels, requirements for assessing and controlling risks and requirements for health surveillance where appropriate.

The European Committee for Electrotechnical Standardization (CENELEC) has issued useful standards documents designed to meet the requirements of the EU Directives and these have been adopted by British Standards. It is likely that any new UK Regulations will lean on the following:-

- BS EN 62479:2010 *Assessment of the compliance of low power electronic and electrical equipment with the basic restrictions related to human exposure to electromagnetic fields (10 MHz to 300 GHz)*
- BS EN 62311:2008 *Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz – 300 GHz)*
- BS EN 50499:2008 *Procedure for the assessment of the exposure of workers to electromagnetic fields*
- BS EN 50413:2009 Basic standard on measurement and calculation procedures for human exposure to electric, magnetic and electromagnetic fields (0Hz – 300GHz)

For a full list of EMF product standards see Table C.1 in BS EN 50499:2008.

2.1 General health effects and other adverse effects of exposure to EMF

There are well established adverse health effects and other hazards from high levels of EMF that require the need for control measures. These need to be considered when carrying out a risk assessment.

2.1.1 Summary of direct health effects

- At frequencies below about 100 kHz, including the power line and domestic supply frequency of 50 Hz, risk of electric shock or burn from touching objects in an electromagnetic field.
- At low frequencies (300 kHz and below), effects on the nervous system and, below 1 Hz, the heart[4].
- At intermediate frequencies (100 kHz – 10 MHz) both nervous system effects and heating effects[5].
- At frequencies between 50 MHz down to about 100 kHz, RF burns are the dominant potential injury.
- At high frequencies (10 MHz and above), heating effects on the body and on specific tissues.
- Another detrimental heating effect produced by exposure of humans to RF fields is the auditory response phenomena (more annoying than harmful).

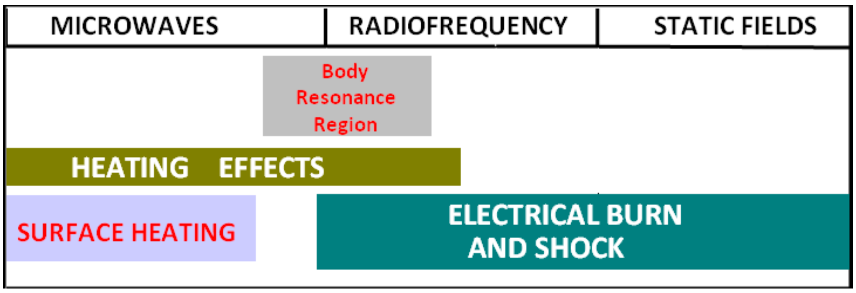


Figure 16. Adverse Effects for different EMF regions

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[4] Up to 300kHz, overexposure can cause small induced electric currents to flow in the body which can interfere with the brain and nervous system. Magnetic phosphenes are a perception of faint flickering light thought to result from interaction of induced electric currents with cells in the retina.

Fields at 0-1Hz can cause cardiovascular effects and even cardiac arrhythmia, and also vertigo and nausea.

[5] Induced currents can cause heating effects at frequencies above 100 kHz and this heating effect must be limited in order to prevent whole-body heat stress and harmful localised heating of tissues in the body

2.1.2 Summary of indirect effects

- Interference with active implanted active medical devices such as cardiac pacemakers
- Projectile risk from ferromagnetic objects in static magnetic fields
- Initiation of electro-explosive devices (detonators)
- Fires and explosions resulting from ignition of flammable materials by sparks caused directly or indirectly by electromagnetic fields.

Further discussion of the effects of specific frequencies of EMF are given later in section 2.3.

2.2 Controlling the hazards and minimising risk

BS EN 50499:2008 *Procedure for the assessment of the exposure of workers to electromagnetic fields* and BS EN 62479:2010 look at procedures for hazard assessment and, just as in guidance on artificial optical, they give guidance as to what is compliant, posing minimal risk, (see Table 1 of BS EN 50499) and what types of equipment are likely to require further assessment (see Table 2 of BS EN 50499). (*NB HSE plan to simplify the procedures for risk assessments so these standards are likely to be amended*).

Examples of potentially hazardous and non-hazardous types of equipment are given below.

2.2.1 Examples of equipment that should be safe to use

- Electricity supply networks in the workplace and distribution and transmission through or over a workplace
- Household appliances
- Computer and IT terminal equipment using wireless technology
- Base station antennas outside the exclusion zones[6] - further assessment would only be required if workers needed access inside of the exclusion zone.

2.2.2 Examples of equipment likely to require further assessment

- Induction heating
- Dielectric heating and welding
- RF plasma devices including vacuum deposition and sputtering
- Diathermy medical equipment with time averaged power >100mW
- Radars
- Industrial microwave heating and drying
- Work inside of exclusion zones of base station antennas

Information on control measures applicable to some common practices is covered in section 2.4.

It is a duty of manufacturers/suppliers to assess the risks posed by equipment they are supplying to the user and to provide the user with information on how to use the

[6] An exclusion zone will be based on a 3D compliance boundary which defines the area that it is not safe for the public, i.e. in excess of ICNIRP exposure limits. Many roofs of university buildings are now used for transmitters and the manufacturers/installers of antennae should be providing users with this information.

equipment in a safe manner and any access restrictions. An installer should undertake a survey to demonstrate compliance with exposure limit values and there are probably limited occasions when users need to undertake or commission measurements themselves.

HSE have stated that '*Taking measurements is not an essential part of the risk assessment*' (http://www.hse.gov.uk/press/record/shp090610.htm). However manufacturers cannot control how some equipment is used and therefore there will be a responsibility on the employer, when work is undertaken with equipment not deemed compliant under BS EN 62479 or other relevant standard, to assess workplace exposure.

Assessments of workplace exposure can be undertaken by calculation from manufacturers' data or by direct measurements and compared with exposure limit values. If undertaking calculations or measurements then BS EN 50413 should be referred to, to ensure that the correct procedures are followed. Procedures for undertaking and recording a risk assessment appropriate to the use of equipment emitting EMF are detailed in BS EN 50499.

2.2.3 Individuals at particular risk

Individuals at particular risk must be considered, include those wearing medical devices and prostheses, cardiac pacemakers and defibrillators, cochlear implants and other metallic implants or body-worn medical devices. Possible problems include electrical interference or physical movement or twisting of the implant which can give rise to safety or health effects, depending on the exposure and the implant.

2.3 EMF regions

When considering the effects of EMF and the precautions that need to be taken it is best to look at each distinct region separately. The regions to be looked at are:

1. Sub-ELF – static and magnetic fields (including NMR) (0 - 30 Hz)
2. Extremely Low Frequency radiation (ELF) (30 Hz - 300 Hz)
3. Microwaves and radiofrequencies (RF) (3 kHz - 300 GHz)
4. Terahertz radiation (300 GHz - 3000 GHz)

2.3.1 Sub-ELF and Static Fields (<30 Hz)

Typical sources: magnetic resonance imaging equipment (MRI) used for scanning people; nuclear magnetic resonance equipment (NMR) used to investigate the properties of materials; magnetic property measurement systems (MPMS); and physical property measurement systems (PPMS).

NB Additional advice is given in Section 2.4 of this document – NMR and MRI both employ RF as well as static fields, and MRI also uses fast switched gradients which are effectively pulses in the kHz range, and induced current effects can also arise.

2.3.1.1 Work with Static Magnetic Fields

Biological, Health Effects and other Hazards – The magnetic flux density (measured in Tesla) is accepted as the most relevant quantity relating to magnetic field effects. Whole body exposure to static (DC) magnetic fields above 4 Tesla (T) can produce severe ill-health effects including nausea, vertigo and increased blood pressure (the principle field interaction with a moving body results in current induction). However, for most people there appears to be no adverse health effects to exposure to large magnetic fields (7 T) for short periods of time and any effects that do occur should be instantaneous (HSE Research Report RR570 and AGNIR 2008 Static Magnetic Fields Report of an independent Advisory Group on Non-ionising Radiation Doc HPA, RCE-6.)

As noted in section 2.2.3, ferro-magnetic and/or electronic medical devices and medical implants can be affected at field strengths as low as 0.5 mT (often termed the 5 Gauss line). There is particular concern regarding disruption of cardio-pacemakers which could result in serious injury or death to the individual. Other implanted ferro-magnetic objects including pins, stents, shunts and also any embedded fragments such as metal splinters or shrapnel can also be adversely affected in magnetic fields (at around 3 mT or 30 Gauss line). These objects can 'realign' in the magnetic field causing trauma to the surrounding tissues. Furthermore, ferro-magnetic objects entering strong magnetic fields (>3 mT) can pose a 'projectile' hazard to those in the local vicinity as they can be drawn rapidly into the magnet 'bore'. Patients undergoing MRI scans have died because ferrous cylinders were brought too close to the magnet bore. For most people the main concern will be the effect that strong magnetic fields can have on magnetically stored data - floppy discs, credit cards and smart cards – be very careful what you take near a large magnet!

Controls – Strict control measures are therefore required to prevent unauthorized access of individuals and equipment to magnetic field strengths of 0.5 mT (5 Gauss) and above. The contour map of magnetic field strength will be provided by the manufacturer/supplier, and should be considered at the project design stage and confirmed during the commissioning process. Areas where the magnetic field strength is 0.5 mT (5 Gauss) and above should be totally enclosed and designated as 'controlled areas' and written "local rules" should be in place. Free access to this area should only be allowed to authorised personnel who have undergone screening protocols and appropriate training. Once sited the magnetic field position will not move unless the equipment producing the field is moved, altered or large ferromagnetic objects are introduced into the vicinity of the equipment.

Access to the controlled area (the area enclosing the 0.5 mT or 5 Gauss line) should involve clearance through a strict screening process to ensure ***all*** those entering the area (from visiting professors to contract engineers) are safe to do so. A high level of supervision will be required to ensure non-authorized persons do not enter the controlled area. For reasons of clinical safety in MRI an advanced screening procedure is required for patients undergoing scans and this must be developed by the department with appropriate input from medical and safety professionals.

When routine maintenance and servicing is being carried out by staff or contractors safe working procedures should be included in the local rules.

2.3.1.2 Maximum Exposure Levels

The ICNIRP guidelines state that workplace exposure limits to static magnetic fields should be limited to 2 T for the body and 5 T for the extremities (but can be up to 8 T for 'specific' work if the environment is properly controlled). There is also a maximum 24 hour average exposure level of 0.2 T.

Exposure limit values have been specified in terms of current densities arising from exposure to time-varying magnetic field gradients but these are difficult to measure in practice. An assurance should be sought from the supplier of the equipment that exposure limit values could not be exceeded in normal operation.

2.3.2 ELF (300 Hz - 30 Hz)

Typical Sources - These are associated with mains electric and power lines.

Biological and Health Effects - Effects are tingling in the skin from electric fields and alternating magnetic fields can induce currents in the body but these are imperceptible at fields normally encountered. There have been various scare stories about ELF effects with fears of possible cancer links but again there are no proven adverse health effects, so, if there are any risks associated with ELF they must be very small indeed.

Controls – occupational exposure arises from the use of electricity in the workplace, and as noted in section 2.2.1, in general, normal use of electrical appliances within an office workplace should require no further control measures (the National Grid has a useful website on this topic that includes good summaries of all national and international guidelines with links to source documents). Significant exposures may arise from the use of relatively high voltages and currents, for example, in certain welding operations and use of induction furnaces and heaters, but equipment should be designed to be safe for intended use. In this low frequency region, it is appropriate to consider the individual electric and magnetic field components. The electric field is easily shielded by use of metal shielding (Faraday cage). For the magnetic field component, distance is typically used to restrict exposure. Safe distances/ exclusion zones and any other appropriate protective measures should normally be specified by the manufacturer to assist the employer in carrying out a risk assessment.

2.3.3 Microwaves and RF (300 GHz – 3 kHz)

Typical sources – radar, microwave communications, microwave heating, RF induction heating and welding.

Biological and health effects –

The main hazards are thermal heating, induced current burns and contact burns.

- <10 MHz - electrical currents can be induced in tissue which can act on the central nervous system (CNS)
- 10 - 100 MHz can affect CNS and cause tissue heating effects leading to a rise in body temperature
- >100 MHz - heating affects and rise in tissue temperature

- >10 GHz – heating of surface tissues only

These radiations generally have a heating effect on the body - some parts of the eye (especially the lens) are more susceptible because they are not served by many blood vessels and therefore heat dissipation is slow. The most susceptible people to these radiations are those whose bodies have difficulty controlling internal temperature, or those suffering from a fever, or people with circulatory problems. There can also be electrical effects affecting the nervous system in RF frequencies and the possibility of shocks and burns from touching objects in an RF field.

Controls - Controls are the same as for any external hazard: minimise time of exposure; keep at a safe distance whenever possible and when necessary employ suitable shielding. These wavelengths can usually be satisfactorily screened out by a metallic mesh (Faraday cage) with access to danger areas protected by interlocks – as we find with microwave ovens. If open sources are used great care needs to be taken with their siting and cordoning off of areas and display of warning signs are very important. Safe distances/ exclusion zones should normally be specified by the manufacturer.

The work will need to be covered by a risk assessment and users will need to be trained and the training recorded. Anyone who may be at particular risk from exposure to these radiations needs to be identified.

Exposure limit values should be observed and some monitoring of exposure levels may be required (although SAR cannot be measured directly). This will require specialist equipment to measure the electric field and magnetic field strengths and compare these with exposure action values.

There have been scare stories relating to the use of mobile phones and concerns about long-term exposure of starting from an early age but there are no proven adverse health effects although this is the subject of on-going research.

A useful guide to understanding radiowaves and their effect (produced by PHE) is available.

2.3.4 Terahertz radiation (300 GHz – 3000 GHz)

Terahertz radiation lies on the boundary between microwaves and infra-red radiation. Methods of propagation have only recently been developed and safety limits in this region are only based on extrapolation from infra-red and microwave regions. Research is being undertaken to establish exposure limit values but we know that the effects on tissue will be thermal.

Terahertz radiation can penetrate a wide range of non-conducting materials but can be reflected by dense materials and metals leading to the first application in security screening – see picture below from Terahertz Science and Technology Network. There is likely to be increased research in this area developing further applications.

Figure 17. Superhuman vision with Tetrahertz waves.

2.4 Common practices in Universities

There is a wide range of equipment used in research establishments which generate significant electromagnetic fields and this section covers some common applications, including magnetic resonance imaging equipment (MRI), nuclear magnetic resonance equipment (NMR), magnetic property measurement systems (MPMS), and physical property measurement systems (PPMS).

Equipment may generate electromagnetic radiation in different frequency ranges, for example, MRI and NMR both employ RF as well as static fields, and MRI also uses fast switched gradients which are effectively pulses in the kHz range, and induced current effects can also arise. NMR equipment is normally well shielded to prevent RF exposure, but can be an issue in MRI as noted below.

MPMS and PPMS equipment can also produce significant static magnetic fields, and it is worth noting that modern equipment incorporates increasingly better shielding for the static fields, it is often not possible to achieve less than 0.5 mT (5 Gauss) on the outside of the equipment.

Applications involving radiofrequency fields include radar, microwave communications, microwave heating, RF induction heating and welding.

The International Labour Organisation (ILO) have produced a very useful publication *Safety in the use of radiofrequency dielectric heaters and sealers.*

The emf safety issues depend on the design equipment and its operation; please refer to sections 2.2 which refers to manufacturers' duties and section 2.3.3 which refers to RF and typical control measures.

2.4.1 Static magnetic fields in common applications

Access to areas with significant static magnetic fields (such as MRI, NMR, MPMS or PPMS) should be restricted to authorised personnel who have been subjected to a basic screening process for implanted medical devices. Physical security measures such as keypad, swipe-card or traditional locking systems would be an acceptable method of preventing unauthorised access. It is preferable to locate equipment in dedicated areas, but where staff unconnected with the work need enter rooms where equipment is sited then the position of the 0.5 mT (5 Gauss) line should be demarcated as a 'restricted area' and clearly indicated to permitted staff entering the room providing they have been fully trained.

Items of equipment that are intended for use in areas where magnetic fields are present must be tested and designated as MR safe/compatible as appropriate (or non-ferrous for NMR or similar systems) to prevent the likelihood of causing projectile hazards and electromagnetic interference.

If an individual (member of staff, visitor, patient or volunteer) who needs to enter the controlled area has an implanted medical device their clinical consultant should be asked for advice. A list of MR "safe" implants has been compiled (but note the disclaimer) on the website http://www.mrisafety.com/list.asp .

In addition to the potential for serious injury, MRI and similar equipment is expensive and serious financial costs can be incurred as a result of damage from projectile incidents. As a consequence of projectile incidents, a rapid 'quenching' of super-cooled magnet can occur (depending on the equipment). This results in discharge of pressurized cryogenic gases into the local environment depleting the available oxygen. Specific 'Quench' ducting to remove rapidly expanding gas and oxygen-depletion monitoring systems are basic requirements in areas housing super-cooled equipment. Advice is provided in the MHRA guidance (see reference 13). The dimensions of the quench pipe must be specified by the MR manufacturer and the installer must install as specified by manufacturer. Quenching and other incidents can be common at installation and it is important to clarify in writing that the installer is in charge of the area at this time and they must have a risk assessment for the installation.

2.4.2 Time-varying magnetic field gradients in MRI

The biological effects from time-varying magnetic field gradients can interfere with normal function of nerve cells and muscle fibres, while more serious effects can cause ventricular fibrillation. In such cases frequencies >1MHz are regarded as significant with those >30MHz wavelength influencing the electric field and current distribution in conductive tissues. Peripheral nerve stimulation in patients undergoing MRI scans has been observed. In gradient fields no movement is necessary to induce currents, unlike in static fields.

In addition to the biological effects, time-varying magnetic field gradients produce acoustic noise (sound waves) when alternating between low frequency currents. Noise levels can reach dangerous levels and therefore appropriate measures (e.g. hearing protection) should be implemented to prevent noise-associated injury where it is deemed necessary through practical measurement.

2.4.3 Radiofrequency fields in MRI

Induced current burns result from people coming into contact with conductive loops that may become hot during operation (generally in MRI). This can be avoided through equipment design and from the positioning of subjects in the MRI equipment. Contact burns can result from metallic objects in close proximity to the subject becoming heated when the radiofrequency induces currents in conductors such as metal in objects of clothing or probes attached to subjects.

Significant exposures arising from RF are only relevant for the extremities (limbs) of workers accessing the MRI suites and when placing hands in the vicinity of the bore. The limit on SAR of 20W/kg applies for RF fields from 100kHz to 10GHz. Again an assurance should be sought from the supplier of the equipment that exposure limits could not be exceeded in normal operation.

2.4.4 Associated hazards

There are other common hazards that will also need to be addressed by a risk assessment, and always refer to manufacturer's instructions:

Manual Handling: The excess heat produced by strong magnets will require a liquid cryogen to act as a coolant. This may involve the manual handling of Dewars and other heavy equipment in the refilling procedure.

Cryogenic Gases: The potential hazards associated with handling cryogenic liquids include cold-burns or oxygen depletion due to accidental escape of cryogenic gas. Personal protective equipment must be worn if required in the risk assessment.

Electrical & General: As with all equipment using the electricity supply the likelihood of electric shock and fire etc. should be considered in any risk assessment. Care should be taken if handling flammable and other liquids around this equipment and only competent service engineers should gain access to electrical workings. General health and safety issues such as the positioning of the equipment and supply cables should be considered during the planning and installation stages.

Noise: Noise can be an issue in MRI suites. Action levels for noise exposure are set which if exceeded require that action is taken to reduce the harmful effects of noise on hearing. The lower exposure action value is a daily or weekly average noise exposure level of 80 dB, at which the employer has to provide information and training and make hearing protection available. The upper exposure action value is set at a daily or weekly average noise exposure of 85 dB, above which the employer is required to take reasonably practicable measures to reduce noise exposure. The use of hearing protection is mandatory if the noise is unavoidable through practical measures.

2.4.5 New and developing technologies

In 2008 ICNIRP published a statement on emf-emitting new technologies http://www.icnirp.de/documents/NewTech.pdf which includes information on a wide range of mobile communication and wireless technologies, and non-communication uses such as ground penetrating radar, medical MRI and wireless transport of electrical energy.
There have also been recent developments in whole body image scanners. These are increasingly used for security purposes and emit either terahertz radiation (see section 2.3.4) or "millimetre wave" (30 - 100 GHz) radiation. Exposures have been assessed to be within current guideline limits for millimetre wave radiation (ICNIRP statement on health issues associated with millimeter wave whole body imaging technology 2012).

2.5 Safety Signs and Labels

Warning signs shall comply with the Health & Safety (Safety Signs and Signals) Regulations 1996. BS ISO 3864-1:2011, *Graphical symbols. Safety colours and safety signs. Design principles for safety signs and safety markings* published September 2011 should be used.

Typical signage for entrance to a controlled area, for example, an MRI/NMR area.

No Cardiac Implants

Static Magnetic Field

General hazard warning sign for non-ionising radiations

2.6 What should we currently be doing?

Although there are no specific regulations governing EMF at present there are still the responsibilities under the HASAW etc Act to follow recognised good practice, which means following the advice of HSE and the recommendation in British Standards.

There should be a policy in place that identifies who is going to be responsible for overseeing the use of EMF. This may be the Safety Officer or Radiation Protection Officer or some other person depending on local circumstances. The important thing is that somebody is identified in every user department who will take on board the job of identifying whether there are any non-compliant EMF sources being used and ensure that they are used in a safe manner. The first thing to consider is whether these sources are really needed and whether safer alternatives could be used. Then the following measures need to be considered:-

- Setting up an inventory of all equipment that may emit hazardous levels of EMF
- Ensuring hazardous EMF is risk assessed and the findings documented
- Ensure safe systems of work are in place and that workers involved have received suitable and sufficient information, instruction and training
- Ensure clearly visible hazard warning signs are displayed at the entrance and boundaries of hazardous areas.
- Controlling access by engineering controls and design features of equipment e.g. interlocked screening
- Restrict access to hazardous areas to trained, authorised personnel only
- Increase distance between staff and harmful source
- Issue PPE when appropriate
- Have a procedure for effectively dealing with accidents.

2.7 Information, instruction and Training

Information, instruction and training is required when a risk assessment indicates that exposure in excess of any ELV is reasonable foreseeable.

Training should include:-

- What is being done to minimise exposure
- Who is managing the risks
- What are the exposure limit values and action levels
- Findings of risk assessment, measurements taken
- Reporting of any adverse effects
- Any health surveillance required
- Safe working practices
- Use of PPE
- Workers at particular risk

2.8 Exposure limit values and action levels

The EMF Directive sets out exposure limit values (ELV) and action levels (AL). The use of action levels simplifies the process of demonstrating compliance, as these are easily measurable quantities. The Directive distinguishes between health effects (adverse effects which are likely to cause harm) and sensory effects (minor transient effects).

For full details including definitions and explanatory notes relating to the application of these values refer to the Physical Agents Electromagnetic Fields Directive (June 2013). Annex II of the directive covers non-thermal effects, and Annex III covers thermal effects.

2.9 References (EMF):

1. BS EN 50499:2008 Procedure for the assessment of the exposure of workers to electromagnetic fields
2. BS EN 62479:2010 Assessment of the compliance of low power electronic and electrical equipment with the basic restrictions related to human exposure to electromagnetic fields (10 MHz to 300 GHz)
3. Cardiff University Guidance document NIRP3 “Electro-magnetic Fields”
4. PHE guidance on the biological effects of Static Magnetic Fields (RCE-6), http://www.hpa.org.uk/webw/HPAweb&HPAwebStandard/HPAweb_C/1211184025666?p=1199451989432
5. HSE response to Health and Safety Practitioner – “Wave theory” http://news.hse.gov.uk/2010/07/21/hse-responds-to-safety-health-practitioner/
6. ICNIRP Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz) 2010 http://www.icnirp.de/documents/LFgdl.pdf
7. ICNIRP Guidelines on exposure to high frequency electromagnetic fields, biological effects and health consequences (100 kHz-300 GHz) 2009 http://www.icnirp.de/documents/RFReview.pdf
8. ICNIRP Guidelines on Limits of Exposure to Static Magnetic Fields 2009. http://www.icnirp.de/documents/statgdl.pdf
9. ICNIRP statement on emf-emitting new technologies, 2008 http://www.icnirp.de/documents/NewTech.pdf
10. ICNIRP statement on health issues associated with millimeter wave whole body imaging technology, 2012 http://www.icnirp.de/documents/mmwavesICNIRPstatement2012.pdf
11. NRPB-W24, T G Cooper, 2002 *Occupational Exposure to Electric and Magnetic Fields in the Context of the ICNIRP Guidelines*
12. AGNIR (2008). Static Magnetic Fields. Report of an independent Advisory Group on Non-ionising Radiation. *Doc HPA*, RCE-6.

MRI references

13. HPA guidance on the 'Protection of Patients & Volunteers undergoing MRI procedures (RCE-7) http://www.hpa.org.uk/web/HPAweb&HPAwebStandard/HPAweb_C/1222673275443

14. HSE Research report: Assessment of electromagnetic fields around magnetic resonance imaging (MRI) equipment Report RR570

15. MHRA http://www.mhra.gov.uk/home/groups/dts-iac/documents/publication/con2033065.pdf Safety Guidelines for Magnetic Resonance Imaging Equipment in Clinical Use December 2007 (3)

Other useful references and websites

16. PHE website – "understanding radiation" http://www.hpa.org.uk/Topics/Radiation/UnderstandingRadiation/UnderstandingRadiationTopics/ElectromagneticFields/

17. The possible harmful biological effects of low level electromagnetic fields of frequencies up to 300GHz The Institution of Engineering and Technology (IET) http://www.theiet.org/factfiles/bioeffects/emf-position.cfm

18. ICNIRP website http://www.icnirp.de/PubEMF.htm various guidelines and fact sheets

19. WHO website http://www.who.int/topics/electromagnetic_fields/en/ including WHO Fact sheet No 322 Electromagnetic fields and public health