

Safety Code of Practice 22

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CONTROL OF EXPOSURE TO ULTRAVIOLET RADIATION



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1 SUMMARY

- This Safety Guide represents University policy for all work that may involve exposure to Ultraviolet Radiation (UVR), whether the UVR originates from the sun or from an artificial source. The aim of this policy is to ensure that University staff are not exposed to amounts of UVR that may be hazardous to health.
- **Compliance with this policy requires that Managers/ Supervisors assess the risks to their staff that may arise from any exposure to UVR during the course of the work.** They must then identify and put in place all necessary measures to control those risks. They must also ensure that staff are given appropriate information, instruction and training on the risks that their work may entail, and on the measures necessary to control those risks. Appropriate records must be kept.
- Staff who work outdoors¹ for a large part of their time are most at risk from **UVR from the sun**, and are referred to as "Outdoor Workers" in this Guide. Use of the Meteorological Office Solar UV Index is recommended to help assess the risks of UVR to Outdoor Workers.
- Those who work primarily in laboratories or workshops where arc welding is undertaken are most at risk from UVR from **artificial sources**. Staff are potentially at risk from equipment designed to **emit** UVR into the environment, or if the **shielding** on other UVR-generating equipment **is disturbed or damaged**.
- Workers who may be exposed to any UVR during the course of their work must adopt all the control measures, including the wearing of personal protective equipment, that are identified in the risk assessment. In general, **exposure prevention** should be the primary means of exposure control – the use of properly designed interlocked shields, for example, would prevent staff from being exposed to UVR from artificial sources.
- If exposure cannot be prevented, then it must be adequately controlled by methods such as:
 - administrative controls, to limit the duration of exposure, and
 - the use of personal protective equipment, including the use of suitable clothing to cover areas of exposed skin and protective eye-wear (face shields; goggle or UVR-absorbing spectacles) to protect the eyes and face.
- Staff regularly exposed to UV during the course of their work should be under Occupational Health Surveillance to help detect any consequences of exposure during their work. See Section 3.2. Anyone suffering an acute over-exposure from work activities is advised to contact the Occupational Health service.
- Schools/ Departments should keep a register of staff liable to be exposed to UV, together with a register of UV-emitting equipment or processes.

The Technical Annex of this Safety Guide offers information on the nature of the hazards (including the biological effects on Man), and guidance on some common items of laboratory equipment that may emit UVR into the environment.

2 INTRODUCTION

This Safety Guide is intended to ensure that no-one in the University is exposed to excessive amounts of Ultraviolet radiation (UVR) because of the work they undertake. In this context, the

¹ Including Grounds and farm staff; field workers; some Maintenance workers

term “excessive” is used to denote exposures that could result in any form of injury, such as sunburn (erythema, or reddening of the skin) and/ or damage to the eyes (resulting in effects such as conjunctivitis or keratitis – *Technical Annex Section 4, Biological Effects*.) Exposure may be from a natural source (the sun) or from an artificial source (commonly referred to as a UV light).

This Guide does **not** apply to the use of lasers which emit in the UV region – these are dealt with in Safety Guide 21. However, the use of lasers may result in the emission of UVR when a laser beam interacts with matter. Although this mainly applies to high-power industrial cutting lasers [CO₂ lasers, emitting in the infra-red region], if parts of the workpiece reach high temperatures, UVR can also be emitted as a “byproduct”. This phenomenon is considered along with arc welding in this guide.

Guidance:

In this Guide, the term “exposure to UVR” is used to indicate “exposure to potentially harmful levels of UVR”. This Guide does NOT apply to situations where staff intentionally expose themselves to UV for the purpose of obtaining a sun-tan, i.e., for cosmetic purposes. There are no facilities (such as “sun-beds”) in the University for this, and the previous Safety Note 10 on the use of sun-beds has been withdrawn.

3 RESPONSIBILITIES

3.1 Duties on managers

Heads of Schools/Directorates and other managers must ensure that they prevent, so far as is reasonably practicable, any person being exposed to levels of Ultraviolet radiation (UVR) that may be damaging to health during the course of their work activities.

Managers are therefore required to:

- **Identify** all sources of UVR that may result in staff being exposed during their work. They should keep appropriate records for the use of any **artificial sources** (including maintenance records for sources; training records for staff);
- **Assess** the likely exposure to UVR during work activities and the risks arising from such exposure; and
- **Ensure that:**
 - all staff liable to be exposed to damaging levels of UVR are properly identified, and given appropriate information, instruction and training on the hazards and risks of the activity, including the measures required to adequately control such exposures;
 - all such staff are kept under **Occupational Health surveillance** for as long as they undertake work liable to involve exposure to harmful levels of UVR; and
 - that, as far as is reasonably practicable, appropriate protective measures are adopted and appropriate precautions (including the wearing of personal protective equipment) are taken.

3.2 Duties on staff potentially exposed to damaging levels of UVR

All staff who may be exposed to potentially damaging amounts of UVR during the course of their work should:

- be informed, instructed and given appropriate training related to the hazards and risks from UV radiation during their work activities;
- wear any PPE supplied for the purpose of protection from UVR during their work activities;
- be under Occupational Health Surveillance, if so identified by the risk assessment.

4 AFFECTED PERSONNEL

There are two groups of workers at the University who are liable to be exposed to UV radiation during the course of their work: (a) "outdoor" workers (see 3.2, below), who could be exposed to solar radiation, and (b) laboratory and workshop personnel who could be exposed to UVR from artificial sources (see 3.4).

4.1 General recommendations

Personnel who could be exposed to natural solar radiation will mainly be exposed to long-wave (UVA) radiation, which may present fewer risks to health than short wave (UVB and UVC) radiation from artificial sources. In addition, artificial sources of UVR may produce very much greater intensities of radiation than is present from natural sources. Consequently, the precautions and procedures required for protection from UVR from artificial sources are likely to be more exacting for laboratory/ workshop personnel than those for outdoor workers.

A small minority of the population may be hypersensitive to all, or part, of the UV spectrum. If **you** know (*e.g.*, from previous experience) that **you** are hypersensitive to UVR, you should not work in situations liable to cause exposure to **any** UV radiation **unless you are properly equipped with (and wear) appropriate personal protective clothing/ equipment**. Note that apparent hypersensitivity may be the result of applying photo-reactive perfumes or skin lotions.

Guidance:

Should any abnormal skin reaction develop after using equipment that emits in the UV, you should consult the Occupational Health service or your GP before using the equipment again. You should also seek medical advice if you notice any change in the appearance of a mole, *e.g.*, a change in size or colour, or if it starts to bleed. **Workers suffering from any form of skin cancer must not be permitted to work with any equipment emitting UV radiation**, and should not be required to undertake outdoor work liable to cause exposure to damaging levels of UVR.

4.2 Outdoor Workers

Persons working outdoors *e.g.* when on field trips, or carrying out external building maintenance and Grounds/ Agricultural work, are referred to as "outdoor workers" in this Guide. Guidance for "outdoor" workers has been published by the Health and Safety Executive (HSE) (Reference 13). Provided that reasonable precautions are taken, the risks of exposure to UVR received during work activities should be small.









Regular outdoor workers, *i.e.*, those who spend more than 25% of their time working outdoors, should normally be under Occupational Health Surveillance – see Section 5.

4.3 Risk Assessment

Exposure to UVR during outdoor work will depend on the weather: exposure will be highest when the sky is cloudless, and the sun is high in the sky during the summer months. For fieldworkers, the presence of "reflective" surroundings such as snowfields at high altitude, or beach environments can significantly increase exposure to solar UVR. Note that a significant proportion (up to 45%) of the total UVR exposure is from UVR scattered in the atmosphere, and that where the incident solar UVR flux is high, sunburn (erythema) can be experienced in the absence of direct sun.

The magnitude of the **hazard** is related to the time of day and the predicted weather; that of **the risk** depends on an individual's skin colour, with those with dark skin being less at risk from the erythema or burning effects. However, the **risk to the eyes** is independent of skin colour, and eye protection [UVR-absorbing sunglasses] should be worn by all those exposed where the risk is "medium" or higher.

In the absence of measurements of the actual UV flux, an estimate of the hazard and risk may be deduced from the predicted **Solar UV Index**. The Meteorological Office (website: http://www.metoffice.com/weather/uv/uv_uk.html) publish a regional 5-day forecast of the predicted Solar UV Index for the UK, which relates the predicted strength of the sun's ultraviolet (UV) radiation to the risk of burning for various skin types.

Index	Fair, burns	Fair, tans	Brown	Black
	Low	Low	Low	Low
	Medium	Low	Low	Low
	High	Medium	Low	Low
	Very high	Medium	Medium	Low
	Very high	High	Medium	Medium
	Very high	High	Medium	Medium
	Very high	High	Medium	Medium
	Very high	High	High	Medium

Where possible, at the beginning of each week, Managers and Supervisors of relevant staff should consult the Met Office website for the predicted Solar UV Index for the week ahead.

Relevant staff should be advised to adopt protective measures whenever the risk is *Medium* or above (Index of 3 or greater) – see *Section 4, Protection against UV Radiation*.

4.4 Laboratory and workshop personnel

Workers are at risk of exposure to UVR when UVR is emitted from either an instrument (such as a transilluminator or UV steriliser) or incidentally from a process such as welding in a workshop. Any process that produces temperatures in excess of 5000° K has the potential to emit UV light: the higher the temperature, the greater the amount of UVR emitted, and the shorter the wavelength of peak optical radiation emission.

Guidance:

Many instruments (such as spectrophotometers) which contain a UV source are most unlikely to **emit** damaging amounts of UV radiation into the environment if the instrument is in good working order and has not been modified or "repaired" by unqualified personnel. Artificial sources of UV are dealt with in greater detail in Section 5 of the Technical Annex.

Any instrument designed to emit significant amounts of UVR into the working environment must have appropriate built-in safeguards and/or an appropriate system of work to prevent anyone being exposed when the device is operating – *see Section 4, Protection against UV Radiation*.

4.4.1 Risk Assessment

The first step in the risk assessment is to **quantify** the amount of UVR and then to **identify** the wavelength emitted by the source into the environment of the worker.

- For commercial laboratory equipment **designed** to emit UVR, this data can be obtained from the instrument manufacturer, provided that the equipment is in good condition and has not been modified or repaired by unqualified personnel.
- For "home-made" equipment incorporating one or more UV lamps, the output data from the lamp manufacturer should be used as the basis of the assessment;
- For operations capable of emitting UVR (such as arc welding), specific guidance can be obtained from "trade associations" such as the Welding Institute [http://www.twi.co.uk/professional/protected/band_13/faq_radiation.html]. The main risk from welding operations is the development of "arc eye", i.e., photokeratitis caused by UVR damage to the cornea.
- The risk assessment should also identify whether individuals should be tested for competence in the use of equipment before being allowed to use it without direct supervision – see section 4.4 below.

If the wavelength and intensity of the emitted UVR is such that the radiant exposure will exceed the **effective limit** of 30 J. m⁻² (after weighting for wavelength – *See Technical Annex, section 2*), then appropriate protective control measures must be adopted, and the individual should be placed under health surveillance.

5 PROTECTION AGAINST ULTRAVIOLET RADIATION

Prevention of exposure is the best form of protection. If exposure cannot be prevented, then measures must be taken to adequately control the exposure. In this context, control would be regarded as "adequate" if no damage resulted from the exposure. A risk assessment is required to identify these control measures.

5.1 Natural Sources of UVR

Outdoor workers should adopt protective measures whenever the risk is assessed at "Medium" or above (Solar UV Index of 3 or higher in the Met. Office table (above)). Protective measures include

- reducing exposure by arrangement of work schedules to avoid high exposure work in full sun around mid-day whenever possible, and
- the use of personal protective equipment etc.

It should be noted that the recommended daily (8 hour) exposure limit can be exceeded for unprotected fair skin within as little as 15 minutes at the peak exposure times around Noon in the summer months in the UK (Table 3 in reference 8).

Where adjustment of work schedules is not possible, appropriate personal protective equipment and clothing must be worn, especially around mid-day. Clothing made from a close-woven fabric, such as a long-sleeved workshirt and jeans will stop most of the UVR. HSE recommend that a wide-brimmed hat should be worn to shade those areas most exposed to UVR, although a safety helmet ("hard hat") should also protect the top of the head. Most forms of "work gloves" for example, PVC, leather and fabric would protect the hands from UVR.

For those parts of the body that are difficult to shade from the sun, a high factor sunscreen (minimum sun protection factor (SPF) of 15 for UVA and UVB) should be applied to exposed areas of skin, especially the face and back of the neck. However, note that the effectiveness of these creams is variable due to the difficulty of maintaining an adequate film thickness.

5.2 Artificial sources of UVR

Protection against exposure to UV radiation from artificial sources falls into three categories:

- **engineering controls** - enclosures, interlocks, screens, viewing panels, non-reflective surfaces;
- **administrative measures** - restriction of access, warning signs, training, reduction of exposure using distance and time; and
- **personal protective equipment (PPE)** - eyewear, clothing, gloves, face masks, skin screens. Normally, PPE is regarded as the last resort in the control hierarchy, as it only protects the wearer – and then only if it is appropriate to the task and worn properly.

Engineering controls are the most important and effective and if the design of the equipment is satisfactory, administrative controls and personal protection may not be required.

5.3 Engineering controls

No UVR emitting equipment may be used at the University unless it satisfies all current safety legislation. This requirement applies to equipment that is acquired new or second-hand, as a gift, or on loan, or constructed at the University. The hazards and risks for some common UVR emitters are outlined in Section 5 of the Technical Annex. Regardless of power and energy density, all protective engineering controls must be in working order and in the event of malfunction fail-to-safe.

Where practicable the radiation source should be in a sealed and interlocked housing. If complete sealing is not possible the source should be in a screened enclosure. Interlocks should be fitted where practicable and work should always be conducted using a Safe System of Work. Reflective surfaces and light-coloured glossy paints should be avoided in all areas to which UV radiation may

penetrate in order to minimise stray reflections if shielding should fail, or if interlocks are overridden.

See Technical Annex, Section 6 for information on some materials that preferentially attenuate UV radiation.

5.4 Administrative measures

- **Training:** All personnel who will be using equipment capable of emitting UV radiation must receive training before they use the equipment. Training should include an introduction to the hazards involved (Technical Annex, Section 3). All instructions for the use of the equipment must be followed, and associated warnings properly observed. Training should be undertaken only by appropriately experienced personnel, and should be fully documented by the Manager or Supervisor. Tests of Competence in the use of the equipment may be required (as determined by the risk assessment) before an individual is permitted to use the equipment without direct supervision: if so, appropriate records should be kept along with the training records.
- **Local Rules:** It may be necessary for the Manager or Supervisor to prepare Local Rules to advise workers on the “normal” use of specific items of equipment. Systems of Work may also be required if there is a need to undertake potentially hazardous tasks (such as alignment, adjustment of or UVR source replacement) that may require normal interlocks to be overridden. Such Systems of Work would apply only to named, appropriately trained personnel.

All equipment must be clearly labelled, with attention drawn to any hazards. If equipment is to be kept running out of normal working hours (Safety Guide 7) the name and home telephone number of the responsible person must be displayed on the door of the room and a “Please Leave Running” notice displayed.

Access to areas where UV radiation is being emitted should, as far as is reasonably practicable, be confined to those involved in the work.

Those using UVR emitting equipment must plan in advance to minimise their exposure time and maximise their distance from the source.

Guidance:

Suggested Local Rules for the use of a UV lamp in a microbiological safety cabinet

The UV lamp must never be operated when anyone is working in the cabinet. This operation may only be initiated when the last person leaves the laboratory at night. The timer must be set to terminate the irradiation before anyone enters the laboratory. A warning notice must be placed on the door of the laboratory, giving the times of operation of the lamp.

5.5 Personal protective equipment for “machine” sources

When practicable, Local Rules should be devised that make the use of personal protective equipment unnecessary – for example, when using a germicidal UV lamp to “decontaminate” a microbiological safety cabinet, as in the example above.

Engineering controls and administrative measures should be such that personal protection is required only for named persons performing specific authorised operations, e.g. setting up optical bench work, as stipulated by a Safe System of Work.

If any UVR source can be operated in the absence of engineering controls, such that personnel could be exposed, wherever possible it should be modified to install protective shields. If operation of the shield relies on the operator and is not automatic (and it is not practicable to modify the equipment appropriately), then personal protective equipment should be used routinely as added protection. Mandatory use of the PPE should then be specified in the Local Rules.

Some operations, such as arc welding, require a suitable face shield or goggles that fit tightly to the face around the eyes. Normal sun glasses, even if fitted with side pieces, are not suitable.

See Section 9 of the Technical Annex for more details on personal protective equipment.

6 OCCUPATIONAL HEALTH ASPECTS

As detailed in the Technical Annex, section 4, exposure to UVR can cause both immediate and delayed damage to the skin and the eyes. The aim of occupational health surveillance is to detect any early signs of diseases such as skin cancer or cataract, which are associated with excessive exposure to UV.

If so identified by the risk assessment, staff should be placed under Occupational Health surveillance. Managers/ Supervisors should contact the Occupational Health service and ensure that any new member of staff liable to be exposed to significant quantities of UVR during their work is placed under health surveillance. Because UVR can damage the skin and the eyes, the surveillance would normally take the form of an annual check of the skin on those parts of the body liable to be exposed to UVR – usually, the hands, arms and face, although outdoor workers who wear shorts should ensure that exposed parts of the legs are checked as well. Long-term eye damage (e.g., cataracts) would be detected during an ophthalmological examination, and may require referral to an ophthalmic optician at the discretion of Occupational Health.

In addition to long-term surveillance, relevant staff are advised to contact Occupational Health to discuss any short-term effects of over-exposure, such as severe sunburn or conjunctivitis.

Appendix 1: Technical Annex

7 INTRODUCTION

7.1 Scientific Background

Optical Radiation (OR) is the term applied to electromagnetic radiation within the wavelength range from 100 nm – 1 mm. This range stretches from Ultraviolet (UV) to Infrared (IR), and includes the whole of the visible spectrum (400 – 700 nm). The energy of the radiation is transferred to materials that are exposed to it; if sufficient amounts of energy are deposited, then damage to those materials can occur.

The major source of this radiation is natural – the sun. In addition to natural radiation, many artificial sources of OR will be encountered in the University, **most of which are completely innocuous**, such as luminaires for room or area lighting. However, irrespective of the wavelength, and whether the source is natural or artificial, if the **irradiance** or **radiant exposure** is high (High irradiance optical radiation, HIOR), damage to the eye or exposed skin may result.

Radiation within the optical range has very little penetrating power into tissue, and will only affect the eye or exposed surfaces of the skin. The energy of the radiation is insufficient to cause ionisation of molecules within the tissues, and is therefore classified as Non Ionising Radiation.

The eye has a natural aversion response to an uncomfortably high light intensity, but this does not operate at wavelengths that the eye cannot perceive. Longer (non-visible) wavelengths comprise the infrared spectrum and if the intensity is high enough, a sensation of heat can be felt on the skin. By contrast, there are no receptors either in the eye or the skin which can directly sense the presence of UVR, hence it is relatively easy for overexposure and damage to occur. Within the optical spectral range, UV radiation is the most energetic, and most hazardous – the shorter the wavelength, the greater the energy and the greater the hazard. Because the energy cannot be perceived directly, UVR presents the greatest risk to those exposed because of this ease of overexposure. In addition, there is now increasing evidence that high intensity blue light (wavelengths in the region from 400 – 450 nm) can also be hazardous.

Applications of UV radiation include laboratory instruments (*e.g.*, spectrophotometers and transilluminators), plus safety cabinet sterilisers (and similar devices). In addition to intentional use of UVR, incidental exposure to HIOR (including UVR) could occur because of stray emissions of UVR from “visible” sources; during processes such as welding, as well as working outdoors in sunny weather.

Under the requirements of the EC Physical Agents (optical radiation) Directive (See Ref. 1), exposure to optical radiation from artificial sources will have to be assessed, and where appropriate, adequately controlled. At present, this is not a specific legal requirement in UK law, but is covered by the general risk assessment and control requirements of the Management of Health and Safety at Work Regulations.

Although this guide refers to exposure to **UV radiation**, the Directive requires that similar considerations apply to any other form of optical radiation. If this guidance is followed (adapted as appropriate for other forms of optical radiation), the procedures detailed will meet this risk assessment and control requirement.

7.2 Properties of Ultraviolet radiation

It is conventional to divide the UVR spectrum into three regions:

UVA 400 – 315 nm – sometimes referred to as “long wave” or “blacklight”;

UVB 315 – 280 nm; (“medium wave”) and

UVC 280 – 180 nm. – sometimes referred to as “germicidal”.

The UVR wavelengths technically extend down to 1 nm, bordering the X-ray region, but in practice, wavelengths below 180 nm can be disregarded as they are absorbed by the air². The very short wavelengths are sometimes referred to as “Vacuum UV” or “extreme UV”, as they are only produced in significant quantities in evacuated discharge tubes.

7.3 Sources of UVR

The **main source of UV radiation** contributing to personal exposure is the **sun** and the **major risk is associated with sun exposure**. The sun emits a wide range of electromagnetic energy across the whole of the spectrum from X-rays to radio waves, including a significant proportion of ultraviolet light. Ozone and water vapour in the Earth's atmosphere absorbs the UVC and much of the UVB that is emitted, so that the UV radiation spectrum at the earth's surface does not extend below about 290 nm, except in those areas affected by the “Ozone hole”. In these areas, the UVB and UVC flux at ground level can be much higher, and is sufficiently high to increase the risk of chronic diseases such as skin cancer (see section 4 – Biological effects.)

In addition to natural sources, there are many types of artificial sources of UVR, some of which are discussed in greater detail in Section 5 of this Annex. They rely on the excitation of gaseous atoms or molecules by an energy source – usually electrical, but can be thermal in the case of arc welding – to cause them to radiate energy in the UV frequency regions.

8 EXPOSURE LIMITS

The exposure limit is the cumulative dose of UVR that is assessed to pose no significant risk to those people exposed. The **dose** (in Joules m⁻²) is a function of the irradiance (power density per unit area of the receiving surface) of the radiation (in Watts m⁻²) and the duration of the exposure in seconds.

The International Commission on Non Ionising Radiation Protection (ICNIRP) has produced guidelines for recommended limits of exposure to UVR from artificial sources (Ref. 4), and these form the basis of the limits set in the EC Directive. It is therefore probable that these limits will be transposed directly into UK law, and they form the basis of the recommendations in this guide. Details of the exposure limits are below, from which it may be noted that the limit (in terms of the exposure time for a given irradiance) depends on the wavelength of the radiation – in general, the shorter the wavelength, the shorter the duration of exposure permitted.

An abbreviated version of the table is given below:

² Use of such sources of UVR and short-wavelength UVC can result in the formation of ozone due to absorption by oxygen molecules in the air. Although the UV may not be a direct hazard, the ozone produced may approach toxic levels in confined spaces – the workplace exposure level (WEL) is 0.2 ppm for 15 min exposure. Good ventilation is therefore required when short wavelength UV sources are used. See Section 7.1

UV Band	Wavelength (nm)	Exposure limit, EL (J.m ⁻²)	Spectral weighting function, S(λ)
UVC	200	1000	0.03
	210	400	0.075
	220	250	0.12
	230	160	0.19
	240	100	0.30
	250	70	0.43
	254 (mercury)	60	0.50
	260	46	0.65
	270	30	1.00
UVB	280	34	0.88
	290	47	0.64
	300	100	0.30
	305	500	0.06
	310	2000	0.015
	315	1 × 10 ⁴	0.003
UVA	320	2.9 × 10 ⁴	0.001
	325	6 × 10 ⁴	5 × 10 ⁻⁴
	330	7.3 × 10 ⁴	4.1 × 10 ⁻⁴
	340	1.1 × 10 ⁵	2.8 × 10 ⁻⁴
	350	1.5 × 10 ⁵	2.0 × 10 ⁻⁴
	360	2.3 × 10 ⁵	1.3 × 10 ⁻⁴

Table 1: ICNIRP weighted exposure limits

The table indicates that an **effective** limit of 30 J. m⁻²³ (when corrected for wavelength effectiveness by application of the Spectral Weighting Function, SWF) is applied for unprotected skin or the eyes. The correction factor SWF is a measure of the potential for the radiation to cause damage, and varies from 1.0 at 270 nm to 3 × 10⁻⁵ at 400 nm. The **actual** dose limit thus varies from 30 J. m⁻² at 270 nm to 300,000 J. m⁻² – or 300 J. cm⁻² – at 400 nm.

It may be deduced from this table that the maximum permitted dose (exposure time) is greatest for radiation in the UVA part of the spectrum (above 320 nm), and least around the 250 nm – 300

³ It may be of more practical use to use the limit value of 3mJ cm⁻², as this would apply to small areas of exposed skin, etc.

nm part of the UVC band. This is related to the potential for damage of the radiation – cellular proteins have a maximum UVR absorption at around 280 nm, and nucleic acids in the region from 250 – 270 nm. Although UVA has less severe acute effects than UVB and UVC, it is thought to be responsible for more of the chronic effects (including skin cancers) due to its greater penetration into the dermal layers of the skin.

Example:

If someone is exposed to a UV source emitting UVB with a peak output of 290 nm at an irradiance of 15 W m^{-2} (1.5 mW cm^{-2}) at "working distance", the maximum permitted duration of exposure t (in seconds) will be $[\text{limit}/(\text{power} \times \text{SWF})]$, i.e., $30 \text{ J m}^{-2} / 15 \text{ W m}^{-2} \times 1/0.64 \text{ seconds} = 3.125 \text{ seconds}$. Protection in the form of engineering controls and/or personal protective equipment is therefore required for any operation with a potential for exposure in excess of this time.

By contrast, if the peak output is at 350nm ("Blacklight"), the permitted exposure would be in excess of 2½ hours (all other factors remaining unchanged), and additional protection is unlikely to be required. (This simplified calculation does not take into account any UV emission from the source at other wavelengths.)

Note that a "typical" UV transilluminator may contain up to 6 x 15W UV tubes, and the working distance may be less than 10 cm.

Currently there are no **specific** regulations covering UVR at work that define maximum exposures that must not be exceeded, and there is no requirement to register workers using UV equipment. This situation may change after Regulations derived from the Optical Radiation Directive have been put in place. However, under the general requirements of the Management of Health and Safety Regulations (ref. 2) **a risk assessment must be undertaken and appropriate controls introduced where the assessment indicates that workers could be exposed to hazardous levels of UVR.**

Note that the Directive does not apply to exposure to UVR from natural sources (i.e., the sun), but it is presently unclear whether the anticipated regulations in the UK will also exclude natural sources.

9 PRINCIPLES OF RISK ASSESSMENT AND CONTROL

The formal process of risk assessment follows the procedure:

- a) Identify the nature and the magnitude of the hazard;
- b) Identify the route(s) and extent of exposure to the hazard;
- c) Determine the risks that might arise from this exposure, and
- d) identify and put in place the procedures necessary to either prevent, or to minimise exposure to the hazard.

In the case of exposure to UV radiation,

- the hazard is the energy that could be absorbed by the body from electromagnetic radiation in the UV wavelengths.
- The extent of the hazard will depend on:
 - the wavelength(s) of the radiation involved;
 - the part of the body exposed (i.e., the eye or the skin); and

- the amount of UV energy emitted per unit area i.e., the irradiance).

In the absence of a means to measure the radiant exposure directly, for artificial sources, the assessment of the magnitude of the hazard must rely on manufacturer's data of the output power of the source; the wavelength (or spectrum) of the radiation, and the working distance from the source.

- the risk arising from an exposure is a measure of the probability that damage will result from the exposure, thus for short wavelength UV sources such as UVC at 270 nm with a high irradiance, the risk will be high if exposure occurs. The magnitude of the risk will depend on the duration of the irradiation, i.e., the radiant exposure experienced.

If the assessment identifies that exposure to UVR is possible, appropriate measures must be put in place to adequately control this exposure.

The normal hierarchy of control measures applies:

- the priority is accorded to "engineering controls" (i.e., design and installation of equipment such that the emission of UVR into the "accessible" environment is either prevented or minimised);
- "Administrative" controls should be applied where necessary to control and/ or limit access of personnel to areas where they could be exposed to UV radiation, and (as a last resort),
- Potentially exposed staff should wear appropriate personal protective equipment such as full-face UV-absorbing shields; gloves and cover potentially-exposed skin. The use of sun-block creams would be included within this definition of personal protective equipment.
- Details of the risk assessment must be recorded in writing (Form RA-2), and incorporated into Local Rules for the use of the equipment.

9.1 Exposure assessment and control

A consequence of the spectral weighting factors is that it is not possible to obtain a simple monitor that will give an integrated value for the total of all the UV radiation present. Most sources emit several, or a range, of wavelengths, and a complicated and expensive integrating monitor is required to assess the overall impact of the radiation. The University of Reading does not have access to a monitor of this type, therefore guidance is given in Section 5 which should be applied when using commercial equipment. The intention of the guidance is to prevent any exposure to UV from artificial sources: if the exposure is prevented, then there will be no risk. Where the exposure cannot be prevented, then a risk assessment must be done, and appropriate means must be adopted to ensure that the exposure is adequately controlled. Such a course of action may require the use of a monitor to confirm that the control measures are adequate.

Within the University, UV radiation from artificial sources may contribute significantly to an individual's total exposure. Such sources include:

- UV transilluminators and UV tubes used for sterilisation of surfaces or water treatment;
- high intensity industrial sources (e.g. welding and xenon arcs which can emit throughout the UV spectrum); and
- UV fluorescence tubes designed to illuminate fluorescent markers, e.g., security markers; contamination tracing and for "entertainment" purposes (as in night clubs, etc.)

Note that mercury discharge lamps (e.g. germicidal lamps), unless fitted with a glass envelope or coated with fluorescent material, have a significant emission in the UVC range.

A useful, though rather dated, general description of the hazards of occupational exposure to UV radiation is given in Reference 5, a key point summary of the properties of UV radiation is given in Reference 6, and a review of occupational exposure to UV radiation which contains some useful practical data is given in Reference 7.

10 BIOLOGICAL EFFECTS OF UV RADIATION ON MAN

10.1 Introduction

This section applies to all sources of UV, whether natural or artificial. Exposure to UVC is much more likely in a laboratory/ workshop environment than outdoors, because of the absorption of UVC by the atmosphere. The photon energy associated with electromagnetic radiation is inversely proportional to the wavelength; hence UV photons are more energetic than those of visible light, and have a greater capability of inflicting damage on biological tissue. Nevertheless UV radiation has a low penetrating power, so that the biological effects of consequence are confined to the skin and the eyes.

10.2 Beneficial effects of UVR

As humans have evolved in the presence of UV irradiation from the sun, such exposure can be considered as “natural” – and indeed, some aspects of exposure are beneficial. A small dose of UVB is responsible for the induced synthesis of Vitamin D (calciferol) in the skin, which is essential for healthy bone development in children. However, problems arise when the dose of UVB exceeds this “inducing dose”, and there is normally sufficient Vitamin D in the diet to supply the needs of adults.

Under carefully controlled conditions, UVR is used by dermatologists to treat diseases such as eczema and psoriasis – but careful recording of the total (lifetime) UV dose is undertaken to ensure that the benefits outweigh the risks.

A combination of UVA and UVB is responsible for the increased synthesis of melanin, which in turn offers some protection against the damaging effects of UVB. At best, however, the protection offered by a tan is equivalent to a sun protection factor (SPF) of 3 – 4, and is easily overwhelmed. There is also evidence to suggest that melanin itself may contribute to the formation of free radicals when skin is irradiated by UVB. The presence of a suntan should be regarded as a sign of damage caused by exposure to UVR.

10.3 Harmful effects of UVR

The harmful effects of UVR are a consequence of the deposition of the energy of the radiation in the exposed parts of the body. This deposition of energy can result in the formation of free radicals and reactive oxygen species, as well as direct damage to macromolecules such as cross-linking of DNA; breaking disulphide links in protein, etc.

There are two types of damage associated with UVR:

- **Early effects**, e.g., erythema (sunburn); photoconjunctivitis.

- **Delayed effects**, e.g., skin cancers; skin ageing; cataracts.

There are indications that the different types of UVR can induce different types of damage, and it is not clear whether or not the damage is cumulative, or can be repaired. Some of the damage may be cumulative, as the incidence of skin cancer appears to relate to the frequency with which sunburn has been experienced over the lifetime of the patient. Free radical generation and formation of reactive oxygen species by UVR may contribute to the overall damage.

It had been thought that UVA rays were less damaging than UVB, because, although they penetrate deeper than the shorter wavelength UVB rays that cause most erythema (sunburn), they were thought to have less impact on DNA and protein. However, examination of skin tumours found evidence that UVA rays had damaged cells in the deep basal keratinocyte cell layer. The basal layer contains the mother cells that ensure continual regeneration of the skin through cell division. Subsequent UVB damage may be enough to make skin cells migrating out from this region highly vulnerable to cancer. The most aggressive form of skin cancer, malignant melanoma, is associated with increased exposure to UVA, for example "sunbed" use, but the causation is complex and not completely understood.

UVB has long been associated with burning and erythema as the immediate effect, plus damage to the eyes. Chronic effects include (along with UVC) the induction of skin cancers and cataracts (see below.) Skin cancers have been associated with mutations of the p53 "tumour suppressor" gene in skin exposed to UVB, with the frequency of mutation depending on the degree of exposure to UV (Reference 11A). Similarly, UV irradiation has been shown to depress the immune system, leading to increased susceptibility to infection as well as possibly promoting the development of skin cancers.

UVC has been shown in the laboratory to cause DNA damage such as cross-linking and mutations. Such damage has the potential to induce skin cancer in areas of skin damaged by overexposure to UVR. Solar UVC is almost completely screened out by ozone in the stratosphere, but significant penetration to ground level has been observed in regions of the Earth affected by the hole in the ozone layer. This is of particular importance to anyone undertaking fieldwork in those regions.

At high altitudes, the UVR flux is greater (UVR flux increases by approximately 4% per 300 m. of ascent), and where there is snow on the ground, the reflectance is also increased compared with vegetation or bare rock/ earth.

Individuals have a wide range of sensitivity to UVR, which may be enhanced as the result of:

- suffering from one of several rare diseases (e.g. porphyria);
- taking photoreactive drugs (e.g. some tetracyclines, nalidixic acid etc); or
- using certain cosmetic products (commonly creams or perfumes).

10.4 Acute effects

10.4.1 Skin exposure

Four types of acute (early) effects have been observed in the skin after UVR exposure:

An initial darkening of the melanin already present, and if the dose is high enough:

- **erythema**, which becomes painful about 12 hours after exposure and may remain so for several days;
- an **initial cessation of cell growth** in the skin, followed after a day by

- an **increase in cell division** which thickens the epidermis and eventually causes scaling. This is observed as a loss of elasticity in the skin, and has the effect of accelerating the aging of the skin. The final step is
- **melanogenesis**, which results from an increase in the number, size and pigmentation of melanin granules in the keratinocytes, and is usually referred to as acquiring a sun tan.

10.4.2 Eye exposure

The most damaging wavelengths are in the UVB region, but radiation in the UVC and UVA regions is also hazardous. Damage is concentrated in the outer layers of the eye where the UVR is absorbed, and UVR does not normally penetrate to the retina. Damage to the lens can result in the lens losing its transparency, with the formation of a cataract.

Unless the eye is shielded from UV radiation by well-fitting goggles severe irritation may be experienced because of photokeratitis; conjunctivitis may also occur. "Snow blindness" in the highly reflective environment of a ski slope is one common example of damage to the eyes. The condition typically occurs at high altitudes on highly reflective snow fields or, less often, with a solar eclipse. Lightning flashes can also emit significant quantities of UVR as well as visible light.

Artificial sources of UVR can also cause snowblindness. These sources include suntanning beds; a welder's arc; carbon arcs; photographic flood lamps, and halogen desk lamps. Many of these sources are intended to provide visible light, and the emission of significant quantities of UVR is incidental to the purpose for which the device is operated.

Symptoms may include one or more of the following: excessive watering of the eyes; pain; redness; swollen eyelids; headache; a gritty feeling in the eyes; halos around lights; hazy vision, and temporary loss of vision. These symptoms may not appear until 6-12 hours after the UVR exposure.

Early (acute) effects of over-irradiation become evident within hours or days, but late (chronic) effects may follow many years after irradiation. Permanent damage could occur without the person being aware of it until many years later – for example, excessive UVB entering the eye may cause yellowing of the lens of the affected eye, and could even result in a cataract [opacity of the lens] being initiated but may only be identified many years later. There are indications that the eye damage is cumulative, as marine workers (fishermen) with a high exposure to UVB had a higher incidence of cataracts than those not similarly exposed. All the early effects gradually disappear after the irradiation has ceased.

10.5 Chronic effects

It is unlikely that these effects can be reversed, so that overexposure to UVR should be avoided. It is unlikely that any permanent damage will result from **laboratory** use of UVR-emitting devices if they are used in accordance with the manufacturers' instructions – the UVR source should normally be well shielded. Any non-visible breakdown in the shielding may however only be recognised when the user experiences the early effects of UVR irradiation.

As a result of sunbathing and the use of sunbeds for cosmetic reasons, degeneration of the dermal tissue has become a cause for concern, particularly among middle-aged females. Irradiated skin suffers a decrease in elasticity, which can result in skin fragility and at best the appearance of premature ageing. Of much greater concern is the recent increase, reported from many countries in the incidence of skin cancer. This disease can take three forms: squamous and

basal cell carcinomas, which are readily amenable to treatment if detected early enough; and malignant melanoma, which is likely to prove fatal unless treated in its early stages (Reference 9).

Deleterious late effects of UVR on the eye have been reported. Wavelengths below about 310 nm (i.e., UVB and UVC, but mainly UVB at about 290 – 315 nm) will be transmitted through the cornea and be absorbed by the lens, causing brunescence (a browning of the lens – which may develop into a cataract) and a loss in elasticity. High doses of UVA may also cause cataracts, but there is no evidence that UVR has produced tumours in the eye.

The National Radiological Protection Board (NRPB) (now part of the Health Protection Agency, HPA) have published a report on the health effects from ultraviolet radiation (Reference 11) and the current statement of the NRPB/ HPA regarding the effects of UV radiation on human health is cited at Reference 12.

At present, there is evidence to show that all forms of UVR, whether from solar radiation or from artificial sources “are reasonably anticipated to be carcinogenic for humans”, although the epidemiological data is not as good for artificial sources of UVR as they are for solar UVR.

11 ARTIFICIAL SOURCES OF UVR

It is difficult to gain a quantitative appreciation of the relative effects of UV radiation without recourse to a measuring instrument; consequently the following information is presented to help UVR users understand the relative risks involved.

The data given in this section is mainly extracted from Reference 5. Identical equipment is unlikely to be currently in production, but outputs are likely to be still in the same general range. The figures quoted in the reference are for the actinic region (200-320 nm), and are in terms of an effective irradiance obtained by summing the measured outputs over a range of wavelengths. The units used are μWcm^{-2} (i.e. 1 microwatt = 10^{-6}W). Manufacturers may use units of mWm^{-2} ($1 \mu\text{Wcm}^{-2} = 10 \text{mWm}^{-2}$).

Table 2 indicates which sources of UV radiation require shielding to be used, and those which are normally considered “safe” without other control measures being applied. (Radiation dose of less than 30J m^{-2} integrated over an 8-hour working day). However, sources of UV radiation must be individually assessed and the appropriate control measures employed (Section 3 of this Annex).

Source type	Sub-group	Typical applications	Shielding required
Incandescent	Tungsten	General, display and emergency lighting	No
	Tungsten halogen, quartz envelope	Spotlights, heating and floodlighting	Yes
Solid state lamps	LEDs, electro-luminescent lamps	Display, panel indicators, night lights	No— but see footnote
Open arcs	Various	Welding	Yes
Gaseous discharge	Low pressure Na	General and industrial lighting	No
	Low pressure Hg	General lighting horticultural and germicidal, sunbeds	Yes
	UVA black light Hg	Fluorescence, medical	No, if low power
	High pressure Na	Floodlighting	No
	High pressure Hg or Xe Arcs	Industrial printing, curing and commercial lighting ; Fluorescence microscopy; Photochemical and projection	Yes
	Special High Intensity Discharge (HID)	Polymerisation reprography	Yes
	Xe	Projection and photography	Yes
	Pulsed Xe	Printing	Yes

Table 2 - Some UVR and other light sources indicating the need for shielding (adapted from Reference 5)

11.1 Guidance for some typical applications:

11.1.1 Office photocopiers

Most office photocopiers use a dry process that can emit UVR as well as visible light from a quartz-halogen source. If the lid of the photocopier is raised (as when copying a thick book) some of the UVR may escape through the top glass plate, thus as far as possible, keep the lid down when photocopying. (This is likely to be UVA, with a small component of UVB.) The lamp may also emit some UVC (leading to the formation of ozone during the copying process). The amount of ozone is normally small, but may increase if the copier is used intensively for a period of time.

University personnel should not attempt to undertake any servicing or adjustment operations on photocopiers - a qualified service engineer should be called to deal with any problem. University staff should try to avoid being present in the room whenever a servicing operation is undertaken

that requires operation of the lamp without the machine covers in place (e.g., for lamp replacements and adjustments).

Although outside the scope of this Safety Guide, readers should be aware of the potential for photocopiers to generate Ozone as noted above. The manufacturer's instructions should be consulted in regard to siting of the photocopier – normally this must be in a well-ventilated space where it will not cause an obstruction – thus they must not be located in corridors and thoroughfares.

11.1.2 UV Spectrophotometers

Most spectrophotometers operating in the UVR region are designed to contain the UVR beam, and direct the beam through the sample to be examined. They are frequently based on a hydrogen or deuterium lamp, emitting UVR over the range from 190 – 400 nm. The design of the instrument means that in normal operation, exposure to UVR is most unlikely. However, replacement or adjustment of the lamp would require access to the housing, and could result in exposure. This must be undertaken by a qualified service engineer.

11.1.3 Chromatography viewers

The effective irradiance of the direct beam from a 35 W lamp is typically about 3000 μWcm^{-2} at 50 mm and 200 μWcm^{-2} at 450 mm. The effective irradiance of the **reflected** beam at a position normally occupied by the eyes when viewing a chromatograph would typically be about 10 μWcm^{-2} . For UVR of wavelength 290 nm, this would limit viewing to about 5 minutes per day **unless a protective screen is fitted**. Staff using such equipment must wear appropriate PPE (face shield, lab-coat, and gloves), and the Local Rules must reflect this requirement.

11.1.4 UV Transilluminators

These devices are used for viewing gels following electrophoresis to identify bands (for example) of separated DNA fragments. A typical UV transilluminator would have a peak output in the 302 nm region if it is used for the identification of DNA bands stained with Ethidium Bromide (EtBr). It could contain as many as six 15W low-pressure mercury lamps, and be equipped with a filter on the viewing bed to screen out the majority of the 254 nm radiation. (Other models may be designed with a peak output of 254 nm, and lack this screening filter.) Note that the use of EtBr is itself potentially hazardous (as the dye is a suspect carcinogen), but the UV hazard probably far exceeds the chemical hazard from the use of the dye. Users should consider whether Ethidium bromide could be replaced by an alternative dye such as "SYBR-Safe" which is claimed to be safer than EtBr, and which does not require the use of a UV transilluminator (blue light is suitable, and far less hazardous than UVR of approx. 300 nm wavelength.)

Where a UV transilluminator is used to examine gels, the instrument should always be located in an area that is separate from the main laboratory, so that only the person using it could be exposed to UV. This is frequently in a darkened room to assist in the identification of fluorescing bands, but note that this results in the pupil of the eye being widely dilated, increasing the risk from any UV reaching the lens of the eye.

A full-face protective Perspex shield, vinyl or nitrile gloves and a labcoat must always be worn when using a transilluminator. These must be kept in good condition, and cleaned or replaced if dirty or damaged. When gels are placed on the bed of the instrument for examination, the protective

Perspex screen should always cover the gel so that the operator is not exposed, unless it is necessary to cut out one or more bands from the gel. The design of the instrument should be such that the shield is hinged at the front of the bed, and is raised towards the operator. Any existing transilluminator not already equipped with a shield attached in this way should be modified accordingly. See Figs. 2a and 2b



Fig 2a. A typical transilluminator, showing the raised shield at the front of the flat bed

(Photo from manufacturer's catalogue) Note the viewing area in the centre of the bed. Users should be aware of escape of UVR from the sides of the instrument when the shield is raised, and avoid placing any articles with shiny reflective surfaces close to the instrument. Ideally, the instrument should be operated in an enclosure with dark matt surfaces to the sides and rear.

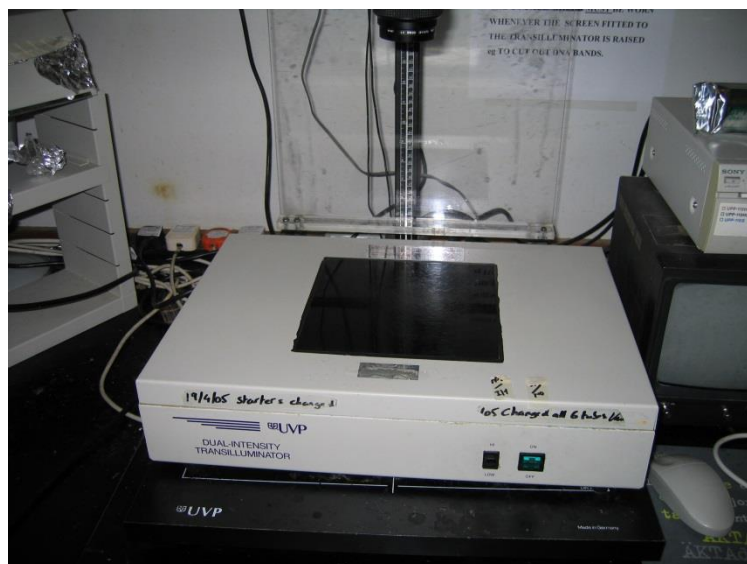


Fig 2b: Transilluminator with shield wrongly fitted at the back of the bed

Note the surfaces to the sides and rear of the instrument, and lack of any screening. Note also that the device has been modified since this photograph was taken.

If the lamps in a transilluminator are changed by University personnel, care must be taken to ensure that all shielding is properly replaced before the instrument is brought back into use. Old lamps must be disposed of as "hazardous waste" due to the presence of mercury and other hazardous components in the lamps. As with all portable electrical equipment, they are subject to regular Portable Appliance Testing, and should be re-tested after any service operations which involve removal of the covers.)

11.1.5 Lamps for viewing minerals

Typical lamps, (fitted with glass filters), have effective irradiances in the range $4\text{--}60\ \mu\text{Wcm}^{-2}$ at 1 m, with a typical wavelength of approx 350 nm (some models may have two or more wavelength peaks, selectable by switching.) The effective irradiation increases when the filter is removed.



Fig 3. Hand-operated UV lamp (can be bench mounted)

11.1.6 Germicidal lamps

A 15W germicidal strip lamp is likely to have an effective irradiance of about $600\ \mu\text{Wcm}^{-2}$ at 200mm distance and $40\ \mu\text{Wcm}^{-2}$ at 1m. It is essential, therefore, that lamps of this type are used only inside closed cabinets, preferably with interlocked doors. Note that the peak output of this type of lamp is approx 254 nm (UVC); it kills microorganisms by damaging DNA, and can therefore damage DNA in human cells. (This wavelength is almost completely absorbed in the keratinised outer layer of the skin – but it can still cause damage. See Section 4)

11.1.7 High intensity / high pressure mercury vapour discharge lamps

Lamps of this type are normally provided with a UVR absorbing glass envelope e.g., for use in exterior lighting applications, but special orders are available without the envelope. A UVR hazard will arise if the envelope is broken, leaving the lamp operating within a quartz inner bulb. Damaged bulbs must not be used, and should be replaced at the earliest opportunity. At a distance of 1m a typical value for the effective irradiance is approx. $17\ \mu\text{Wcm}^{-2}$. Two situations may arise:

- Lamps used in fluorescence microscopy
Even though photomultipliers are used to detect and amplify the emitted light, fluorescence microscopy requires a very high intensity light source to allow sufficient excitation of the fluorophores in the sample to cause a detectable fluorescence. Typical lamps include Mercury Arc and Xenon Arc lamps - they range in wattage from 50 watts to 200 watts for Mercury

lamps and from 75 watts to 150 watts for xenon lamps. A typical "mercury burner" lamp consists of two electrodes sealed under high pressure in a quartz glass envelope which also contains mercury. They emit a significant proportion of the energy in the UV range, and in use, UV-absorbing filters and shielding should protect the operator from exposure. By contrast, Xenon lamps produce much more of their output in the visible spectrum, and emit very little UV. However, both types of lamp require careful handling because of the danger of explosion due to very high internal gas pressures and extreme heat generated during use. Both types have a limited life (a careful log should be kept of the number of hours of operation) and must not be operated once the design life is reached because of the explosion danger. Lamps must never be operated outside of the housing, and no attempt must be made to observe the lamp directly when it is burning (this can cause serious eye damage). Neither mercury nor xenon lamps should be handled with bare fingers in order to avoid inadvertent etching of the quartz envelope. Bulbs must only be changed after the lamp has had sufficient time to cool. Lamps should be stored in their shipping containers to avoid accidents. It is essential to ensure that all shielding and filters are properly re-installed whenever a bulb is changed.

- Old projection microscopes may contain high pressure mercury lamps which do not indicate that a significant part of the emission occurs as UVR. Most of the direct radiation should be absorbed by the glass lens system, but scattered radiation may escape through ventilation apertures. All instruments to which this could apply should be checked to confirm the type of bulb contained, and if applicable, ventilation apertures should be screened to prevent emission of UVR. Precautions relating to bulb handling and changing are as given above.

11.1.8 Electric fly killers

These units (also referred to as "Insectocutors") do not normally present a UVR hazard provided the correct lamps are used and the units are regularly serviced according to manufacturers instructions. Non-standard lamps must never be used as this could result in unacceptable levels of UVB and UVC radiation being produced (Reference 19).

11.1.9 Arc welding

This can be a potent source of UVR because of the high temperatures achieved in the welding process when the arc is struck. Full use must be made of curtains etc to shield other persons from the arc radiation. However, it is not possible to shield the operator from the arc in any other way than to resort to wearing the appropriate personal protective equipment, i.e., visors, gloves etc. These items must be selected and used in accordance with the Personal Protective Equipment at Work Regulations 1992 (Reference 14) and the associated guidance (Reference 15).

12 ATTENUATION OF ULTRAVIOLET RADIATION

The following data on the UVR properties of certain materials is given to assist experimenters when designing and constructing UVR enclosures.

Plastics have very long molecules which are easily damaged by chain scission. UV radiation is particularly effective in degrading these substances, and so for commercial use UVR absorbers are always incorporated. Hence, "transparent" plastics form effective shielding against UVB and UVC.

In the long term all plastics will degrade, so shields against UV radiation must be examined frequently for signs of crazing and cracking.

Acrylic sheet, under the trade names of Perspex, Lucite or Plexiglas is suitable for many applications, being relatively inexpensive and easily machined. It is obtainable as transparent sheet or in several colours. Transparent sheet 6 mm (1/4") thick is highly transmitting above 380 nm and absorbs almost completely below 320 nm, the fall-off in the intermediate region is roughly linear. Other grades are available, including VA (clear) and VE (slightly yellow) Perspex sheet, which are claimed to be highly absorptive below 400 nm. Coloured Perspex sheet is equally effective: amber transmits only above 520 nm and red above 590 nm.

Ordinary sheet glass is not a particularly effective shield for UVA, although UVB and UVC are absorbed. At 316 nm (about the lower limit of UVA) a thickness of 1mm is said to absorb 50% of the incident radiation. A typical thickness of 3 mm (1/8") will thus show a transmission of about 12% at the lower end of the UVA range, with higher transmission as the wavelength increases. Vitreous silica and fused quartz are highly transparent at wavelengths below 200 nm, and so shielding is required [Figures 4 and 5]. Much useful information on optical filters is summarised in the monograph published by the Hospital Physicists Association (Reference 16). Note that both oxygen and nitrogen in the air absorb wavelengths below 200 nm, and this could form the basis of an effective shield if the distance from the source is great enough.

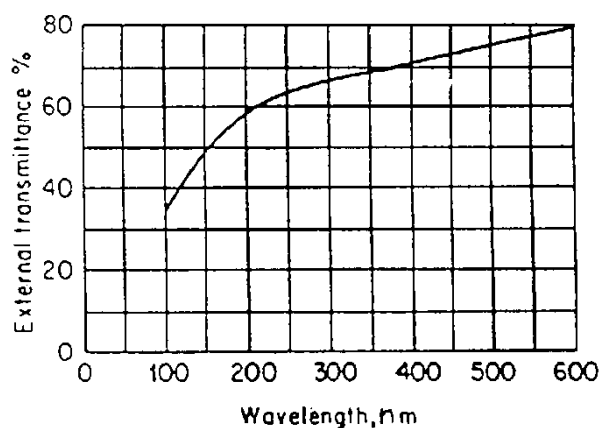


Figure 4 - Transmission of fused silica

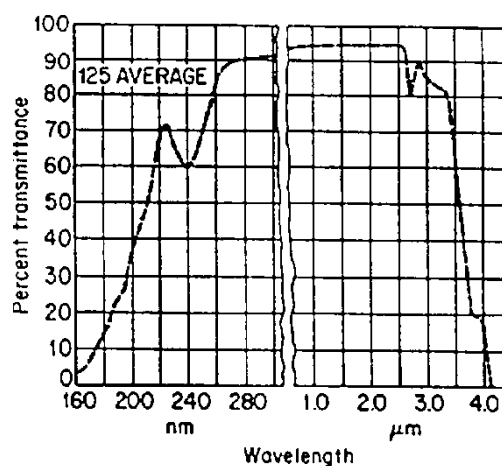


Figure 5 - Transmission of ultraviolet and visible radiation by fused quartz

Reflection of UV radiation may be high from polished metal surfaces and glossy ceramic tiles. The reflectance of a white pigment in the UV region depends on its composition and is not always

related to that in the visible. Matt coloured pigments are generally poor reflectors. The tables below gives some typical values.

Material	Percent reflectance at 254 nm
Aluminium, etched	88
Aluminium foil	73
Chromium	45
Nickel	38
Stainless steel	20-30
White paper	25
Glass	4

Table 3 - Reflectance values of various materials at 254 nm (the UV peak wavelength in the mercury emission spectrum) (from Reference 17)

Material	Percent reflectance			
	254 nm	297 nm	365 nm	Visible
Zinc oxide	2.5	2.5	4	88
White titanium oxide	6	6	31	94
Magnesium oxide	77	86	87	94
Flat black lacquer	5	5	5	5

Table 4 - Reflectance values of various pigments (from Reference 18)

13 OTHER HAZARDS

13.1 Gaseous dissociation

Wavelengths below about 250 nm are capable of dissociating oxygen in the air to form ozone. Particularly critical is the 185 nm line in the mercury spectrum. Ozone is therefore commonly produced as a by-product of short-wave UVR emissions, but because of the absorption by atmospheric gases, the range of such radiation is extremely short – the by-products are more likely to be a hazard than the radiation itself, unless the UVR source is in direct contact with the skin. In addition, below 160 nm nitrogen can be dissociated, which can then interact with oxygen to form nitrogen oxides. Hughes (Reference 5) reports that UV irradiation of some halocarbons can form hydrogen chloride and phosgene.

13.2 Pressurised lamps and cooling water

Some UV lamps operate at pressures as high as 200 atmospheres. Persons using lamps and equipment should be protected against an explosion should the tube envelope be damaged. Lamps of this type frequently require water cooling. Water leaks from an unattended lamp can damage electrical circuitry operating at mains or higher voltages and pose other dangers.

14 LEGAL BACKGROUND

Currently there are no specific regulations in the UK which cover the exposure to optical radiation (OR) from artificial sources at work. However, a risk assessment for exposure arising from artificial sources of Optical Radiation will be a requirement of the Regulations to be derived from the European Physical Agents Directive 2006/25/EC (artificial optical radiation) (Reference 1). The Directive was agreed on 5 April 2006, and the text was published on 27 April 2006.

The Directive also sets out the exposure limits (derived from the ICNIRP limits quoted above in Section 2), and the control hierarchy that must be adopted, and sets out the criteria to be adopted for worker information and training and for health surveillance. The Directive must be transposed into National Law (in the form of new regulations) by April 2010, i.e., 4 years following the date of the above Directive. Note that this Directive does not cover exposure to natural sources of optical radiation (i.e., the sun), even though this is likely to be the greatest source of exposure for the majority of people.

At the moment the use of OR sources is broadly governed by:

- the general duty of care requirement derived from Section 2 of the Health and Safety at Work etc Act 1974; and
- the risk assessment requirement of the Management of Health and Safety at Work Regulations 1999 (References 2 and 3), insofar as any "relevant statutory provisions" apply.

15 PERSONAL PROTECTIVE EQUIPMENT

The Personal Protective Equipment Regulations 1992 (Refs. 14 and 15) impose a series of duties on employers, including one to make an assessment to determine whether the personal protective equipment is suitable. There are other specific and separate duties to maintain personal protective equipment (PPE), to replace damaged items, to provide suitable storage, and to give information, instruction and training about the risks to be avoided, and the manner in which the PPE should be used. In addition, PPE cannot be supplied in the EU unless it is legitimately "CE marked". This basically means that the supplier must certify that the PPE complies with all relevant harmonized standards (designated BS ENs in the UK).

In the case of UVR protection, there are several relevant BS ENs covering "eyewear". These are applicable to a visor (or ocular) and the helmet (or frame). Each requires an indication on the PPE of the standard(s) to which it conforms, and the protection it provides.

The marking must be clear and indelible. Each number indicates compliance with a level of performance specified in the relevant BS EN. The details are given at length in BS EN 166 : 2002 (Ref 20) Personal eye protection – specifications, and in BS EN 170 : 2002 Personal eye protection: Ultra violet filters Transmittance requirements and recommended use. (Ref. 21)

16 GLOSSARY AND EXPLANATION OF TERMS

Cataract - Clouding of the lens of the eye caused by UVR exposure.

MED - Minimal Erythmal Dose. The amount of UVR exposure required to cause perceptible reddening of the skin of fair-skinned people. MED is not a standard measure of UVR exposure and only considers individuals sensitivity to UVR. One MED is equivalent to an erythmal effective radiant exposure of 200 Jm^{-2} .

Erythema - Reddening of the skin due to UVR exposure, as in sunburn.

Nanometre - (nm) A unit of length that is 10^{-9} metre, or one billionth of a metre.

Photoconjunctivitis - a painful inflammation of the conjunctiva, the tissue coating the eyelid and part of the eyeball.

Photokeratitis - a painful inflammation of the cornea of the eye.

SED - Standard Erythmal Dose. The International Committee of Illumination (CIE) undertook a review of the current terminology used to describe erythmal effects. Until recently the term MED was used widely as a measure of erythmal radiation. The term SED was introduced as a standardised measure of erythmal UVR. One SED is equivalent to an erythmal effective radiant exposure of 100 Jm^{-2} .

SPF - Sun Protection Factor. Applied to sunscreens and is a measure of the amount of protection against UVR provided by a sunscreen. Sunscreen SPF ratings are determined by testing sunscreens on the skin of human volunteers in accordance with Australian Standard AS2604: 1998.

Skin cancer - Malignant skin damage due to UVR exposure. Three common types are basal cell and squamous cell carcinomas and melanoma.

Sunburn - Reddening of the skin due to UVR exposure, also known as erythema.

UPF - Ultraviolet Protection Factor. This value is a measure of the UVR protection provided by a fabric.

UVR - Ultraviolet Radiation. Refers to all ultraviolet radiation in the range 100 nanometres to 400 nanometres. Solar UVR that reaches the earth's surface contains radiation in the range 290 to 400 nanometres due to atmospheric absorption of shorter wavelengths by gases in the atmosphere (Oxygen; water and Ozone)

UV-Index - The Solar UV-Index was developed from a joint recommendation of the World Health Organization (WHO), the World Meteorological Organization, the United Nations Environment Programme, and the International Commission on Non-Ionizing Radiation Protection. The UV Index is a unitless number relating to how much solar UVR reaches the earth's surface. The higher the UV-Index the more UVR present and the greater the potential for skin and eye damage. In 2002 the UV Index categories were revised to improve its use as an educational tool to promote sun protection worldwide. The "Global Solar UV Index - A Practical Guide" can be found at the WHO's Intersun web site.

17 FURTHER INFORMATION

Further information may be gained by consulting the following references:

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 16. Ultraviolet Radiation and its Medical Applications, Hospital Physicists Association, 1978
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 19. Acute sunburn due to accidental irradiation with UVC, Contact Dermatitis, Vol. 24, No2, pp141-142, February 1991
 20. BS EN 166 : 2002 Personal eye protection – specifications. BSI, London
 21. BS EN 170 : 2002 Personal eye protection: Ultra violet filters Transmittance requirements and recommended use. (Updated 2005) BSI, London

Appendix 1: Version control

VERSION	KEEPER	REVIEWED	APPROVED BY	APPROVAL DATE
X.X	H&S	Every four years	XXXXX	XX/XX/XX
X.X	H&S	Annually	XXXXX	XX/XX/XX