INTRODUCTION

Non-ionising radiation is an umbrella term for various types of radiation that are harmless in low doses and if exposure is not prolonged. The main difference between non-ionising and ionising radiation is that the former causes no ionisation in biological systems (body cells), even at very high levels of intensity. It can have other effects, however: it can heat tissues and cells or produce electrical currents in them.

This means that exposure to high doses or concentrations can be harmful to humans. This is the case, for example, with radio-frequency radiation from sealers and transmitters, infrared radiation from welding arcs, hot objects and lasers (e.g. laser pens!), and UV radiation from welding processes and sterilisation lamps. Far less is known at present about effects such as fatigue, drowsiness and carcinogenicity. There is a good deal of discussion in this area, for example on the safety of mobile phones, GSM masts and radars.

LEGISLATION

The Health and Safety at Work Act (*Arbowet*) and Health and Safety at Work Decree (*Arbobesluit*) do not lay down any statutory standards for non-ionising radiation. But that does not mean that ‘anything goes’ when it comes to non-ionising radiation. Employers are responsible for providing a safe, healthy working environment and therefore need to prevent harmful effects of non-ionising radiation. Devices and equipment that emit non-ionising radiation must be properly constructed.

Health limits are laid down for each type of radiation. Detecting and assessing sources of non-ionising radiation is part of the risk survey that any organisation is required by law to carry out. Employers are required to take measures to prevent the limits being exceeded.

SPECIFIC INFORMATION

UV radiation (frequency between 750 x 10^{12} and 3,000 x 10^{12} Hz):

The main organs affected by UV radiation are the skin and eyes. UV-A radiation penetrates most deeply and is therefore the most dangerous type. Its acute effects include skin burns (‘sunburn’) and keratitis and conjunctivitis (‘arc eye’ or ‘welder’s flash’). In the long term, skin cancer and cataract (clouding of the ocular lens) can develop.

UV light with a wavelength of less than 240 nm can convert oxygen into ozone, which is a very harmful substance (the MAC value is 0.06 ppm 1 hour).

The Health Council of the Netherlands has issued a recommendation on maximum exposure to UV radiation (1993). Unintentional UV radiation should be kept to a minimum.

Visible light (frequency between 385 x 10^{12} and 750 x 10^{12} Hz) and infrared (frequency between 3 x 10^{11} and 385 x 10^{12} Hz)

The harm that can be caused by the visible part of the spectrum is limited. Eyes have their own protective mechanism (‘squinting’), and they can only be damaged by too much exposure to visible light. The risk of damage to the retina is highest at a wavelength between 400 and 500 nm (‘blue light hazard’).

Infrared is divided into three frequency bands: IR-A, IR-B and IR-C. Short-wavelength infrared radiation (IR-A) can penetrate deep into the skin and eyes and cause thermal (heat) damage to the retina. Chronic exposure of the eyes can lead to cataract. The wavelengths of IR-B and IR-C are unable to penetrate beyond the cornea and cause less damage. Excessive exposure to infrared can cause skin burns.

Setting standards for this part of the spectrum is a very complex matter, as physical sensitivity is highly dependent on the wavelength emitted; also, the various parts of the body are not equally sensitive. More information on the subject can be found in the Health Council recommendation (1993).

Microwaves (frequency between 3 x 10^{8} and 3 x 10^{11} Hz) and radio waves (frequency between 3 x 10^{5} and 3 x 10^{8} Hz)

Microwaves raise the temperature of the exposed tissue. The organs most sensitive to this are the eyes, skin and testicles. There is no clear evidence for associated (subjective) symptoms such as headache, irritability and drowsiness, but these are often mentioned in the literature.

The effects of radio waves are largely similar to those of microwaves. Touching an object in an area where there is strong radio-frequency radiation can even cause burns. Many subjective symptoms are attributed to radio waves: headache, sleep disorders, fatigue, general weakness, etc.

When setting limits, the current densities (in mA/m^2) and the ability of the body to absorb them are taken into account. This variable is referred to as the ‘specific absorption rate’ (SAR), but the SAR and the induced current in humans are not measurable. The exposure limits have therefore been based on derived parameters that are measurable, i.e. electrical and magnetic field strength.

The Health Council recommendation (1997) on microwaves and radio waves gives exposure limits for radio-frequency and microwave radiation by frequency band.

STATIC ELECTRICAL AND MAGNETIC FIELDS/ELF FIELDS

(frequency below 3×10^5 Hz)

Electromagnetic fields can be subdivided into static and ELF fields. Static electrical fields are often ‘natural’ fields such as the earth’s magnetic field and fields that develop during electrical storms, whereas ‘technical’ fields (i.e. those created by human action) are mainly alternating-current fields with a frequency of 50 Hz. The latter are caused by high-voltage lines and electrical equipment.

There is a good deal of uncertainty regarding the effects that electromagnetic and magnetic fields can produce. We do know that people who use electronic aids (e.g. pacemakers and hearing aids) can be inconvenienced or harmed by ELF fields.

In exceptional circumstances – under very high field strengths – these can cause acute health effects in humans.

According to the Health Council, based on current knowledge, ELF fields are not expected to cause any health problems in normal circumstances. Advice on maximum exposures can be found in various Health Council recommendations (see References). The limit for people with a pacemaker is 0.5 mT. Measures to prevent hazards from flying metal are required at flux densities higher than 3 mT. Analogue watches, credit cards and computer disks can be affected by exposures higher than 1 mT (this mainly causes inconvenience but no safety risks).

IMPLEMENTATION AT THE UNIVERSITY OF TWENTE

There are many sources of non-ionising radiation at the UT. In practice it has been found that almost everyone is exposed to one or more sources of non-ionising radiation. For the most part this is of no significance as regards possible harm to health, but it is important to be sufficiently aware of the presence or absence of sources that – intentionally or unintentionally – emit non-ionising radiation.

RISK SURVEY AND EVALUATION

The aim of a risk survey must be to identify harmful sources of non-ionising radiation and the circumstances in which people could be exposed to them. It is not easy to determine the dividing line between harmful and harmless radiation; in case of doubt a more detailed survey will be needed.

We should remember that exposure is often due to unintentional release (as in the case of UV radiation from welding). A survey is certainly necessary where:

- ultraviolet radiation is released or used: from lasers (see also the *Richtlijnen en Voorschriften bij gebruik van lasers* [Guidelines and Requirements when using lasers] and due to welding and disinfection using UV light;
- infrared radiation is released from welding or lasers;

- radio-frequency sources such as radio transmitters, industrial microwaves and plastic sealers are being used;
- staff are working with large static electromagnetic fields (NMR), electrolysis equipment or high-voltage cables.

I INFORMATION ON THE SOURCES

- What is the non-ionising source?
  State what source is involved (UV, IR etc.).
- Information on the size of the source:
  What are the relevant frequencies of the radiation and the associated wavelengths? The information may be known (from the manufacturer or supplier), otherwise measurements may need to be conducted. Expertise on how to carry out such measurements is essential: contact an occupational health expert or safety expert at the Occupational Health & Safety and Environmental Service.
- Effects that can occur:
  Possible harmful effects due to contact with the non-ionising radiation (risks mainly to the skin and eyes, or the release of other gases such as ozone). The most recent information in Health Council publications should be used here (see References and www.gr.nl).

II INFORMATION ON THE ACTIVITIES

What activities could involve a release of non-ionising radiation? Is it:

- intentional radiation (transmitters, UV disinfection)?
- unintentional radiation (released e.g. from welding or using lasers (continuous, periodic))?

III EXPOSED GROUP(S)

- What groups of staff, students or others could come into contact with the source?
- Are there any groups that are at risk from exposure (e.g. people with pacemakers)?

IV ACTION PLAN

- State what measures are being taken to prevent harmful effects. Consider the following:

OPTICAL/IR/UV RADIATION

- Shield the source. Almost any material can be used, e.g. glass, perspex, curtains.
- Maintain a safe distance from the source (radiation decreases with the square of the distance).
- Limit the time for which the source is used.
- Protect the eyes and skin (using personal protection). Make sure that the goggles being used protect against the right wavelength.
- Ozone or other harmful gases can be released as a by-product (due to heating). In that case use a good extractor system.

RADIO-FREQUENCY/MICROWAVE RADIATION

- Take precautions on equipment to ensure that the maximum radiation level can never exceed what is strictly required for correct functioning.
- Encase the source in a metal shield (a Faraday cage, properly earthed).
- Switch equipment off when it is not in use.
- Introduce zoning so that people cannot enter a high radiation field without realising it.
- Maintain a safe distance from the source (radiation decreases with the square of the distance).
- There is little available in the way of personal protective equipment.

ELF RADIATION

- Try to maximise the distance between the radiation source and staff members.
- Switch equipment off when it is not in use.
- Use maximum shielding by enclosing radiation beams, shielding against reflections and encasing current-carrying components.
- Mark areas that could potentially be hazardous for people with pacemakers.
- Mark areas that are hazardous because metal and cards etc. could be attracted and damaged.
- There is little available in the way of personal protective equipment.

LITERATURE/FURTHER READING

1. Gezondheidsraad (Health Council of the Netherlands), *Optische straling, gezondheidskundige adviezen voor blootstelling aan elektromagnetische straling met golflengten tussen 100 nm en 1 mm*, Publication 93/09.
2. Gezondheidsraad, *UV-straling, Blootstelling van de mens aan UV-straling*, Publication 86/09.
3. Gezondheidsraad, *Blootstelling aan elektromagnetische velden (0 Hz - 10 MHz)*, Publication 00/06.
4. Gezondheidsraad, *Gevaren van microgolfstraling en de daaruit afgeleide aanvaardbare stralingsniveaus*, Publication 75/21.
5. Gezondheidsraad, *Radiofrequente elektromagnetische velden*, Publication 97/01.
6. Ministerie van SZW (Ministry of Social Affairs and Employment), 1995, *Elektromagnetische straling in arbeidssituaties*.
7. www.gr.nl (website of the Health Council of the Netherlands).
8. Ministry of Social Affairs and Employment brochure *Veilig werken met niet-ioniserende straling en velden* (see www.minszw.nl).

APPENDIX 1: INFORMATION ON NON-IONISING RADIATION

Radiation is described in terms of its frequency (in hertz) and wavelength (in metres). Non-ionising radiation has a frequency below 3 x 10^{15} hertz (Hz), corresponding to a wavelength of over 100 nm.

NOMENCLATURE

The nomenclature associated with non-ionising radiation can be very confusing. Different terms are used for different types of radiation (visible light is expressed as a wavelength and microwave radiation as a frequency). The frequency range covering very long wavelengths is referred to not as ‘electromagnetic radiation’ but as ‘electrical and magnetic fields’. As a rule of thumb, when the distance between the source and the exposed person is less than one wavelength the term ‘fields’ is used; if it is greater than a wavelength the term ‘radiation’ is used. The dividing line lies approximately at a frequency of 100 MHz.

The table below shows the various types of radiation classified by wavelength and frequency, along with the most common characterisations.

Type of radiation	Wavelength	Frequency	Most common characterisation
ELF fields	>3,000 m	<0.3 MHz(1)	Electromagnetic field (V/m) and magnetic flux density (T)
Radio waves	1 – 3,000 m	0.3 - 300 Mhz	Electromagnetic field (V/m)
Microwaves	1 – 1,000 mm	0.3 - 300 GHz	Frequency (Hz)
Infrared radiation	0.78 – 1,000 µm	0.3 - 385 THz	Wavelength (m): IR-A: 780 – 1,400 nm

			IR-B: 1,400 – 3,000 nm IR-C: 3,000 - 10^6 nm
Visible light	400 – 780 nm	385 - 750 THz	Wavelength (m)
UV radiation	100 – 400 nm	750 - 3,000 THz	Wavelength (m) UV-A: 315 – 400 nm UV-B: 280 – 315 nm UV-C: 100 – 280 nm

(1): M (mega) = 10^6
G (giga) = 10^9
T (tera) = 10^{12}