The Ultraviolet Radiation Safety Program

at the University of Toronto

Introduction

Coherent and non-coherent ultra violet (UV) light sources are used in a variety of situations. The safe use of coherent UV light is covered in the University of Toronto Laser Safety Program. The safe use of non-coherent artificial UV radiation sources in buildings under the authority of the University of Toronto will be covered by the Ultraviolet Radiation Safety Program.

The University of Toronto is committed to ensuring that the use of UV radiation sources is carried out in a safe manner with due regard for employees, students, the public and the environment. The University of Toronto Radiation Protection Authority (UTRPA) is the executive body charged with ensuring that effective radiation safety programs exist for all sources of radiation. The Radiation Protection Service (RPS) is responsible for the development and administration of the radiation safety programs.

The current UV radiation safety program does not cover exposure to solar UV light. Exposure to solar UV radiation is the predominant cause of skin cancer, particularly when the sun is highest in the sky, such as in summer during the middle of the day. Limiting UV light exposures at these times has the greatest potential for reducing skin cancer incidence. The best approach to implementing successful strategies in reducing skin cancer will be to encourage sun protection policies and practices that reduce sun exposure in both occupational and recreational activities. Solar UV radiation also affects the eyes by increasing the risk of photokeratitis, photo conjunctivitis and cataracts. Wearing sunglasses and a broad brimmed hat can prevent most of the UV light from reaching the eyes.

Possible sources of UV Radiation at the University of Toronto

Work places in which the potential for exposure to artificial UV radiation may exist are:

- biological laboratories where gels are visualized under a trans-illuminator
- areas in which germicidal UV lights are used, including biological safety cabinets
- Kitchens where UV lights are used for germicidal and/or insecticidal purposes
- libraries where UV light may be used to examine documents
- science laboratories where UV radiation is used to cause fluorescence
- light emitting diodes (UV LEDs)
- mercury vapor lamps
- welding operations

For some of the sources described, the user may not be fully protected from UV light exposure by any inherent shielding around the source, or the user may not be aware of the hazards of UV light. The purpose of the UV Radiation Safety Program is to ensure that the safeguards necessary to limit exposure have been implemented.

NOTE: When using UV radiation as a germicidal control the following factors can influence the efficiency of the UV lamp:
- distance from the lamp - the efficiency decreases in inverse proportion to the square of the distance
- time of exposure - the efficiency increases in direct proportion to the exposure time
- aging of the UV lamp - the UV lamp should not be used more than the recommended life time (in general 8000 hours)
- cleanliness of the UV lamp - the UV lamp must be dust free
- direction of the UV light - to ensure maximum efficiency, the surface that needs to be sterilized must have direct exposure to the UV light. Indirect exposure (scattered UV light) is less efficient in killing microorganisms.

To verify the efficiency of the procedure follow the tests recommended in [6] or similar.

Health Effects

The UV part of the electromagnetic radiation spectrum extends from 3.1 eV (400 nm) to 124 eV (10nm). Most of the UV radiation is absorbed in air and does not pose a health risk. However the UV radiation in the range from 400 nm to 180 nm is less absorbed in air and can cause harm to the eyes and to the skin. This portion of the UV spectrum is separated into three parts: UVA from 400 nm to 315 nm, UVB from 315 nm to 280 nm, and UVC from 280 nm to 180 nm. Most of the UVC from the Sun is absorbed by the atmosphere. The UVC radiation produced by artificial sources can pose a health risk to a person situated in the vicinity.

UVA penetrates the most in the eye and in the skin being absorbed in the lens and in the subcutaneous layer of the skin. Having less energy per photon than UVB and UVC radiation, UVA radiation cannot cause direct DNA damage but can create free radicals and oxidative stress which can cause indirect DNA damage. UVB and UVC are absorbed in the cornea and in the dermis and epidermis. These types of UV radiations carry a higher amount of energy per photon and can cause direct DNA damage.

Large amounts of UVC can produce ozone above the limits.

Positive health effects

UV exposure induces the production of vitamin D in the skin. Vitamin D has regulatory roles in calcium metabolism (which is vital for normal functioning of the nervous system, as well as for bone growth and maintenance of bone density), immunity, cell proliferation, insulin secretion, and blood pressure. Too little UV radiation may lead to a lack of vitamin D. An appropriate amount of UV (which varies according to skin color) leads to a limited amount of direct DNA damage. This DNA damage is recognized and repaired by the body, and then melanin production is increased, which leads to a long-lasting tan. This tan occurs with a 2-day lag phase after irradiation.

Negative Health Effects
In humans, prolonged exposure to UV radiation may result in acute and chronic health effects on the skin, eyes, and immune system. An unfortunate property of UV radiation is that there are no immediate warning symptoms to indicate overexposure. Symptoms of overexposure including varying degrees of erythema (sunburn) or photokeratitis (welder's flash) typically appear hours after exposure has occurred.

UV radiation can initiate a photochemical reaction called erythema within exposed skin. This "sunburn" can be quite severe and can occur as a result of only a few seconds exposure. Effects are exaggerated for skin photosensitized by agents such as coal tar products, certain foods (e.g., celery root), certain medications and photo allergens.
Short over-exposure of the eyes to UV radiation can injure the cornea. Photokeratitis is a painful inflammation of the eye caused by UV radiation-induced lesions on the cornea. Symptoms include a sensation of sand in the eye that may last a few days.

An overexposure to UV radiation can cause sunburn and some forms of skin cancer. However the most deadly form - malignant melanoma - is mostly caused by the indirect DNA damage. UVC rays are the highest energy, most dangerous type of ultraviolet light. Chronic skin exposure to UV radiation has also been linked to premature skin aging, skin darkening, and wrinkles. Chronic eye exposure to UV radiation can create cataracts.

When the possibility of producing ozone is high, the ozone concentrations can increase over the limits. Most people can naturally detect about 0.01 ppm of ozone in air where it has a very sharp, specific odor, somewhat resembling chlorine bleach. Exposures of 0.1 to 1 ppm produce headaches, burning eyes, and irritation to the respiratory passages

University of Toronto Exposure Limits to UV Radiation from Artificial Sources

The limit for occupational exposure to non-coherent artificial UV radiation incident upon the skin or eyes is 30 J/m^2 (or 3 mJ/cm^2) [1-5].

The exposure limit is based on a normal 24 hour cycle of light and dark where cellular repair takes place mainly when the exposure is discontinued. The exposure limit is intended to be used as a guideline only for Solar UV Radiation exposure.

Permissible exposure time (measured in seconds) for exposure to UV radiation incident upon unprotected skin or eyes may be computed by dividing the 30 J/m^2 (or 3 mJ/cm^2) exposure limit by the effective irradiance measured in W/m^2 (or mW/cm^2). The maximum exposure duration may also be determined using Table 1 which provides representative exposure durations corresponding to effective irradiances in W/m^2 (and mW/m^2).

Table1: Limiting UV Exposure Durations Based on Exposure Limits

Duration of Exposure Per Day	Effective Irradiance		
	E_{eff} (W/m^2)	E_{eff} (mW/cm^2)	E_{eff} (microW/cm^2)
8 hours	0.001	0.0001	0.1
4 hours	0.002	0.0002	0.2
2 hours	0.004	0.0004	0.4
1 hour	0.008	0.0008	0.8
30 minutes	0.017	0.0017	1.7
15 minutes	0.033	0.0033	3.3
10 minutes	0.05	0.005	5
5 minutes	0.1	0.01	10
1 minute	0.5	0.05	50
30 seconds	1.0	0.1	100
10 seconds	3.0	0.3	300
1 second	30	3	3000

If the effective irradiance is a superposition of different wavelengths, it can be determined by using the formula and information from Appendix 1.

The effective irradiance changes with distance. If the effective irradiance is known at a certain distance but not known at the position of exposure it can be calculated with information from Appendix 1. If there are any doubts about the application of these limits please contact the University of Toronto's Radiation Protection Service (RPS).

Inventory

All supervisors of work places where potential for exposure to artificial UV radiation exists must register the equipment with the University's RPS.

Controls

Since UV radiation can be easily blocked, the best control is to shield the UV radiation at the source [7].

a. Training

All persons with access to open UV radiation must receive training covering: UV radiation hazards identification, health effects, signs, engineering control measures, and operating procedures. Periodic refresher training will be delivered. The refresher training will cover: changes in the regulations and in the University of Toronto UV Radiation Safety Program, changes in work procedures, etc.

b. Engineering controls

When exposure is from artificial sources, engineering control measures are preferable to protective clothing, goggles, and procedural safety measures. Light-tight cabinets and enclosures (including dedicated rooms) enclosed with opaque materials or UV radiation absorbing glass and plastic shielding and fail-safe interlocks are the key engineering control measures used to prevent human exposure to UV radiation. For applications where cabinets are not practical, shields, curtains, barriers and a suitable separation distance are used to protect individuals against the UV radiation emitted by open sources.

A high-power UV radiation source must have failsafe interlock access so that it is shut off when protective enclosure is open.

Ventilation may be required to exhaust ozone and other airborne contaminants produced by UVC radiation.

c. Administrative Controls

The work place supervisor is required to identify all potential UV radiation hazards associated with the workplace and equipment and then restrict all unauthorized workers and people from close proximity to the equipment or work area. The workers operating the equipment need adequate training to understand the hazards involved and to carry out their work safely.

Warning signs, lights and labeling of potential equipment that emit UV radiation are additional measures that may be used to aid the protection of workers (see Appendix B).

When enclosures with fail-safe interlocks, curtains or barriers cannot be installed, the distance from which workers operate the equipment has to be assessed as well as the duration of any exposure.

When unprotected UV lights are used in a room access to the room must be restricted to person with training and wearing personal protective equipment (PPE). A warning light indicating that UV light is on must be clearly visible from outside the room.

Employees with photosensitivity reactions to UV radiation require additional protective measures.

d. Personal Protective Equipment (PPE)

UV radiation is easily absorbed by clothing, plastic or glass. In case of working with open UV radiation during maintenance, service or other situations, particularly if safety shielding is removed, all personal will be provided with personal protective equipment covering all areas of skin, eyes and face. Long sleeve lab coats, gloves, eye glasses and face shields must be used.

e. Measurements

RPS does not routinely measure the intensity of UV radiation or determine the duration of an individual’s permitted use time. RPS will survey a source for light intensity upon request or if an accidental exposure is suspected and it is necessary to determine the potential extent of injury. Sources may also be surveyed at the discretion of RPS.

f. Work Place Inspections

Annual inspection of all existing areas where UV radiation is used and where the possibility of UV radiation exposure above the acceptable limit may be present will be performed by a Radiation Safety Officer (RSO). In addition, all new equipment or devices that can produce high levels of UV radiation will be inspected by the RSO before the equipment or device is used.

In performing a workplace inspection involving UV radiation, the check sheet in Appendix C will be used.

Table 2 – Summary of control measures for common laboratory equipment

Controls \ Equipment	Cabinet with interlock*	Cabinet without interlock	Trans-illuminators	Open UV source
Shields, curtains, barriers	-	-	Yes	Yes
Signs	Yes	Yes	Yes	Yes
Procedural controls	-	Yes	Yes	Yes
Awareness training	Yes	Yes	Yes	Yes
PPE (goggles, skin cover)	-	-	Yes	Yes
Work place inspection	Yes	Yes	Yes	Yes
Measurements	-	-	At request	At request
Time and distance calculations	-	-	Yes	Yes

*The UV source shuts down when the cabinet/enclosure is open

First Aid

For high power UV radiation sources overexposure can occur in few seconds. As mentioned above there are no immediate warning symptoms to indicate a UV radiation overexposure. Symptoms of overexposure including varying degrees of erythema (sunburn) or photokeratitis (welder’s flash) typically appear hours after exposure has occurred.

For UV radiation over exposure of the eye, place a sterile dressing over the eye and get medical attention.

For UV radiation over exposure of the skin, apply cold water or ice to the skin burns and get medical attention.

After the incident the Radiation Protection Service and the Principal Investigator will:

- Identify the sources and circumstances that produced the overexposure
- Discontinue their use to prevent other incidents
- Determine UV exposure levels and make sure that adequate controls are put in place

Appendix A – UV Irradiation Exposures

Intensity of UV radiation diminishes over distance. UV rays are predominantly emitted perpendicular to the surface of the lamp. In order to determine the intensity of UV radiation on a surface at different distances from a UV lamp, multiply the effective irradiance of the lamp rating at 1 meter (in microW/cm^2) by the intensity factor opposite the distance selected as in Table 1. This table provides an approximate simplified method for quickly calculating UV radiation E_{eff} at different distances when E_{eff} at a certain distance is known and when air absorption is neglected.

Table 1: Correction intensity factor with distance

Distance From Lamp (cm)	Correction Factor
5	400
10	10
20	25
25	16
30	11.11
40	6.25
50	4
60	2.77
70	2.04
75	1.77
80	1.56
90	1.23
1 meter	1

Good sources of information about your UV lamp will the manufacturer web page. Usually the effective irradiance of the UV lamps is given at 1m.

What time may a person be irradiated by a lamp with effective irradiance at 1m 91.3 microW/cm^2 **without reaching the UV limit at a distance of 50 cm?**

Using information from Table 2 a correction factor of 4 is required to calculate the effective irradiance at 50 cm.

E_{eff} (at 50cm) $= 91.3 \text{ X } 10^{-6}$ W/cm^2 X 4 = $365 \text{ X } 10^{-6}$ W/cm^2 = 0.365 mW/cm^2

Using the limit 3mJ/cm^2 the time required to reach the UV radiation limit is:

Time = 3/0.365 = 8.2 seconds

At 1m the exposure time increases to 33 seconds and at 2 m to 131 seconds.

Appendix B – Warning signs

Every device that can produce UV radiation above the exposure limit must have warning sign with the following (or similar) content:

Danger: This device produces potentially harmful UV light. Do not expose eyes and skin to UV light.

Warning signs are available from commercial suppliers or may be available from the manufacturer of the ultraviolet light product. Examples of commercially available UV warning signs are:

Appendix C – Inspection check list

UV Radiation Safety Checklist

Building ________________________________ Room __________ Principal Investigator _______________________ Date _________

Audit Performed by ______________________________

	Y	N	NA	COMMENTS
A. Sources of Ultra-Violet Light				
1. UV sources are properly labeled as being UV sources.				
2. Hazard warning information is present.				
B. Engineering Controls				
1. The UV source is properly enclosed				
2. Fail-safe interlock present				
3. Fail-safe interlock functioning				
C. Training and Information				
1. UV users have received training				
2. Training is documented				
3. UV users are aware of the hazards of UV light				
D. Administrative Controls				
1. The UV source is registered with the RPS				
2. The functioning of the interlock is verified routinely				
E. PPE				
1. UV goggles and/or full face shields are worn.				
2. Gloves and protective clothing are worn.				
3. Exposure time is limited.				

References

[1] - Guidelines on Limits of Exposure to Ultraviolet Radiation of Wavelengths Between 180 nm and 400 nm (Incoherent Optical Radiation), International Commission on Non-Ionizing Radiation Protection, Health Physics Society, April 2004

[2] - Directive 2006/25/EC of The European Parliament and of the Council of 5 April 2006 on the Minimum Health and Safety Requirements Regarding the Exposure of Workers to Risks Arising from Physical Agents (Artificial Optical Radiation) (19th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC)

[3] – Occupational Exposure to Ultraviolet Radiation, Radiation Protection Standard, Australian Radiation Protection and Nuclear Safety Agency, Australian Government, Radiation Protection Series Publication No.12, December 2006

[4] – Health Canada, Environment and Work Place Health, Ultraviolet Radiation, http://www.hc-sc.gc.ca/ewh-semt/radiation/ultraviolet/index-eng.php

[5] – American Conference of Governmental Hygienists (ACGIH) Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs) Booklet: www.acgih.org

[6] - Carrier Tests to Asses Microbicidal Activities of Chemical Disinfectants for Use on Medical Devices and Environmental Surfaces, V. Susan Springthorpe and Sayed A. Sattar, Journal of AOAC International, Vol. 88, No. 1, 2005

[7] Ultraviolet Radiation in the Workplace – Ontario Ministry of Labour, http://www.labour.gov.on.ca/english/hs/pubs/uvradiation/gl_uvrad_4.php