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Federal Department of Home Affairs FDHA
Federal Office of Public Health FOPH

Fact sheet on UV-C disinfection lamps for home use

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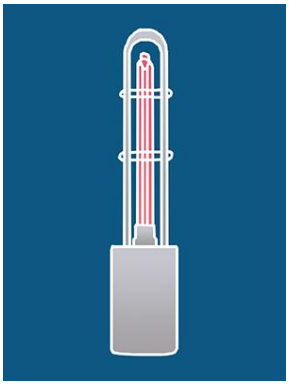

Ultraviolet radiation (UV radiation) can kill off microorganisms, such as bacteria, viruses or fungi on surfaces, in airflows and in liquids. UV radiation has therefore long been used for drinking water purification to destroy dangerous pathogens in water. UV disinfection lamps are also suitable for disinfecting objects, surfaces and the air in medical or industrial facilities. Depending on the intensity, exposure time and wavelength, these sorts of professional devices can eliminate over 90% of microorganisms present with their energy-rich UV-C radiation. Such devices should only be operated by trained staff, who must wear personal protective equipment (clothing, goggles and face shields) if they are exposed to UV radiation.

For some time – and increasingly since the outbreak of COVID-19 – products have been available that are aimed at consumers. These devices claim to eliminate bacteria, viruses, dust mites, fungi, yeasts, mould, allergens and organic and inorganic odorous substances. Many of the devices available are hand-held UV-C lamps. Because these devices are purpose-built to allow UV-C radiation to be released, they may present a risk to users and bystanders. For example, UV-C radiation in the eye can burn the ocular surface and induce an acute temporary inflammatory response. Devices with a closed disinfection chamber, from which no UV-C radiation should be emitted into the environment, are also commercially available. They are marketed as a tool for the disinfection of small appliances.

The minimum UV-C radiation dose needed to eliminate molecules, pathogens and in particular COVID-19 on surfaces, objects and in indoor areas is not currently known. However, it has been proven that excessive UV-C radiation can be hazardous to the health of those who are exposed to it. To prevent damage to the skin and eyes, the UV-C radiation of devices must not exceed the applicable UV exposure limits.

Measurements conducted on behalf of the FOPH show that UV-C disinfection devices for home use either exceed the UV-C limits and therefore pose a health hazard, or else they only produce weak UV-C radiation or none at all, making the disinfection properties unrealistic.

The following recommendations should help you protect yourself:

- Do not use devices at home or for everyday use that emit UV radiation from their housing to disinfect surfaces, objects or indoor spaces. Such devices are reserved for professional users. Do not import such devices from abroad.
- Do not follow any instructions or recommendations that suggest people should be exposed to UV radiation to protect themselves from infectious agents.
- Follow the rules issued by the Federal Office of Public Health to protect yourself from dangerous pathogens such as the coronavirus.

1 Technical principles of UV disinfection devices

1.1 Classification of UV radiation

Ultraviolet radiation is short-wavelength radiation. It is classified into the following bands:

- UV-C radiation with a wavelength range of 100-280 nm is the most energy-rich UV radiation. It comes from the sun or can be produced by man-made sources. UV-C does not naturally reach the Earth's surface as it is completely filtered out by the upper layers of the atmosphere.
- UV-B radiation with a wavelength range of 280-315 nm mainly comes from the sun. As the Earth's atmosphere filters out a large part of UVB radiation depending on the thickness of the ozone layer, only a fraction of it reaches the Earth's surface. UVB radiation can also be produced by man-made sources, such as solariums.
- UV-A radiation with a wavelength range of 315-400 nm mainly comes from the sun. As the Earth's atmosphere does not filter it out, it is the main component of UV radiation on the Earth's surface. UV-A radiation can also be produced by man-made sources, such as solariums.

1.2 UV radiation sources for disinfection devices

Disinfection devices work with UV-C radiation. Traditional sources of UV-C radiation are mercury vapour lamps, which are also known as quartz lamps. These lamps contain mercury vapour and two electrodes. When power is applied, a conductive plasma is produced between the electrodes, whose electrons use energy to bump the mercury atoms up to unstable higher energy levels. When the mercury atoms fall back to their original energy level, the energy is released, partly as UV-C radiation.

The mercury vapour gas charge in UV-C lamps is encased in a quartz glass bulb or a sodium-barium glass bulb, both of which are permeable to UV-C radiation. Depending on the material properties of the bulb and the pressure inside the lamp, these lamps emit UV-C radiation with a wavelength of 254 nanometres (nm) or several additional wavelengths. UV-C lamps can be recognised by their transparent and clear glass bulbs. If the glass is broken, the mercury in the lamps does not pose a proven health risk; it is therefore sufficient to properly ventilate the room after disposing of the broken glass.

New technologies are based on UV-C LEDs (light emitting diodes), which do not contain mercury. Depending on the doping of the semiconductor, they can emit various UV wavelengths. The intensity of radiation is typically below that of traditional mercury vapour lamps.

1.3 Professional UV-C disinfection systems

Professional UV-C disinfection devices and systems are designed in such a way that enclosed or locked housings shield the UV lamps (water purification and air treatment systems). Air treatment systems can also be set up so that in high-ceiling rooms they only emit radiation in the upper part of the room that is not occupied. In premises where the whole volume of the room needs to be irradiated, human radiation exposure can be prevented through organisational measures to vacate the rooms while they are being irradiated. If people with the relevant training must be present in the irradiated areas, they must protect themselves from UV radiation with the appropriate personal protective equipment.

1.4 UV-C disinfection devices for home use

For some time, consumer UV-C disinfection devices have been commercially available, which manufacturers claim can disinfect room air, water in swimming pools or garden ponds, objects, items of clothing, sanitary facilities or other surfaces. Devices are also available that claim to destroy odour molecules with UV-C radiation.

Some of these products are devices where the UV lamp is encased in an enclosed housing. In such devices, UV-C radiation can only be emitted during maintenance work, if people do not have defective UV lamps replaced by a professional. Such maintenance work should therefore always be carried out paying close attention to the user manual and in power off mode. A device whose housing starts to leak UV-C radiation due to maintenance must be disposed of.

The commercially available devices with open UV radiation sources must either be guided over surfaces and objects by users, or they are devices that must be placed in rooms to disinfect the air. The non-enclosed UV-C lamp can result in users and bystanders being exposed to UV-C radiation from the device. Direct UV-C radiation can also cause materials such as plastics to become hard or brittle, and harm plants and animals.

2 Effects of ultraviolet radiation

2.1 Health effects of UV radiation

The wavelength range of ultraviolet radiation lies between visible radiation and ionising radiation. Visible radiation with wavelengths of between 400 and 700 nanometres (nm) is non-ionising on account of its limited energy and is thus unable to damage biological tissue directly, but only via secondary biological processes. Conversely, higher-energy ionising radiation with wavelengths smaller than 100 nm can directly damage molecules such as genetic material. Ultraviolet radiation is the transition range in which direct damage may or may not be possible depending on the wavelength. It is subdivided as follows:

- UV-C radiation is ionising and can damage biological molecules. It has the strongest germicidal effect.
- UV-B radiation can be ionising and damage biological molecules.
- UV-A radiation cannot ionise molecules directly, but only via secondary biological processes.

Excessive UV radiation exposure in humans can damage the skin and eyes. In the eye, UV-C and UVB radiation can burn the ocular surface and induce an acute temporary inflammatory response. Photokeratitis is inflammation of the cornea, which is the eye's outermost layer. Inflammation of the cornea is caused by UV radiation with wavelengths of between 200 nm and 400 nm, where wavelengths of between 220 nm and 320 nm are the most dangerous. Maximum sensitivity is at wavelengths of 270 nm. The cornea is particularly sensitive to UV radiation as it is not protected by a layer of dead cells like the skin. Photoconjunctivitis is inflammation of the conjunctiva, which cover the white sclera of the eye. Both inflammatory responses occur as a result of UV radiation, usually together. They are colloquially referred to as 'snow blindness' and 'arc eye'. Symptoms include severe pain and the sensation of a foreign body in the eye (gritty feeling), severe eyelid twitching, and blurred or cloudy vision. These symptoms typically subside within a week, but they may last longer in the case of severe exposure. In children and adolescents in particular, UV-A radiation can pass through the outer layers of the eye to some degree, penetrating and damaging the retina. Regarding long-term effects, people may suffer from cataracts due to chronic UV-C or UV-B exposure. It is not known whether short-term exposure to UV-C radiation also contributes to cataracts.

In the skin, UV-C radiation penetrates the outermost layer of the skin, the epidermis. It only reaches the tissue beneath the epidermis if the epidermis is thin. Like UVB radiation, UV-C radiation can lead to erythema (skin redness) and sunburn. The skin is more sensitive to comparable doses of UV-C than UVB radiation (SCHEER 2017). These symptoms subside after a certain time.

Laboratory and human trials show that both UV-C and UVB radiation can cause cellular DNA damage if they penetrate the deeper layers of the skin. This leads to the formation of cyclobutane pyrimidine dimers in the DNA, which have carcinogenic properties and can result in cancer. Currently available data are insufficient for making a quantitative cancer risk assessment of UV-C exposure (SCHEER 2017). On the other hand, UV-B and UV-A radiation in particular can penetrate the deeper layers of the skin. They are proven to be carcinogenic and in the case of chronic exposure, can lead to skin cancer and in the case of UV-A exposure also to premature skin ageing (IARC 2010). UV radiation also presents a major risk to people in whom even small doses of ultraviolet radiation can trigger serious diseases of the skin and of the whole body.

2.2 Germicidal effects of UV radiation

The germicidal effect of UV radiation is greatest at wavelengths of between 260 nm and 280 nm in the UV-C range as UV radiation in this range absorbs the most genetic material (deoxyribonucleic acid: DNA, ribonucleic acid: RNA) of microorganisms A sufficient dose of UV-C radiation inserts cyclobutane pyrimidine dimers into the microorganism's genetic material, thereby preventing its DNA from replicating, and preventing the microorganism from multiplying. UV-C radiation can also denature and damage the proteins of the microorganism. With too small UV-C doses, however, there is a risk that the microorganism's biological repair systems will repair the damage to the genetic material. The radiant exposure (dose) required to achieve a germicidal effect depends on the type of microorganism, the state of the surfaces to be sterilised and other parameters, such as atmospheric humidity (CIE 2003). There is not yet any scientific consensus on the sensitivity of the COVID-19 virus to UV-C radiation and on the radiation doses needed (Derraik 2020, Heilingloh 2020, Sabino 2020, CIE 2020, IUVA 2020).

2.3 Health effects of UV-C devices

There are very few studies on the potential adverse health effects of UV-C disinfection devices. A recent study shows that commercially available UV-C disinfection devices for home use can be hazardous to health (Leung 2020). One family used such a disinfection device in an attempt to kill any COVID-19 viruses present in their home. Family members experienced skin redness on the face and neck, visual acuity reduced by up to 50%, and symptoms attributed to photokeratitis and to photoconjunctivitis as a result of UV-C radiation. Other case studies describe situations in which individuals or groups of individuals were exposed to radiation from professional UV-C disinfection equipment and facilities (SCHEER 2017). These cases of accidental exposure were due to incorrect operation of devices or faulty disinfection systems. The persons affected suffered burning and inflammation of the skin, corneas or conjunctiva. In most cases, symptoms subsided within a week. However, one study showed that in the event of more severe exposure, symptoms can last for up to two years. A current study shows that UV-C disinfection lamps that are commercially available for private use can also pose a risk to human health (Leung 2020). Members of a household used a lamp of this type to try and kill off any COVID-19 virus in their home. The UV-C radiation caused the family members to suffer erythema on the face and neck area, reduced visual acuity of up to 50% and symptoms that were attributed to photokeratitis and photoconjunctivitis.

2.4 Exposure limits and standards

The International Commission on Non-Ionizing Radiation Protection has recommended exposure limits for ultraviolet radiation that are designed to protect the skin and eyes (ICNIRP 2004). The ICNIRP exposure limits use the unit of radiant exposure (dose) per unit area (J/m^2). The radiant exposure is calculated based on the radiation intensity (radiant power) multiplied by the exposure time. The exposure limits are wavelength-dependent. For the biologically most effective wavelength of 270 nm, the exposure limit is 30 J/m^2. Traditional UV-C mercury vapour lamps emit radiation on a wavelength of 254 nm, for which the exposure limit is 60 J/m^2. In order to determine the exact exposure limit for a specific UV lamp or UV LED, it is essential to be aware of the wavelength of the UV-C radiation it emits.

The ICNIRP exposure limits form the basis of the Swiss and European standards which manufacturers

must use to assess the safety of their devices. As UV disinfection devices consist of UV-C lamps and the wavelengths of the UV lamps used typically exceed 200 nm, the Swiss-European BS EN 62471 standard (Photobiological safety of lamps and lamp systems) applies. This standard requires manufacturers to assign each of their lamps to a risk group. These risk groups are based on the ICNIRP exposure limits and/or on the exposure times at which a lamp reaches the ICNIRP exposure limit. The standard draws a distinction between lamps that do not pose a hazard even when used for an unlimited period due to their low radiation, and those that may only be used safely for limited or very short periods on account of their powerful or very powerful radiation. For ultraviolet radiation these groups are defined as follows:

- Exempt group: does not pose a hazard, even in the event of very long exposure of the skin and eyes lasting more than 30,000 seconds.
1. Risk group 1: does not pose a hazard in exposure times of up to 10,000 seconds (“low risk”). The exposure limit is reached at exposure times of between 10,000 and 30,000 seconds. The maximum risk-free exposure time is lamp-specific.
- Risk group 2: does not pose a hazard in exposure times of up to 1,000 seconds (“moderate risk”). The exposure limit is reached between 1,000 and 10,000 seconds. The maximum exposure time for risk-free use is lamp specific.
- Risk group 3: the exposure limit is reached in exposure times of less than 1,000 seconds (“high risk”). The exposure time is lamp-specific.

UV lamps in risk groups 1,2 and 3 must also bear a warning or precautionary label on the packaging or include a package insert (IEC TR 62471-2). For UV-C sources in risk group 3, appropriate UV protective measures should be taken (EN 62471 series and EN 60598-1 Annex P).

The maximum permissible human exposure is set out in the standard ISO 15858. This standard does not define the permissible UV-C radiation of a specific product, rather the permissible time period that humans, with unprotected eyes and skin, can be exposed to the radiation from UV-C lamps. The corresponding exposure limits for the UV-C range in this standard are based on the ICNIRP recommendations.

3 Intensity of ultraviolet radiation emitted by UV-C disinfection equipment for home use

The Federal Institute of Metrology (METAS) measured the ultraviolet radiation emitted by UV-C disinfection equipment for home use on behalf of the FOPH, and assigned them to different risk groups. The results presented in Table 1 show that most devices belong to risk group 3. Some devices that do not emit UV-C radiation belong to the exempt group. The time it takes for the health risk exposure limit to be reached depends on the distance between the device and the irradiated object. Device 11 is a device with an enclosed disinfection chamber whose safety mechanism can be easily bypassed, allowing open operation, which was not intended by the manufacturer.

Device	**Handling**	**Radiation source**	**Time in seconds in which health risk exposure limit is reached at a distance of 0 cm, 20 cm or 100 cm**			**UV band**	**Risk group**
			0 cm	**20 cm**	**100 cm**		
1	hand-held	open	0.7	112	2 358	UV-C	3
2	hand-held	open	2.7	640	11 733	UV-C	3
3	hand-held	open	2.1	354	8 411	UV-C	3
4	hand-held	open	>30 000	>30 000	>30 000	UV-A	Exempt
5	hand-held	open	0.7	738	14 761	UV-C	3
			88.7			UV-A	
6	table-top model	open	1.2	59	1 621	UV-C	3
7	hand-held	open	0.3	13	257	UV-C	3
8	hand-held	open	0.8	18	351	UV-C	3
9	Lamp with screwed socket	open	0.1	5	83	UV-C	3
10	table-top model	open	0.8	18	351	UV-C	3
11	Closed disinfection chamber	Closed if used properly	In the case of improper open use			UV-C	3
			0.9	303	8346		
12	hand-held	open	>30 000	>30 000	>30 000	UV-A	Exempt
13	hand-held	open	>30 000	>30 000	>30 000	UV-A	Exempt
14	table-top model	open	>30 000	>30 000	>30 000	UV-A	Exempt

Table 1 Radiation properties of UV-C disinfection devices

4 Health assessment

On the basis of the METAS measurements, we can draw the following conclusions regarding the health effects of UV-C disinfection devices for home use:

- UV-C disinfection devices that – as advertised by manufacturers – produce UV-C radiation fall into the highest risk group. When used close to the body, they may cause adverse health effects in very short exposure times within a matter of seconds. At greater distances the radiation exceeds exposure limits in a matter of minutes or hours.
- UV-C disinfection devices with enclosed disinfection chambers must never be used in their open state, even if a faulty safety mechanism allows it.
- UV-C disinfection devices that – contrary to manufacturers' claims – do not produce UV-C radiation do not present a health risk. However, on account of such falsely-marketed devices, it is not clear for users whether a product advertised as a UV-C disinfection device actually produces germicidal UV-C radiation. Users cannot be certain that UV-C disinfection devices actually have a disinfectant effect.

Additionally, at present there is no reliable information about the UV-C radiation doses required to eliminate microorganisms and particularly the COVID-19 virus with sufficient certainty. In addition, it is impossible to check whether the surfaces to be disinfected using such devices have been sufficiently irradiated with UV-C. There is a danger that devices give a false impression of sterilisation and that treated surfaces are not actually disinfected due to shadow effects, the multiple layers of materials, insufficient device power and too great distances during the irradiation process,

The Federal Office of Public Health therefore advises against using UV-C disinfection devices marketed to consumers for private or professional purposes.

5 Legal regulations

As low-voltage electrical equipment, UV-C disinfection devices must comply with the fundamental requirements of the Ordinance on Low-Voltage Electrical Equipment (SR 734.26). Low-voltage electrical equipment may not endanger persons or objects and may only be placed on the market if it meets the fundamental health and safety requirements set out in the European Low-Voltage Directive 2014/35/EU. The fundamental requirements are specified in European standards. The permissible optical radiation of UV-C disinfection lamps is set out in European standard BS EN 62471 and is based on the recommended exposure limits of the International Commission on Non-Ionising Radiation Protection (ICNIRP 2004). Manufacturers are responsible for ensuring their devices meet these compliance criteria.

6 References

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