Effective disinfection of surfaces and air by ultraviolet radiation

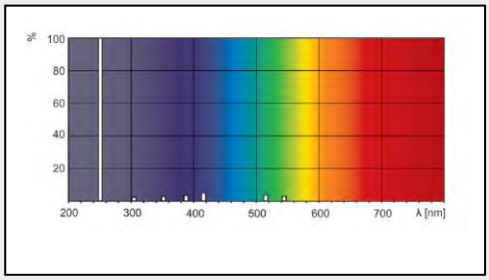
Germicidal lamps


90°
135°

Germicidal lamps under direct and indirect radiation

Ultraviolet radiation
Ultraviolet radiation can be described as an optical, electromagnetic radiation with a wavelength of 100 nm to 1 mm. Ultraviolet radiation with a wavelength of 100 nm to 400 nm can be divided into:

UVA 315 - 400 nm
UVB 280 - 315 nm
UVC 100 - 280 nm – **253.7 nm**



Germicidal radiation
UVC wavelength 253.7 nm is invisible. This radiation, in the UVC spectrum, causes decay of microorganisms by disrupting their DNA structure and thus destructing them. The blue light produced by germicidal lamps is only a side product in this case and it is not disinfecting. Germicidal radiation does not permeate through dim, non-transparent materials, plastic, plastic foils or regular glass. These materials create a natural obstacle for the radiation. This radiation only permeates through a clear quartz glass and special Teflon foil.

Germicidal lamps
Germicidal lamps are devices used for disinfection by using ultraviolet radiation with a wavelength of 253.7 nm. Germicidal lamps are tested and verified by an accredited testing laboratory for EMC and LVD tests. They are also verified by numerous clinical tests and assessments. Their usage and effectiveness have been tested over decades of practical experience. If used correctly, there can be no undesirable exposure to UVC radiation. It is however necessary to adhere to certain principles:

1. When constructing and positioning the device it is inevitable to ensure that, under no circumstances, the personnel or the patients are directly exposed to the dangerous UVC radiation. Given that this radiation can effectively destroy germs in a large spectrum, it creates a healthy environment and thus protects individuals from various diseases and possible infections. This is a complementary, however, when used correctly, very effective disinfection. The radiation is homogenic and therefore destroys germs also at places where no disinfectants have been applied (outside the shadow created by obstacles).

The radiation that passes through the room can also destroy germs found on dust particles in the air and therefore it also disinfects the actual air. The sources of radiation, in this case germicidal lamps PHILIPS TUV 30W LL, or an equivalent OSRAM HNS OFR 30W LL, have a guaranteed lifetime of 8000 hours when the intensity of UVC radiation is lowered to 80% of the initial value. After this period, it is necessary to replace them. The lifetime of these lamps might also be affected by the number of times they have been turned on and off and whether electronic ballasts with a ‘soft start’ have been used. In the case of , all the above-mentioned conditions are fulfilled and the lifetime of UVC sources is extended to 18000 hours.

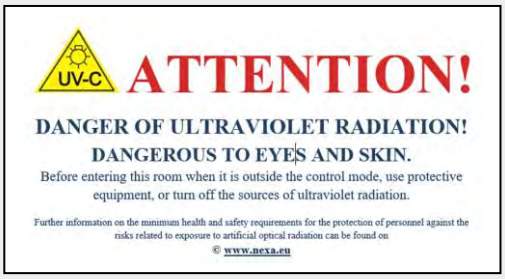
2. Germicidal lamps can be operated only by individuals who have been thoroughly instructed about their use and the potential associated risks. A written record must be kept of every operation performed with the germicidal lamps. Usage of germicidal lamps in the presence of people is only possible in areas with a monitored regime, where the personnel have been taught and informed

accordingly and where safety is guaranteed by additional technical means. These are for instance places with a regular regime, which avoids the occurrence of accidental and unforeseen situations. Installation may only be carried out by competent persons, trained with an appropriate authorisation, according to a project of an authorised designer. In order to put the device into operation, it is necessary to apply the operating rules designed for each specific workplace and prepared in accordance with the valid legislation, verified and approved by the relevant public health authority.

3. It is necessary to complete an annual check-up of the performance of germicidal lamps and perform an inspection of operating switches and other additional technical devices, if any have been used.

4. Labelling of germicidal lamps with warning labels about the danger of UVC radiation. The entrance doors in each hospital room where germicidal lamps are at use must have a visible warning label informing about the presence of UVC radiation. To increase safety when using directly radiating lamps, it is possible to use an inverted motion sensor. If the sensor detects any movement of persons in the area of UVC radiation, it will automatically turn off the device for a time interval that has been pre-determined. Once the time interval has passed, the sensor will automatically turn on the device. Germicidal lamps have such a sensor integrated as part of their standard design.

In order to completely avoid interference with unwanted radiation in a room where the germicidal lamp is operating, it is possible to use a door sensor. When the door opens, the device will immediately turn off and it will only turn back on once the door is closed. In order to ensure complete protection against radiation in the exposed area, it is necessary to employ both of the aforementioned methods simultaneously. A situation can occur where the hospital personnel closes the door from the inside of the room and thus the lamps turns back on. The afore-mentioned measures must be applied in all areas with a large movement of people. In these areas, despite careful instruction and training, the personnel can make errors resulting from routine work. It is therefore necessary to ensure a high standard of cleanliness of the environment, even if it requires investing in technical safety protection against unwanted UVC radiation.

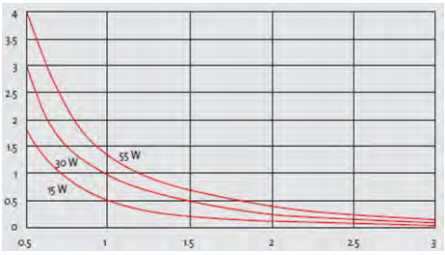


Exposure to UVC radiation doses

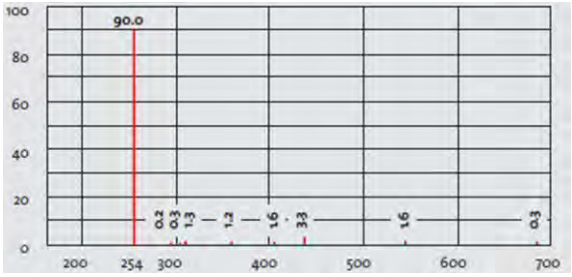
Given the use of UVC sources with a hot cathode (relatively high power of UVC radiation up to 0.5 m distance from the source), long exposure times are not necessary for the destruction of microorganisms. The intensive airflow across the active zone of UVC radiation leads to effective disinfection of air and surface in the irradiated space. The deactivation process might take only a few seconds. It is, however, necessary to ensure repeated exposure to radiation within 24 hours.

Programmable switch timer SPH 01, 02 enables repeated switching on of the device at four predetermined times. The efficiency of UVC radiation decreases by square distance. When using directly radiating germicidal lamps, it should be taken into account that with a certain temperature and humidity of air, disinfection in the room may be less effective at a certain distance. A noticeable decrease occurs from about three meters from the UVC source when using a 30W germicidal lamp. When using a 55W UVC source, this drop can be seen from a distance of about five meters from the UVC source.

Intensity of UVC radiation according to distance



Intensity of UVC radiation at 253.7 nm, 30W source



When disinfecting by UVC radiation, it is necessary to distinguish between germicidal lamps used without the presence of people - directly radiating, and in the presence of people - indirectly radiating. Directly radiating germicidal lamps are used e.g. at night, or during breaks when there is no activity in the room. When using indirectly radiating germicidal lamps, there is no direct exposure to UVC radiation in the room. Radiation at very high doses is enclosed inside of the device, where only air disinfection occurs. These devices should therefore only be used in the presence of people, for extended periods of time. Indirectly radiating germicidal lamps are suitable for use at intensive care units or departments of anaesthesiology and intensive medicine, where they can be in continuous operation. In this case, it is also necessary to ensure that there is no unnecessary air circulation between the disinfected area and other areas - e.g. a corridor. In a closed room, all the air gradually passes through the germicidal lamp, thus ensuring air disinfection in a precisely defined space.

Table: Radiation dose required for 90% inactivation of microorganisms from a distance of 1 m from the UVC source (dose in µW/sec/cm²)

(The exposure values apply when using sources of UVC radiation with an intensity 90 µW - OSRAM HNS OFR 30W LL and PHILIPS TUV 30W LL)

Microorganisms	Exposure [s]	Dose [µW]	Microorganisms	Exposure [s]	Dose [µW]	Microorganisms	Exposure [s]	Dose [µW]
Bacterium			Salmonella			Paramyxovirus		
Bacillus (vegetative)			Salmonella typhimurium	89	8000	Sindbis virus	61	5500
Bacillus anthracis	50	4500	Salmonella enteritidis	44	4000	Newcastle Disease	17	1500
Bacillus Megatherium	14	1300	Salmonella typhi	23	2100	Orthomyxovirus	39	3500
Bacillus paratyphosus	36	3200	Serratia marcescens	36	3200	Influenza	39	3500
Bacillus subtilis 58	64	5800	Shigella paradysenteriae	19	1700	HIV (Lentiv)		
Bacillus (spore)			Staphylococcus			HIV (HTLVIII)	667	60000
Bacillus Megatherium	30	2700	Staphylococcus albus	20	1800	HIV (Sup T1)	1611	145000
Bacillus subtilis	133	12000	Staphylococcus aureus	29	2600	HIV (H9)	2667	240000
Bacillus anthracis	50	4500	Staphylococcus epidermis	122	11000	HIV (PHA-stim. PBL)	1444	130000
Bacillus subtilis (ATCC6633)	406	36500	Streptococcus			**Phages**		
Bacillus subtilis	12	1100	Streptococcus haemolyticus	24	2200	Bacteriophage		
Bac. subt. spore ATCC6633	169	15200	Streptococcus lactis	69	6200	Bacteriophage subt. phage SP02c12	167	15000
Campylobacter jejuni	32	2900	Streptococcus viridans	22	2000	Bacteriophage subt. phage SPP1	217	19500
Clostridium tetani	144	13000	Streptococcus faecalis ATCC29212	72	6500	Bacteriophage subt. phage Ø 29	78	7000
Coryneb. diphtheria	38	3400	Streptococcus faecalis	61	5500	Bacteriophage F specific	324	29200
Citrob. freundii (ATCC8090)	47	4200	Streptococcus pyogenes	24	2200	Coliphage f2	344	31000
Enterob. cloaca (ATCC13047)	71	6400	Streptococcus salivarius	22	2000	Staph. phage A994	72	6500
Escherichia coli:			Streptococcus albus 18	20	1800	**Yeasts**		
Escherichia coli	33	3000	Vibrio	27	2400	Oospora lactis	56	5000
Escherichia coli (in air)	8	700	Yersinia enterecolitica	17	1500	Saccharomyces cerevisiae	73	6600
Escherichia coli (in water)	60	5400	**DNA-Viruses**			Saccharomyces ellipsoideus	67	6000
Escherichia coli ATCC 11229	28	2500	Parvovirus			Saccharomyces sp.	89	8000

Microorganisms	Exposure [s]	Dose [µW]	Microorganisms	Exposure [s]	Dose [µW]	Microorganisms	Exposure [s]	Dose [µW]
Bacterium			**DNA-Viruses**			**Fungi**		
Escherichia coli K 12 AB 1157	64	5800	Bov. parvovirus	44	4000	Aspergillus glaucus	489	44000
Escherichia coli B/ r ATCC 12407	59	5300	Kilham rat virus	33	3000	Aspergillus flavus	667	60000
Klebsi. pneumon. ATCC4352	47	4200	HCC (Dog hepat. Adenov)	294	26500	Aspergillus niger	1467	132000
Legionella			**Herpes virus**			Aspergillus niger (pasta)	1667	150000
Legionella dumoffi	27	2400	Pseudorabies virus	78	7000	Aspergillus amstelodami (meat)	778	70000
Legionella gormanii	29	2600	Herpes siamplex MP str.	74	6700	Candida paraposilosis	244	22000
Legionella micdadei	17	1500	Herpes simplex MP str.	17	1500	Cladospor. herbarum (cold stores)	556	50000
Legionella longbeachae 1	13	1200	Herpes simplex, type 1	183	16500	Mucor racemosus	189	17000
Legionella longbeachae 2	11	1000	Vaccinia	20	1800	Mucor mucedo (meat, bread, fat)	667	60000
Legionella oakridgensis	24	2200	**RNA-Viruses**			Oospora lactis	56	5000
Legionella micdadei	20	1800	**Picornavirus**			Penicillium chrysogenum (fruit)	556	50000
Legionella jordanis	12	1100	Poliovirus	122	11000	Penicillium roquefortii	144	13000
Legionella wadsworthii	4	400	Poliovirus type 1 Mahoney	74	6700	Penicillium expansum	144	13000
Legionella pneumophila	28	2500	Poliovirus	148	13300	Penicillium digitatum	489	44000
Legionella bozemanii	22	2000	Poliovirus type 1	40	3600	Rhisopus nigricans	1222	110000
Leptospira			Poliovirus Mahoney 45	50	4500	Rhizopus nigricans (cheese)	1222	110000
Leptrospira biflexa	26	2300	ECBO	89	8000	Scopulariopsis brevicaulis (cheese)	889	80000
Leptrospira illini	9	800	Coxsackiev	207	18600	**Protozoa**	889	80000
Leptrospira interrogans	31	2800	**Reovirus**			**Algae**	5000	450000
Micrococcus			Reovirus type 1	53	4800	Green algae, blue algae, diatoms		
Micrococcus candidus	68	6100	Reovirus type 1 (Lang str)	181	16300			
Micrococcus sphaeroides	111	10000	Rotav	177	15900			

Exposure limit values for non-coherent optical radiation

Wavelength [nm]	Exposure limit values	Unit	Body part	Risk
180 - 400 nm (UVA, UVB, UVC)	Heff = 30	[J.m^2]	- Eye cornea - Ocular conjunctiva - Eye lens - Skin	- Photokeratiti - Conjuktivitis - Cataractogenesis - Erythema - Elastosis - Skin cancer

Correct use of exposure time / ensuring proper recurrence of exposure time within a specified time interval - directly and indirectly radiating germicidal lamps

Lamps with a hot cathode are used as sources of UVC radiation. When a 30W source is used, 90 microwatts per second are produced from a distance of 1 m for a 1 cm^2 surface. Exposure times at this distance are very short for disinfection in the core to be fully effective. Therefore, it is important to repeat this operation at short intervals with as much UVC radiation as possible. Given the flow and exchange of air, a large volume of air in the room is effectively disinfected (without the use of air conditioning, every six hours there is a complete replacement or relocation of air in the monitored space).

a) The above-mentioned information applies only when using directly radiating lamps - without the presence of people. During their operation, it is necessary to ensure strict adherence to the safety regulations and recommendations pursuant to Government Regulation 410/2007 of the Slovak Republic regarding the minimum health and safety requirements for the protection of employees against the risks of exposure to artificial optical radiation.

b) When using indirectly radiating lamps, the disinfected air passes through the enclosed space of the lamp at a very short distance from the UVC sources. This leads to a very effective disinfection of air passing through; however its volume is limited by the power of the ventilators used. The volume is

determined by the size of the germicidal lamp itself, but also the fact that when a larger volume of air is being filtered, an increase in acoustic noise occurs.

With indirectly radiating lamps, it is not necessary to ensure strict adherence to the safety regulations and recommendations during the lamps' operation. When these devices are used correctly, there is no possibility to get in contact with the dangerous UVC radiation. The level of this radiation is zero at both the input and output grid. In order to ensure proper disinfection by these lamps, it is necessary to extend their operating time as much as possible. This applies especially in situations where contamination might occur, created by the people present in the room, or in order to ensure the highest level of disinfection possible. If needed, these lamps can be used in a continuous mode without interruption. To achieve an economic operation, it is recommended that programmable switch timer SPH01 or SPH01A is used, which is part of the lamp.

Keeping a regular and accurate exposure to UVC radiation in the active zone

Regular and accurate UVC exposure times must be ensured to achieve proper disinfection by UVC radiation. It is absolutely necessary to exclude the human factor as a source of potential errors and inaccuracies. Given that the lifetime of UVC sources is limited, it is necessary to use a programmable switch timer with a counter of the lamp's operating hours. The performance of such a switch timer must be checked four times a year. It is also necessary to check the operating hours against the programmed exposure values. Only then, it can be ensured that there is no increased and unwanted exposure. It is essential to keep a written record of all these facts, so that any potential problems can be traced and corrected.

Risk of exposure to artificial optical radiation

During the operation and use of germicidal lamps, peoples' exposure to artificial optical radiation may occur due to the following reasons:

- Incorrect use of exposition time and incorrect positioning of the germicidal lamp in a room (it is important to follow the recommended exposure times in order to comply with the limit values of exposure to optical radiation on the one hand and to achieve effective disinfection on the other hand). It is essential to ensure that the lamps are correctly positioned in a room and that the direction of radiation rays does not create unwanted exposure to UVC radiation.
- Incorrect handling of germicidal lamps during their operation and maintenance by the personnel (the personnel must be thoroughly trained and instructed about the UVC disinfection process, as well as the potential risks of unauthorised and incorrect handling of UVC sources).
- Unforeseen malfunctions (the personnel must be trained to deal with and solve unforeseen malfunctions and events such as release of a mounted device - change in the radiation pattern, inability to turn the device off, incorrect positioning of the device in the room, breakage of UVC source, mercury contamination of the surrounding area as a result of breakage.

Measures to follow in case of intervention with artificial optical radiation (accidents or other unforeseen circumstances)

When operating germicidal lamps UVC radiation must under no circumstances come into contact with persons who are in the vicinity of the lamps. Accordingly, exposure of an unprotected human body to UVC radiation produced by these lamps must be excluded. Despite compliance with all safety measures when using these lamps, a situation may occur in emergencies and unforeseen circumstances where one is exposed to a small dose of unwanted UVC radiation that does not exceed the maximum value allowed = 30 $J.m^2$.

Due to the nature of UV radiation (no visible effects - colour, odour, thermal effect), there are no accompanying phenomena at the moment of one's exposure to it. These effects appear after a certain period of time - several hours, depending on the size of the exposure. Lighter symptoms of exposure to UVC radiation are strong burning in the eyes or redness of the skin. In the case of larger or long-

term exposures, eye damage, skin burns, or skin cancer can occur. Even if there is a suspicion of possible exposure to UVC radiation or signs of exposure to UV radiation, it is necessary to seek medical help. The operator of germicidal lamps must immediately remove the cause, analyse the cause of the problem, take effective preventive measures and continue to monitor safety in all areas where germicidal lamps are installed.

Other potential risks

Tubes - sources of UVC radiation - are essentially linear discharge lamps containing mercury vapours without an inner luminophore layer. If these lamps break, the surrounding area gets contaminated by mercury, which is a toxic substance for the human body. When handling the lamps, it is necessary to ensure that under no circumstances they break or get damaged. Their disposal in the case of damage and after their lifetime has passed, corresponds to the toxic waste disposal regime, either directly at the manufacturer or at an authorised waste disposal company. Prevention of mercury vapour leakage into the environment and protection against fragments can be achieved by using tubes with a protective Teflon coating, which serves as a packaging for the broken tube and thus prevents the leakage of mercury vapours and glass splinters into the environment. Such shatter-proof tubes (sources of UVC radiation) must be used in mobile germicidal lamps, as these are more vulnerable to damage due to their constant movement and relocation in the room as necessary.


Shatterproof tube


Shatterproof tube

Questions and answers

1. What is the lifetime of a germicidal lamp?

The lifetime of germicidal lamps is typically seven years - when regular maintenance is performed annually. The lifetime may vary slightly depending on the quality of the environment (dry-wet / clean-dirty).

2. By exposure to UVC radiation, do we achieve disinfection or sterilisation?

Exposure to UVC radiation results in disinfection only.

3. Is disinfection solely by UVC radiation (germicidal lamps) sufficient?

This type of disinfection is very effective, but it is always a complementary disinfection.

4. Do germicidal lamps emit ozone?

No, germicidal lamps do not produce any ozone.

5. For how long is it possible to radiate with germicidal lamps?

The dose and duration of radiation is determined by the power of the UVC source. When using a 55W power supply, the effective distance is about 6 m and the time required for adequate disinfection is about one hour. It is recommended to perform two rounds of exposure to UVC radiation - disinfection.

The first one - after finishing work at a workplace; the second one - before resuming work at a workplace. By applying this disinfection mode, the values of pathogenic microorganisms approach the level of a sterile environment.

In areas where it is necessary to ensure high disinfection efficiency, it is necessary to use 55 W sources of UVC radiation. In this case, it is possible to shorten the exposure time to UVC radiation. In areas such as surgery rooms or rooms with high requirements for cleanliness, it is advisable to adhere to an exposure of one hour after finishing work and one hour before work in the designated area resumes. Disinfection by ultraviolet radiation is highly efficient and effective, however, it must be considered as complementary.

6. Is it possible to enter the room immediately after switching off the germicidal lamps?

Yes, the disinfection process always takes place only during the exposure to UVC radiation.

7. How to dispose of dysfunctional UVC sources - tubes?

The disposal of UVC sources in the case of damage or after their lifetime has passed, corresponds to the toxic waste disposal regime, either directly at the manufacturer or at an authorised waste disposal company.

8. How to clean the surface of a germicidal lamp?

The body of a germicidal lamp should be cleaned with a damp cloth and a non-aggressive detergent.

9. How to clean UVC radiation sources?

UVC sources should be cleaned with a damp cloth, but not with a detergent that leaves a coating on the surface of the tube when dried. It is recommended to use ethanol.

10. How to clean the interior of closed germicidal lamps?

This activity may be carried out only by instructed persons with appropriate electro-technical training, or persons trained and certified by the manufacturer. Attention, there is a risk of UVC radiation.

11. What is the noise level of closed germicidal lamps when in operation?

When closed germicidal lamps are in operation, a noise emission of 14.8 dB is created, which is at the limit of audibility.

12. What is the value of UVC radiation on the grids of enclosed germicidal lamps ?

The UVC value on the grids is zero. These devices can be used in the presence of humans without any restrictions.

13. Can germicidal radiation cause skin cancer?

Yes, the personnel’s exposure to germicidal radiation can lead to skin cancer. The operator of the germicidal lamps must however ensure that there is no possibility for persons’ contact with such radiation, even in the event of failure or unforeseen events.

FINAL PROVISIONS

The manufacturer declares that if full compliance with the aforementioned rules and regulations is ensured, the use of germicidal lamps is highly effective and safe.


Dräger
Agila
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