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Ultraviolet Radiation Exposure to Health Care Workers From Germicidal Lamps

Dawn Tharr, Column Editor

Case Report by C. Eugene Moss and Teresa A. Seitz

Introduction

On January 9, 1990, the National Institute for Occupational Safety and Health (NIOSH) received a request from a medical facility seeking assistance in documenting occupational ultraviolet (UV) radiation levels emitted by germicidal lamps. The request also asked for information that could be used for developing guidelines for the safe use and installation of such lamps. UV radiation measurements were made on all germicidal lamps at the facility by NIOSH personnel on April 3–6, 1990.

The medical facility under study used germicidal lamps to disinfect the air in their tuberculosis (TB) and aerosolized pentamidine clinics. The facility provides care for large numbers of patients who may be at increased risk for TB and has installed ceiling and wall-mounted UV lamps in an attempt to further reduce transmission of TB in clinics that these patients visit.

The germicidal lamps used in this facility are low-pressure mercury vapor lamps which are primarily a line, rather than broadband, source and emit UV and visible radiation at specific wavelengths. Over 95 percent of the radiant energy is emitted at a wavelength of 253.7 nm. These lamps have been in general use for many years to aid in the control of TB by "disinfecting" the air. This evaluation addressed only occupational exposure to UV radiation emitted by germicidal lamps. The issue of efficacy was not addressed.

Evaluation Criteria

There is a potential hazard resulting from exposure to the UV radiation emitted from these types of lamps. The organs potentially affected by the 254-nm radiation from these lamps are the eye and skin. At this wavelength, the radiation is absorbed by the outer surfaces of the eye, and overexposure can result in inflammation of the cornea (photokeratitis) and/or conjunctiva (conjunctivitis). Keratoconjunctivitis is a reversible injury, lasting 24 to 48 hours, but it is a debilitating condition while it runs its course. There is a latent period of a few hours, depending on the dose, so it is sometimes not recognized as an occupational injury by the worker. Skin exposure to UV radiation can result in the familiar sunburn effect. This is also a reversible injury, and the time course depends on the severity of the burn.

In 1972, NIOSH formulated criteria for a recommended standard for occupational exposure to UV radiation.[1] It is designed to protect the worker against the aforementioned eye and skin injury. The recommended standard is wavelength-dependent in the spectral region of interest and is based on an action spectrum established in human and animal studies. The NIOSH recommended exposure levels for UV radiation are similar to the American Conference of Governmental Industrial Hygienists' Threshold Limit Values (TLVs).[2]

In the spectral region evaluated in this study, total effective irradiance incident upon the unprotected skin or eye should not exceed 0.1 microwatt per square centimeter ($\mu W/cm^2$) for an 8-hour exposure.

Evaluation Design and Methods

The measurement system consisted of a calibrated International Light (IL) radiometer, Model 700, connected to a SED240 detector incorporating a special diffuser/filter combination that permitted the system to read UV levels directly in units of biologic effective watts per square centimeter. UV radiation measurements were made at the edge of the germicidal lamp fixture (approximately 4 in. from the lamp), at a location near the installed lamp at a distance of one foot from the ceiling (to estimate the reflected level), and at the closest tabletop location where it was thought an occupational exposure could occur to health care workers. The lamp fixture measurement was taken to simulate a potential maintenance worker exposure for cleaning or lamp replacement duties. The measurements at one foot from the ceiling were chosen to simulate possible top of the head exposure levels due to ceiling reflections. The tabletop results provided an estimate of exposure involving desk or table work.

In the process of evaluating the UV radiation from germicidal lamps, the NIOSH investigators made observations on how the lamps were installed and used, the presence of protective equipment and warning signs, and other safety-related issues.

Discussion and Results

Maximum irradiance levels were documented since the lamps were not stable in their radiant output, probably due to aging characteristics. The levels of direct, reflected, and tabletop UV radiation measured as shown in Table I exceeded the 8-hour recommended exposure level of 0.1 effective $\mu W/cm^2$. These findings, concerning the potential for overexposure from germicidal lamps, are in agreement with previously published findings.[3–5] No attempt was made to determine how long workers were in a given location since they move quite extensively in performing their duties. UV radiation levels close to the lamp source exceeded the TLV by at least 4000 times, while tabletop exposure levels exceeded the TLV by at least two times. Permissible

TABLE I. Maximum Readings Obtained in Medical Center Rooms

			Distance in inches of Wall-mounted Lamps		UV Irradiance (μW/cm²)†		
Location	Room Size (ft²)	No. of Lamps*	From Floor	From Ceiling	4 in. From Lamp	12 in. From Ceiling	Table Top
Room 1	150	1	87	19	1200	2.3	0.5
Room 2	76	1	93	25	500	0.9	0.2
Room 3	40	1	86	30	400	1.0	0.7
Room 4	120	1	93	22	‡	0.7	0.3

*All lamps in fixtures were rated 30 watts.
† Values expressed in effective biological units.
‡ Could not measure.

exposure times in seconds, for exposure to far UV incident upon the unprotected skin or eye, are shown in Table II.

Using Table II and the results shown in Table I, one can estimate the length of time an unprotected worker could stay at certain places within the rooms that contained these lamps without exceeding the recommended exposure level. The maximum permissible exposure time in seconds for exposure to far UV radiation incident upon the unprotected skin or eye may be computed by dividing 0.003 joules per square centimeter (J/cm^2) by the maximum recorded effective irradiance (E_{eff}) level in watts per square centimeter (W/cm^2). When this is done, the highest level measured [1200 μW/cm^2 at 4 inches] corresponds to a permissible exposure time of 2.5 seconds. The maximum ceiling reflected value of 2.3 μW/cm^2 at one foot from the ceiling corresponds to an exposure time of about 22 minutes. If one assumes a male health care worker is six feet tall, then a top of the head exposure from this reflected UV beam, assuming inverse square law considerations, would be about 0.29 μW/cm^2, which exceeds the maximum recommended exposure for an 8-hour day. Taller workers would be at a higher risk. The tabletop maximum value of 0.7 μW/cm^2, shown in Table II, yields a permissible exposure time of about 72 minutes. Obviously, the closer the tabletop is to the lamp fixture, the higher the exposure.

These calculations can be used to guide the relative placement of people and objects in the room to minimize exposure. These values also suggest the use of control measures such as goggles, ceiling louvers, and thin plastic UV-absorbing materials which may be of benefit to workers in some situations.

Summary

Several items of interest were apparent from the observations made in these rooms:

1. There was no protective eyewear available in the rooms and none had been purchased by the safety department for use by workers exposed to UV radiation.
2. All rooms used a 30-watt germicidal lamp. A lower wattage bulb in these small rooms could have reduced the occupational UV exposure level.
3. Bulb changers need to be aware of the need for protective clothing and gloves from both the UV radiation as well as possible glass breakage. As mentioned earlier, the levels of UV near the surface of the bulb will exceed the permissible exposure limit in as little as 2–3 seconds.
4. Reflectance levels of UV radiation can be quite high and varied as shown in Table I. While high reflectance may be desired for increasing the effect of UV on air contaminants, it increases the potential for skin and eye problems among unprotected workers.
5. Worker exposure to germicidal lamp UV levels was dependent on many factors; however, some of the most important ones are position of the bulb in the room, age of the bulb, obstruction of the UV radiation by objects near the bulb, and height of the workers.
6. While no ozone measurements were made in this evaluation, it should be noted that some germicidal lamps do generate a small amount of 185-nm radiation, a wavelength that is responsible for producing ozone. Provisions may need to be made to ventilate this generated ozone.
7. Information is not presently available regarding optimum ventilation conditions that allow good air mixing between the irradiated upper room air and the breathing zone of occupants in the lower room air zone, while at the same time providing a sufficient dose of UV radiation for effective killing of infectious droplet nuclei.

TABLE II. Permissible Exposure Time to Far UV Radiation

Duration of Exposure Per Day	Effective Irradiance (μW/cm²)
8 hrs	0.1
4 hrs	0.2
2 hrs	0.4
1 hr	0.8
30 min	1.7
15 min	3.3
10 min	5
5 min	10
1 min	50
30 sec	100
10 sec	300
1 sec	3000
0.5 sec	6000
0.1 sec	30,000

While there are no consensus guidelines on ventilation systems designed for areas where germicidal lamps are used, the provision of good room air distribution and mixing is recommended to prevent stagnant air conditions or short-circuiting of supply air within the room. Additionally, the use of local exhaust ventilation (booths, hoods) may be appropriate in some situations to contain contaminants generated during certain procedures such as aerosolized drug treatments and sputum induction procedures.

Care must be taken in the selection of the instrumentation used to quantify the energy of the source. This means that whatever instrumentation is used must have the correct spectral range to match the unique source output. In addition, awareness of the solarization and aging properties of lenses, tube envelopes, and detector components is important. Often high concentrations of water vapor in the atmosphere may cause absorption of the UV energy.

Finally, it should be recognized that numerous epidemiological studies have indicated chronic exposure to UV radiation (at wavelengths less than 290 nm) is associated with the induction of skin cancer.[1,6,7] In view of the potential for health care workers to be exposed to high levels of UV radiation (at 254 nm) from germicidal lamps, it is recommended that indiscriminate use of these lamps be stopped. Exposure of health care workers to these sources should be reduced to the lowest feasible level using appropriate engineering controls and work practices.

Recommendations

This evaluation addresses only occupational exposure concerns from germicidal lamps and does not deal with the effectiveness or use of such lamps. If the lamps are used, the following specific recommendations are offered to reduce potentially significant occupational exposure to UV radiation:

1. There should be a uniform policy for when germicidal lamps are to be replaced. This could be determined from either a time/use log or a system based on cumulative time.
2. A training course should be provided to lamp replacers to ensure awareness of the potential health hazards.
3. Under no conditions should germicidal lamps be used as replacement lamps for conventional fluorescent lamps since this could result in widespread public and/or occupational health problems.
4. There should be a policy on how to label these UV lamps, including the use of warning signs on doors.
5. The use of door interlocks as a control measure to minimize health care worker exposure should be considered. For example, if the UV lamps were connected to a door switch, they could only become activated when the door was closed; if the door was opened, the lights would go off. If this type of control measure was implemented, it would afford protection to individuals outside the room/area where the lamps are in use.
6. The importance of ventilation as a combined control measure should not be underestimated. This includes the provision of good air distribution and mixing. The rooms evaluated during this survey were not optimal from a ventilation design standout; doors and windows were used as supplemental ventilation, and supply or exhaust air diffusers were not always present.
7. All highly UV-reflecting material (i.e., aluminum foil) used in the various rooms with these lamps should be removed or replaced with low UV-reflecting materials.
8. If personnel must work in rooms having activated germicidal lamps, wearing of UV protective eyewear and equipment is necessary unless measurements and calculations of the UV irradiance levels clearly indicate exposure below existing TLVs. Concerns about UV protective eyewear must also be considered for patients and other occupants.
9. Equipment used to measure germicidal UV radiation should be maintained and calibrated on a regular schedule.
10. It may be necessary to perform ozone measurements when germicidal lamps are used within a restricted area.

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