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JOHN C. MURPHY FAMILY HEALTH CENTER
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NIOSH INVESTIGATORS:
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I. SUMMARY

On March 5, 1991, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Senior Industrial Hygienist, Department of Community Health and Medical Care, St. Louis County, seeking assistance in documenting occupational exposure to ultraviolet radiation emitted by germicidal lamps (GUV) at the Tuberculosis (TB) Clinic located at the John C. Murphy Family Health Center (JCMFHC). GUV radiation measurements were made on all of the lamps at the TB clinic by NIOSH personnel on July 18-19, 1991.

The results of this evaluation showed that the levels of occupational exposure to GUV radiation produced at JCMFHC in most of the work areas were below the NIOSH Recommended Exposure Limit (REL) of 0.1 effective microwatts per square centimeters ($\mu W/cm^2$). The only exceptions found were GUV levels at very close distances to lamps. Other findings noted were the presence of old lamps, inappropriate labelling and posting of signs, and ventilation deficiencies in the TB clinic area.

On the basis of GUV radiation measurements, it was determined that a health hazard could exist from exposure to the germicidal lamps at a distance of 10.2 cm, if JCMFHC workers did not wear protective eyewear. Except for one situation, exposure to GUV at distances greater than 10.2 cm did not represent a health hazard on the day of measurement. Recommendations are offered for minimizing the UV exposures as well as improving certain ventilation parameters.

Keywords: SIC:8099 (Health and Allied Services), germicidal ultraviolet radiation, TB clinic, ventilation.

II. INTRODUCTION

On March 5, 1991, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Senior Industrial Hygienist, Department of Community Health and Medical Care, St. Louis County, seeking assistance in documenting occupational radiation levels emitted by germicidal ultraviolet (GUV) lamps at the Tuberculosis (TB) Clinic located at the John C. Murphy Family Health Center (JCMFHC). GUV radiation measurements were made on all lamps at the TB clinic by NIOSH personnel on July 18-19, 1991.

III. BACKGROUND

At the time of the survey, the JCMFHC employed approximately 140 staff and provided care to about 200-400 patients per day, five days per week, including some weekends. Approximately 30-40% of their patient load comes from walk-ins. There are several health clinics within the facility including an OB clinic, a TB clinic, a lead screening clinic, an AIDS testing clinic, and a Women, Infant, and Children (WIC) clinic. There are 10 heating, ventilating and air-conditioning (HVAC) units which supply conditioned air to this facility, (with a separate HVAC unit for the TB area). Return air is not ducted and the return plenum above the suspended ceiling is open, allowing mixing between different areas of the clinic. Concerns regarding the potential for TB transmission were heightened as a result of a TB outbreak which had occurred at a local school about one year prior to this NIOSH survey. Many patients were seen at JCMFHC as a result of this outbreak. All staff members (including maintenance) receive annual TB skin tests. NIOSH investigators were told that, as of the date of these measurements, there had been five staff TB conversions.

Since JCMFHC provides care for large numbers of patients who may be at increased risk for TB, wall-mounted UV lamps have been installed in an attempt to further reduce the transmission of TB in the clinics by irradiating the upper room air. The germicidal lamp used at JCMFHC is a low-pressure mercury vapor lamp which is primarily a line, rather than broad band, source which emits UV and visible radiation at specific wavelengths. Over 95 percent of the radiant energy is emitted at a wavelength of 253.7 nanometers (nm). These lamps have been used for many years to aid in the control of TB by "disinfecting" the air. This evaluation addressed only occupational exposure to GUV radiation emitted by lamps. Further discussions about the effectiveness of such lamps to "disinfect" can be found in references 1-5.

IV. EVALUATION CRITERIA

There is a potential hazard resulting from exposure to GUV radiation emitted from these lamps. The critical organs of exposure for the 254 nm radiation from these lamps are the eyes and skin. At this wavelength, the radiation is absorbed by the outer surface of the eye, and overexposure can result in inflammation of the cornea (photokeratitis) and/or conjunctiva

(conjunctivitis). Keratoconjunctivitis is a reversible injury, lasting 24-48 hours, but it is a debilitating condition while it runs its course. There is a latent period of a few hours, depending upon 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.[6] This recommended standard is designed to protect the worker against the eye and skin injury mentioned above. The recommended standard is wavelength-dependent in the spectral region of interest here and is based on an action spectrum established in human and animal studies. Recently the American Conference of Governmental Industrial Hygienists (ACGIH), whose Threshold Limit Value (TLV) is the same as the NIOSH recommended standard, has recommended a revision for certain wavelengths.[7-8]

V. EVALUATION DESIGN AND METHODS

The measurement system consisted of a calibrated model 1400A International Light (IL) radiometer connected to a SEL 240 detector incorporating a diffuser/filter combination that permitted the system to read UV levels directly in units of watts per square centimeter (W/cm^2). The value for effective W/cm^2 at 254 nm is found by dividing the measured UV levels by 2. The radiometer used in this evaluation had been calibrated within six months of use by the manufacturer.

UV radiation measurements were made at eight different locations within JCMFHC. At each of these eight locations, measurements were made at sites where the NIOSH investigators thought an occupational exposure could occur to health care workers (HCW). In general, measurements were taken in the four corners of each room at 1.22, 1.52, and 2.44 meter heights. The detector was aimed at the GUV source to yield the highest possible level.

The measurements at 1.22 and 1.52 meters were performed to simulate possible eye exposure in either a sitting or standing mode. Since the values obtained at these two distances did not vary much from one another, results were combined and are reported as a lower room irradiance value. (See Table 1.) Measurements at 2.44 meters were taken to represent an upper room atmosphere irradiance value useful for indicating possible killing potential. Finally, measurements were made at the edge of the GUV lamp fixture (approximately 10.2 cm from the lamp) to simulate a potential maintenance worker exposure that could occur during cleaning or lamp replacement activities.

In the process of evaluating GUV radiation from lamps at JCMFHC, the NIOSH investigators made observations on how the lamp was installed and used, the presence of protective equipment and warning signs, and other safety related issues.

A brief, qualitative ventilation assessment was also performed which included a walk-through survey of the facility, discussions with facilities personnel concerning the HVAC systems, and a review of ventilation plans and a ventilation survey conducted in April 1991, after the HVAC systems had been balanced. Additionally, ventilation smoke tubes were used to assess the air pressure differential between various areas of the TB clinic.

VI. RESULTS

A. GUV Radiation Assessment. Table I shows the results obtained in making GUV radiation measurements at JCMFHC during the NIOSH evaluation. Most of the rooms surveyed at JCMFHC had one lamp mounted on a wall about 221 cm from the floor. The rooms ranged in size from 2.6 to 13.4 square meters (m^2). Occupational GUV exposures ranged from 5.9 to 31.3 effective $\mu W/cm^2$ as compared to the REL of 0.1 effective $\mu W/cm^2$. While making the GUV measurement, relative humidity and temperature levels were documented and ranged from 50 to 58% and 73 to 78.6°F, respectively.

In addition to GUV measurements, the following observations were noted:

1. In several rooms, both the germicidal lamp and fixture were dirty and needed to be cleaned. In one room, the metal cap on one end of the lamp was loose and had to be replaced with another bulb by the NIOSH investigators. In discussions with the staff at the facility, the NIOSH investigators were told that the lamps had not been changed since October 1990.

2. The investigators did not observe the use of any lamp fixture-door interlock, availability of protective eyewear or posting of GUV warning signs or labels in conspicuous locations notifying workers as to the presence of UV radiation. There was, however, a small label affixed to some lamp fixture housings. Unfortunately, this label could only be read at close distances to the lamp while standing on a ladder. While no protective eyewear was available, some of the health care workers did wear prescription glasses which could offer some degree of UV protection.

3. There was one situation where the only way to turn a lamp off was to disconnect the power cable from a receptacle (no wall switch to control the UV lamp). As a result, the lamp had been left on for long periods of time. At several locations, the door leading to rooms containing GUV lamps remained open all the time, with no signs indicating the presence of GUV.

4. A health care worker complained of eye discomfort and felt that the effects were caused by exposure to GUV. The worker

reported that 6-7 hours per day were spent in a room having a GUV lamp and that the ocular discomfort subsided over the weekend.

B. Ventilation Assessment. A review of the ventilation survey conducted in April 1991, indicated that individual rooms had much greater supply air flow rates than exhaust, and that the number of room air changes per hour (ACH) ranged from 11 in one exam room to 40 in another exam room. Sixteen ACH were reported for the waiting room. As previously noted, approximately 10% outside air is supplied to this facility.

Because the area above the suspended ceiling (which spans the entire length of the facility) acts as the return air plenum, there is potential for air mixing between the TB clinic and other clinics within JCMFHC. In addition, there are no isolation rooms within the clinic. Most rooms were found to be under positive pressure with respect to surrounding areas, and room doors were often kept open, further increasing the potential for air mixing within the facility.

VII. DISCUSSION

In conducting this evaluation, several items were noted as requiring some further discussions. These items included: 1) GUV radiation issues related to health care personnel, 2) ventilation concerns, 3) potential health effects on JCMFHC workers, and 4) GUV instrumentation requirements.

A. GUV Radiation Issues. Using Table I, the permissible exposure time an unprotected JCMFHC HCW can be exposed to GUV radiation without exceeding the NIOSH REL can be calculated. The exposure, in seconds, may be computed by dividing 0.003 joules/cm^2 by the maximum effective irradiance level given in W/cm^2. The result of this calculation is shown in Table II for measurements made at the edge of the lamp fixture (a distance of 10.2 cm from the lamp). The time to exceed the REL occurs anywhere from 5.9 to 31.3 minutes. This time range could be of use to maintenance workers who have to perform lamp replacement or cleaning procedures at close distances to the lamp while the lamp is on. In addition, these findings indicate that maintenance workers who perform such duties need to be aware of the need for protective clothing and gloves to protect against the GUV radiation levels, as well as possible glass breakage issues.

The permissible exposure time an unprotected HCW may be exposed to GUV radiation in the lower room space (i.e. at heights of 1.22 and 1.52 m) is computed in a similar manner and is shown in Table III. Note that in all rooms, except one, the permissible times exceed 8-hours. The permissible exposure time for the sputum induction room is 33.5 minutes. It should be noted that no HCW remained in that room with the patient.

This evaluation found GUV levels above the NIOSH REL at 10.2 cm from the lamp, and indicates that appropriate GUV protective equipment (such as UV protective eyewear) should be available to JCMFHC workers who must enter or work at those locations that represent hazardous situations. These results concerning the potential of overexposure from GUV lamps have been reported previously.[9-11] It should be noted that this evaluation found most GUV levels in the medical rooms to be below the NIOSH REL.

However, it should be remembered that exposure to GUV radiation is dependent on many factors such as position of the lamp fixture in the room, type of fixture, age of the bulb, movement of the worker, obstruction of the UV radiation by objects near the bulb, and height of the workers. In addition, it should not be forgotten that the intent of the GUV lamps is to kill TB bacteria. If lamps are never changed, then their output will drop and the killing effectiveness will be altered. There must be a uniform policy as to when germicidal lamps are to be replaced in order to maximize their effectiveness in killing TB. This could be determined from either a time-use log or one based on cumulative time. Another way to determine if the bulbs are producing GUV radiation is to document the GUV levels with an appropriate GUV radiation meter.

At JCMFHC, specially designed metal slats (called louvers) were affixed to the lamp fixture to aid in directing the GUV radiation to certain positions. While the devices will divert and realign the UV radiation emitted from the fixture in a given direction, they will also reduce the total UV output in all directions (including occupational exposure). Measurements made at JCMFHC indicated that this drop-off can be about 30 to 40%.

The GUV radiation levels measured in this evaluation are significantly lower than those reported by NIOSH in other similar evaluations. In one survey, the measurement made at 10.2 cm from the lamp ranged from 400 to 1200 effective $\mu W/cm^2$ measured with the same wattage bulb compared to 1.6 to 8.5 effective $\mu W/cm^2$ in this survey. Furthermore, the GUV radiation sensitivity level for the meter used at JCMFHC is 0.15 effective $\mu W/cm^2$.[12] This means that radiation levels reported in Table I are in many cases below the instrument minimal sensitivity level and are not due to GUV radiation. Since NIOSH was informed that the bulbs may not have been changed for a long time, it may be reasonable to speculate that the reason for the low occupational values are related to "GUV"-dead bulbs. This "GUV"-dead bulb issue also impacts upon the upper room GUV irradiance (2.44 m) level that is linked to TB bacteria killing potential.

B. Ventilation Requirements. There are two types of ventilation used for controlling airborne transmission of TB: general ventilation and

local ventilation. General ventilation performs two functions. The first is to provide sufficient outside air to maintain comfort. The American Society for Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) recommends a range of 15 to 30 cubic feet per minute (cfm) per person of outdoor air for hospitals.[13] The second function is to provide sufficient air flow to provide infection control. ASHRAE and the American Institute of Architects (AIA) suggest air flows ranging from 4 to 15 ACH, depending on the functional area of the health facility.[14-15] In general, the guidelines for infection control will specify higher air flows than those for comfort. For isolation rooms, ASHRAE recommends that the rooms be ventilated with a minimum of two ACH of outside air and a minimum of six total ACH; the remainder of four air changes need only be clean air, not necessarily outside air. In addition, all air in isolation rooms should be exhausted directly to the outside and should not be recirculated back into the facility, and the rooms should be under negative pressure with respect to surrounding areas. (Air should flow from clean to less clean areas.) Identical recommendations are given for bacteriology labs.

Local exhaust ventilation systems such as isolation booths, tents, or hoods capture the infectious agent in the immediate field of an infectious patient. It is the ideal type of ventilation because the TB bacilli are removed before they can disperse throughout the work area. Local ventilation is most effectively used at a fixed location (e.g., an infectious patient). The hood portion of a local exhaust system may be of exterior design, where the infection source is near but outside the hood, or enclosing where the infection source is within the hood. Enclosures (booths) are available for aerosol-generating activities, such as sputum collection and aerosol therapy. These devices may be exhausted directly to the outside or can exhaust through a high efficiency particulate air (HEPA) filtration unit back into the room.

C. Reported Biological Effects. One HCW at JCMFHC reported the effects of facial skin reddening and peeling after a week's exposure to a GUV lamp. The HCW spent 7 hours per day in the room. The highest irradiance (254 nm) measured was 7.5×10^{-8} W/cm^2 (effective). This irradiance level multiplied by an all day exposure time of 2.52×10^4 seconds yields a radiant exposure of 1.9 millijoules per square centimeters (mJ/cm^2). The 1.9 mJ/cm^2 is below the NIOSH unprotected skin/eye limit of 6 mJ/cm^2 for GUV radiation. It is also noted that dosage is based on levels measured at 10.2 cm which is not a typical worker location.

In view of the "GUV"-dead bulb potential discussed earlier, and the low dose of 1.9 mJ/cm^2, health effects such as these would not be expected to occur. However, it should be realized that erythemal thresholds can vary with skin pigmentation and with thickness of the stratum corneum. If the health effects continue, it would be

prudent to seek ways to reduce potential exposures such as through the use of louvers, limiting time in the room, and moving the worker to a different location.

D. Measuring GUV Radiation Levels in the Workplace. It should be noted that since the UV radiation produced by these lamps can represent an occupational exposure situation while disinfecting the air at the same time, care must be taken in the selection of instrumentation used. For example, it must have the correct spectral range to match the unique source output. In addition, the solarization and aging properties of lenses, tube envelopes, and detector components must be considered. High concentrations of water vapor in the atmosphere may cause absorption of UV energy. Equipment used to measure germicidal UV radiation should be maintained and calibrated on a regular schedule.

VIII. RECOMMENDATIONS

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

A. A training course should be provided to lamp replacers, and to all who may have GUV exposure to insure awareness of the potential health hazards.

B. Under no conditions should germicidal lamps be used as replacement lamps for conventional fluorescent lamps.(16) When GUV lamps are replaced due to low UV outputs, occupational exposures should be re-evaluated using an appropriate GUV meter.

C. There should be a policy on how to label UV lamps, including the use of warning sings on doors.

D. Current Centers for Disease Control (CDC) recommendations should be followed for preventing the transmission of tuberculosis.[17] These recommendations include screening patients for active tuberculosis and tuberculous infection; providing rapid diagnostic services; prescribing appropriate therapy; preventing or reducing microbial contamination of the air; providing isolation rooms for persons with, or suspected to having infectious TB; and screening health care facility personnel for tuberculous infection and tuberculosis. The importance of ventilation, as a combined control measure, should not be underestimated. This includes the provision of good air distribution and mixing.

E. Ideally, ventilation systems used in areas where M. tuberculosis is present should supply air from the outside, discharge exhaust air to the outside, and should not recirculate air back into the facility.[2,3] Where this is not possible, less desirable alternative approaches can be used. Rooms connected to recirculating ventilation systems could utilize HEPA filtration in the room exhaust or system return duct to filter the air before it is recirculated. This may require substantial modifications to the existing HVAC systems which now share a common return air plenum throughout the facility. Consideration also should be given to the addition of isolation rooms for examining and treating patients known or suspected of having active TB. Other general ventilation guidelines established by ASHRAE and AIA for health facilities should be followed.(13-14)

F. Local exhaust ventilation (such as booths, hoods, or tents) should be used for sputum induction procedures and other aerosol generating procedures performed on patients suspected or known to have TB. The exhaust air should be directed to the outside or filtered using HEPA filters before being recirculated into the general room air. The CDC guidelines discussed above provide recommendations in this area.

G. Patients known or suspected of having TB should be taken to the TB clinic as soon as possible to minimize the time spent in the general patient waiting room.

IX. REFERENCES

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2. Department of Community Health and Medical Care, Clayton, MO.
3. NIOSH
4. OSHA, Region VII

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TABLE I

Range of GUV Readings
Obtained at Different Heights

JCMFHC
Berkeley, Missouri
HETA 91-148
July 18-19, 1991

LOCATION	ROOM SIZE (m^2)	NO. OF LAMPS[a]	DISTANCE LAMP FROM FLOOR-CEILING (cm)	RANGE OF UV EXPOSURE LEVELS ($\mu W/cm^2$)[b] 4"[c]	4'/5'[c]	8'[c]
Sputum Ind Room	2.6	1	221 38	5 (1)	2.8 - 3.0 (2)	13 - 30 (5)
Room 1055	8.8	1	221 38	3.1(1)	0.0027 - 0.0083 (10)	0.015 - 0.57 (5)
Room 1051 (D)	7.6	1	221 38	12 (1)	0.004 - 0.07 (10)	0.07 - 0.7 (5)
Room 1049 (D)	7.8	1	224 36	17 (1)	0.021 - 0.15 (6)	0.082 - 0.23 (2)
Waiting Room	13.4	3	221 38	4.3 - 4.5 (3)	0.0053 - 0.027 (5)	0.034 - 0.76 (4)
Room 13	7.8	1	221 38	7 (1)	0.024 - 0.029 (2)	0.24 (1)
Room 16	8.0	1	221 38	7.5(1)	0.013 - 0.016 (2)	0.3 (1)

Registration	4.6	1	224 36		7	(1)	0.016	- 0.031	(3)	0.15 (2)	- 0.75

(A) All lamp fixtures are wall-mounted and contain 30 watt lamps except for 15 watt lamp at Location 2.
(B) GUV (effective) equal to ½ of reported values.
(C) Number in parenthesis indicates number of measurements made.

TABLE II

PERMISSIBLE EXPOSURE TIME TO GUV AT 10.2 cm FROM THE LAMP

JCMFHC
Berkeley, Missouri
HETA 91-148
July 18-19, 1991

LOCATION	MAXIMUM UNWEIGHTED RESULTS ($\mu W/cm^2$)	MAXIMUM WEIGHTED RESULTS[(a)] (EFFECTIVE $\mu W/cm^2$)	PERMISSIBLE EXPOSURE TIME (MINUTES)
Sputum Ind Room	5	2.5	20
Room 1055	3.1	1.6	31.3
Room 1051	12	6	8.4
Room 1049	17	8.5	5.9
Waiting Room	4.5	2.25	22.2
Room 13	7	3.5	14.3
Room 16	7.5	3.75	13.3
Registration	7	3.5	14.3

(A) GUV (effective) equal to ½ of unweighted values.

TABLE III

PERMISSIBLE EXPOSURE TIME TO GUV RADIATION IN THE LOWER ROOM ENVIRONMENT

JCMFHC
Berkeley, Missouri
HETA 91-148
July 18-19, 1991

LOCATION	MAXIMUM UNWEIGHTED RESULTS ($\mu W/cm^2$)	MAXIMUM WEIGHTED RESULTS (EFFECTIVE $\mu W/cm^2$)	PERMISSIBLE EXPOSURE TIME (MINUTES)
Sputum Ind Room	3.0	1.5	33.3
Room 1055	.0083	.004	> 8 hr
Room 1051	.07	.035	> 8 hr
Room 1049	.15	.075	> 8 hr
Waiting Room	.027	.014	> 8 hr
Room 13	.029	.015	> 8 hr
Room 16	.016	.008	> 8 hr
Registration	.031	.016	> 8 hr