UPPER- ROOM UVGI AIR DISINFECTION

National Academies of Sciences, Engineering, and Medicine

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PHILIP W. BRICKNER, MD 1926-2014

Father of Healthcare for the Homeless and Leader in the Reapplication of UV in High Risk Settings

Why Upper-Room UVGI Systems Now?

- Works well with natural and/or mechanical ventilation combined with diffusers and or fans for air-mixing
- 73-80% effective in reducing transmission of airborne pathogens (Escombe et al 2009, Mphaphlele et al2015)
- Works against a wide range of airborne pathogens (regardless of the drug-resistance of the strain) (virus, bacterium, spores, fungi)
- Maintenance of systems is relatively simple
- Human safety can be achieved with proper design, installation, commissioning, operation and maintenance.

Infection control:
Observed practices due to design constraints

Administrative pressures drive Triage procedures

No departmental waiting areas. Health and safety compromised

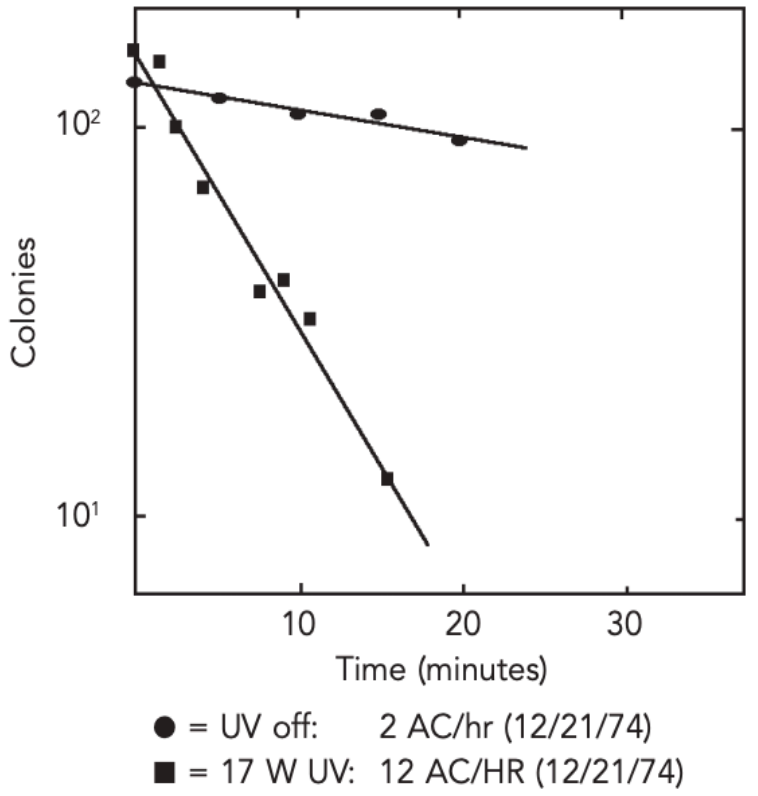
No physical separation among patients until sputum smear results available

How Effective is Upper Room UVGI?

Riley, Johns Hopkins 1976

- Inactivation of aerosolized surrogate TB bacilli from room air with and without upper-air UV irradiation using one 17-watt fixture
- AC/hr = air changes per hour

Figure 2. Disappearance of aerosolized bacillus Calmette-Guérin (BCG) from room air with and without upper room ultraviolet (UVGI) irradiation using one suspended fixture with one 17 W lamp.



AC/hr = air changes/hour

Y-axis = viable colonies remaining in air

X-axis = duration of exposure to UVGI

SOURCE: adapted from Riley.[34]

Riley, R. L.; Knight, M.; Middlebrook, G. Ultraviolet susceptibility of BCG and virulent tubercle bacilli. *Am. Rev. Respir. Dis.* **1976**, *113* (4), 413-8.

Brickner PW, Vincent RL, First M, Nardell E, Murray M, Kaufman W. The application of ultraviolet germicidal irradiation to control transmission of airborne disease: bioterrorism countermeasure. *Public Health Rep.* 2003;118(2):99-114. doi:10.1093/phr/118.2.99

- Riley's Bench-scale Studies Provide Guidance on TB Dosing
- To develop practical application of UV-C_{254nm} in high-risk settings, Riley conducted bench-scale studies where he exposed both virulent and non-virulent bacillus Calmette-Guerin (BCG), tubercle bacilli, and other organisms to UVC_{254nm} of known intensity and duration under conditions of controlled temperature and humidity.
- These studies demonstrated a ***90% lethal dose (LD_{90}) for virulent TB and for BCG for a 12 seconds exposure at 50μW/cm² or 60 seconds at 10 μW/cm². [600μWs/cm²]***
- Practically, these UV-C_{254nm} intensity levels are achievable for the upper room with available upper room UVC_{254nm} lamps and fixtures.

Riley, R. L.; Knight, M.; Middlebrook, G. Ultraviolet susceptibility of BCG and virulent tubercle bacilli. *Am. Rev. Respir. Dis.* **1976**, *113* (4), 413-8.

- Walker and Ko's Bench-scale Studies Provide Guidance on Dosing of Coronavirus

TABLE 1. Ultraviolet Germicidal Irradiation Susceptibility (*Z* Value) of the MS2 Bacteriophage, Respiratory Adenovirus Serotype 2, and Murine Hepatitis Virus Coronavirus, at 50% Relative Humidity

	UV dose (μW s/cm²)	percent survival[a]	*Z* value (×10⁴)[b]
MS2 (*N* = 5)	2608	31.1 ± 2.9	3.8 ± 0.3
adenovirus (*N* = 4)	2608	32.9 ± 2.3	3.9 ± 0.3
coronavirus (*N* = 3)	599	12.2 ± 7.2	37.7 ± 11.9

[a] Percent survival = 100 × (number of plaques in the presence of UV exposure)/(number of plaques in the absence of UV exposure). [b] *Z* values (× 10^4) were calculated as $-10^4 \times \log(\%\ \text{survival})/\text{UV dose}$ (μW s/cm²).

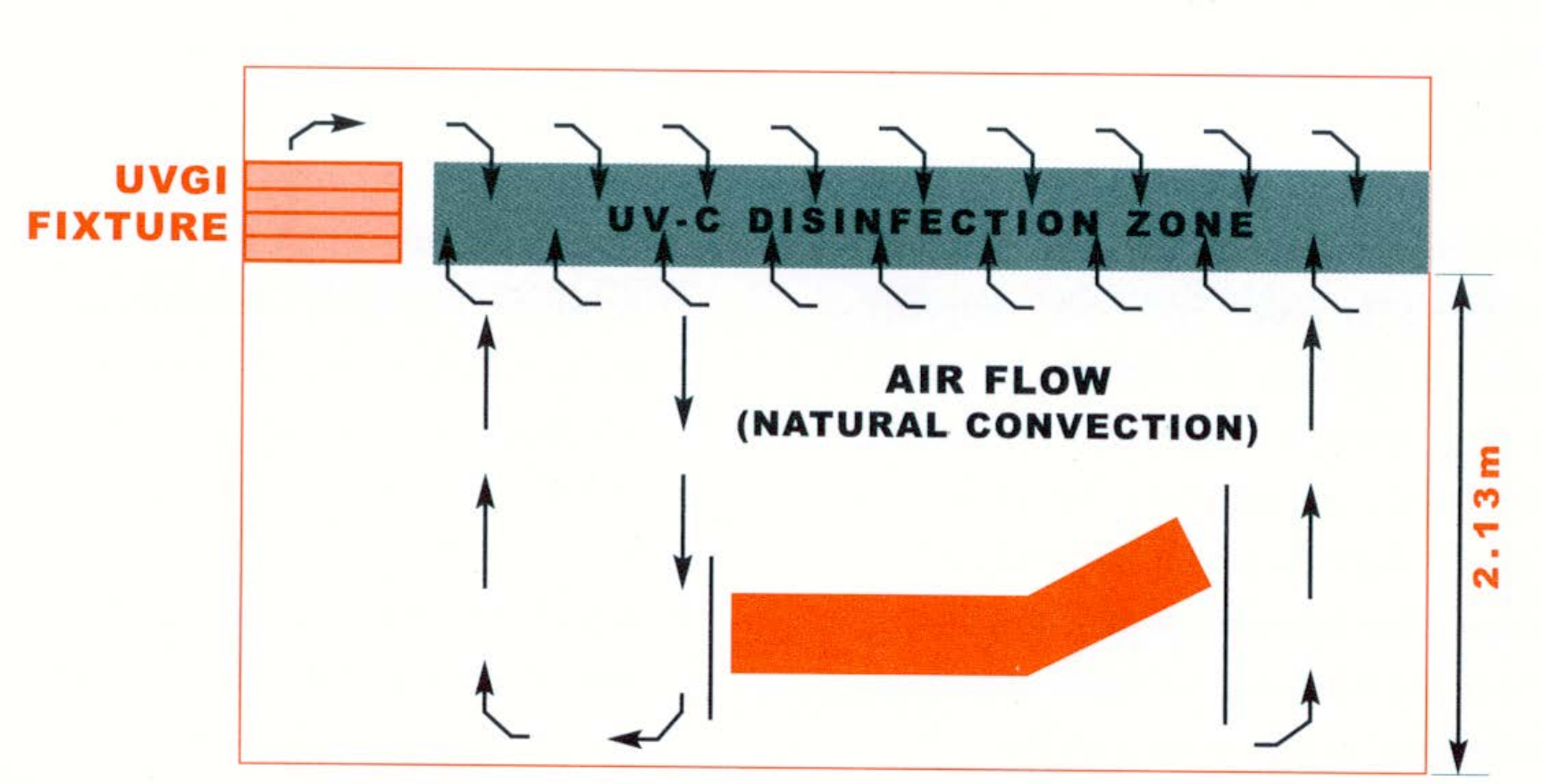
Walker CM, Ko G. Effect of ultraviolet germicidal irradiation on viral aerosols. *Environ Sci Technol*. 2007;41(15):5460-5465. doi:10.1021/es070056u

TB/UV Shelter Study (TUSS)

St. Vincent's Hospital and Harvard School of Public Health
Philip W. Brickner, MD, P.I., Ed Nardell, MD, Co-PI

- TUSS (1997-2004) was a double-blind, placebo controlled field trial in 6 USA cities, with 14 shelters
- Nearly 1200 UVGI luminaires were installed covering 200,000 sq. ft in a diverse set of buildings
- Upper air systems were monitored at set intervals, and measured before and after cleaning
- UVC lamps were replaced when output fell below a set criteria

Upper-Room Disinfection With UV-C (Section View in Hospital Room)

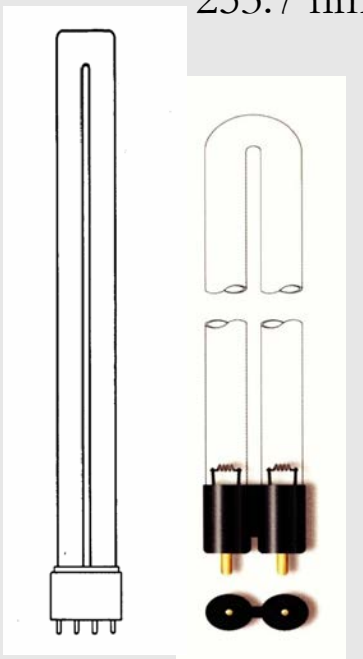


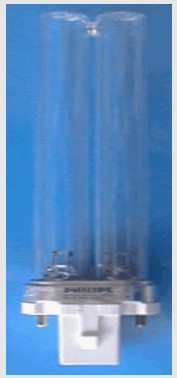
Source: South Africa Medical Research Council

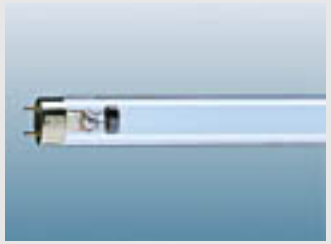
UV-C LAMPS and Radiometers

- Upper air UVGI is generated by a low-pressure Hg vapor discharge lamp
  - 35% electrical input wattage is converted to UVC energy for which 253.7 nm is the strongest wavelength
- UV-C irradiance is measured in $\mu W/cm^2$
- Electrical input to the UV-C lamp is regulated by a ballast (magnetic and electronic)
- LEDs and Krypton Chloride Lamps require different detectors for selected wavelengths

Low Pressure Hg lamps
253.7 nm

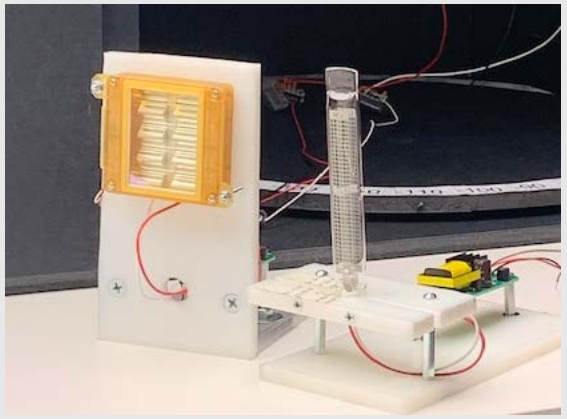






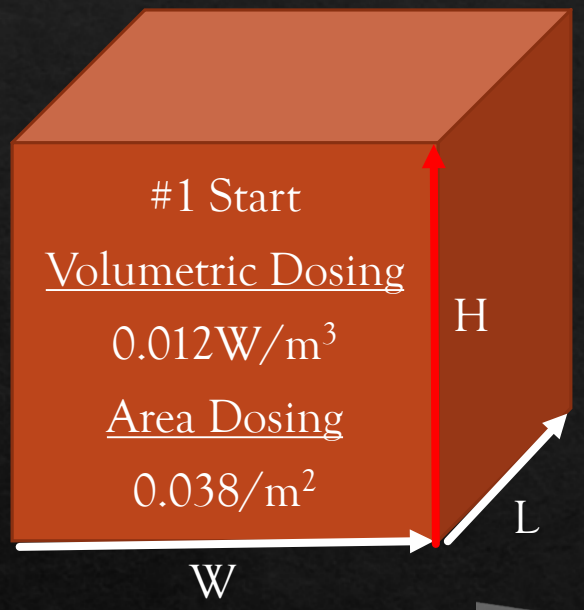
Low Hg UV-C Lamps

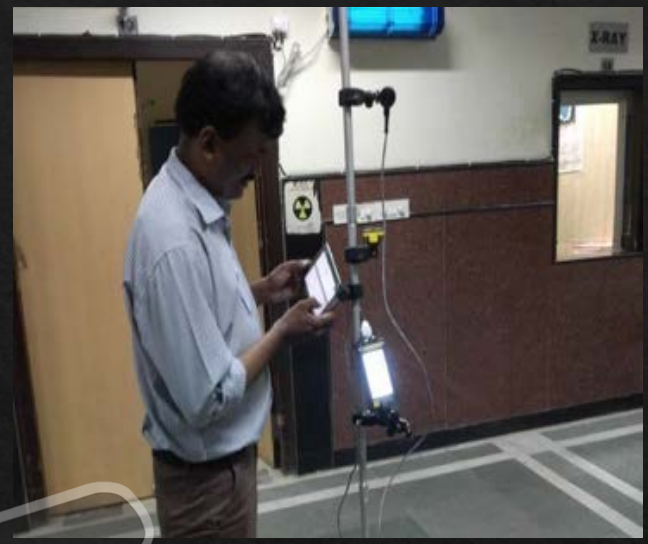
Future LED Germicidal Lamps
(265-280nm)



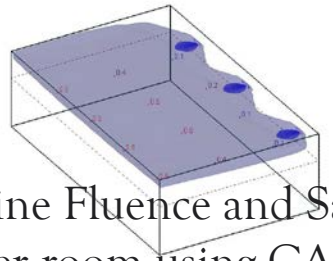
Krypton Chloride (excimer lamp 222nm)

3 Criteria for Programming Upper Room UVGI into a Space + Air-Mixing



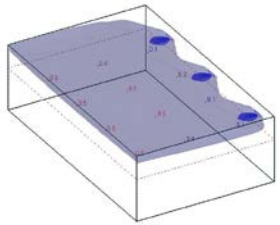


#3 Verify Safe levels in Occupied Space and Performance Output



#2 Refine Fluence and Safety in upper room using CAD Tool Target 6μW/cm^2 average in room volume

Air-Mixing for Effectiveness Adjusting Diffusers or adding fans



#2 Refine Fluence and Safety in upper room

Computer Aided Design (CAD) Dosing Method

- Visual-3D Lighting Software – modified to calculate UVGI from multiple UVGI luminaires
- Using the volumetric dosing strategy #1 as a first approximation, the Visual™-UV can be used to verify the number, design, and optimal location of luminaires
- Model and calculate eye level readings.
- Calculate the average UV fluence rate for the entire room
- Rapidly interchange different models of upper-room UVGI luminaires that have a gonioradiometric data saved in .IES file
- Can calculate (NIOSH (2009) dose for the upper-room

Simulation

#Fixtures Open for10’ Ceiling Place in 32’ Ceiling Room

Total UV Watts Needed (E) = 1646.34m3 x 0.012 UVC W/m3 = 19.76 UVC W

Total Open Fixtures Needed = 19.76 UVC W ÷ 3.7 UVC W/fixture = 5.34 or **5 Fixtures**

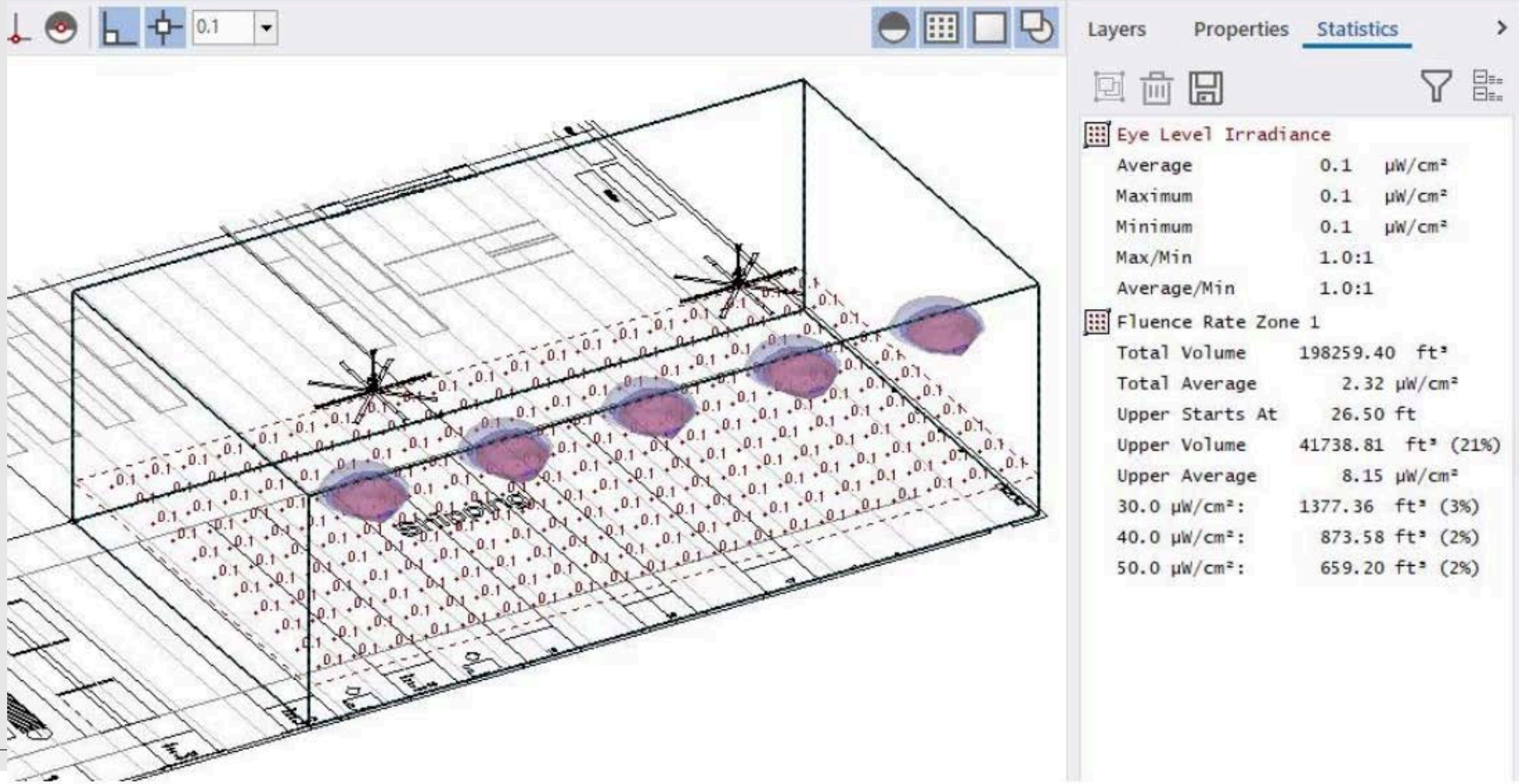
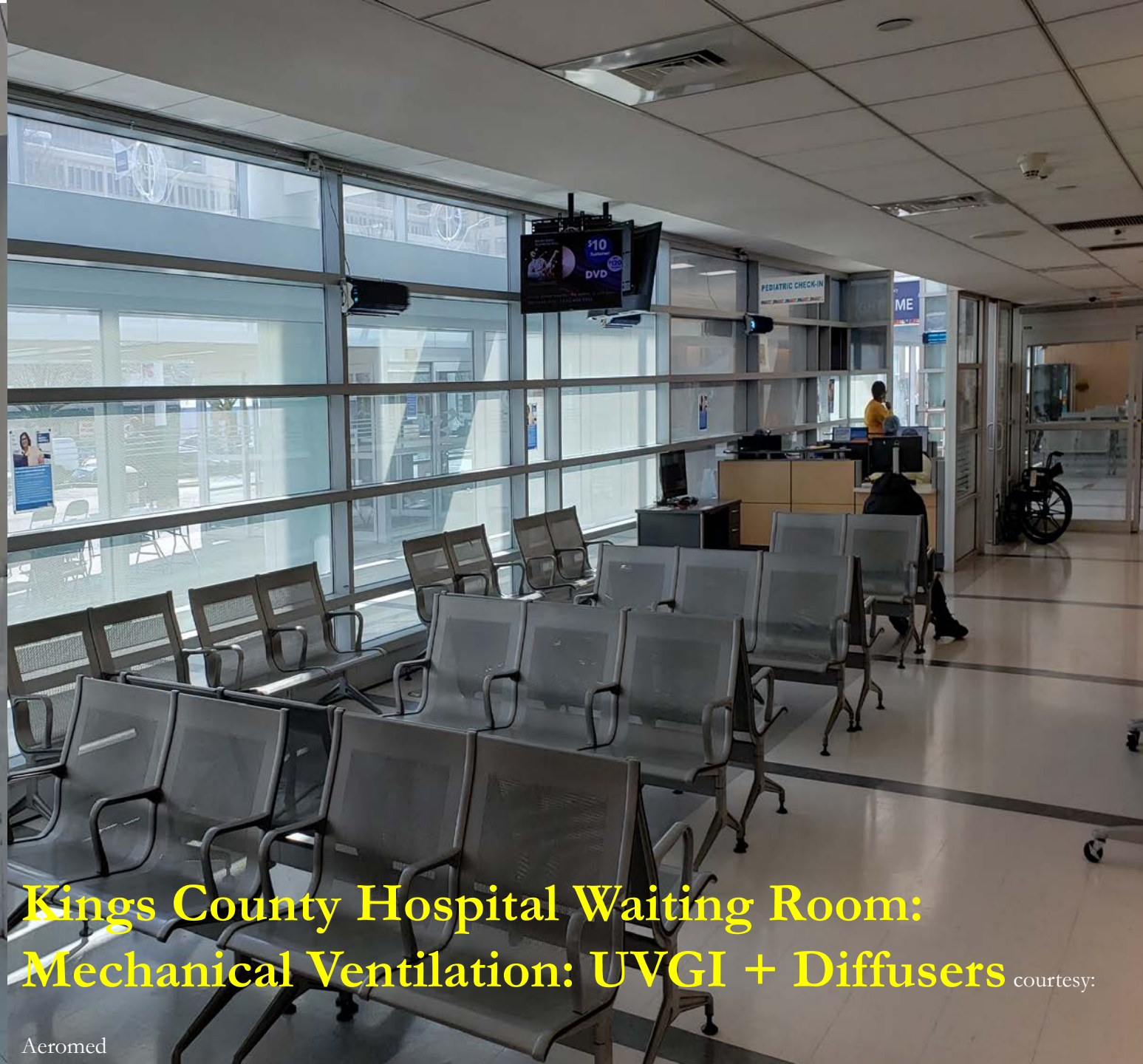


FIGURE 3. Classroom, Swarthmore public schools, slide wall fixtures.

SCHOOLS-THEN AND NOW

Karachi Hospital Corridor Natural Ventilation UVGI + Fan courtesy: IRD

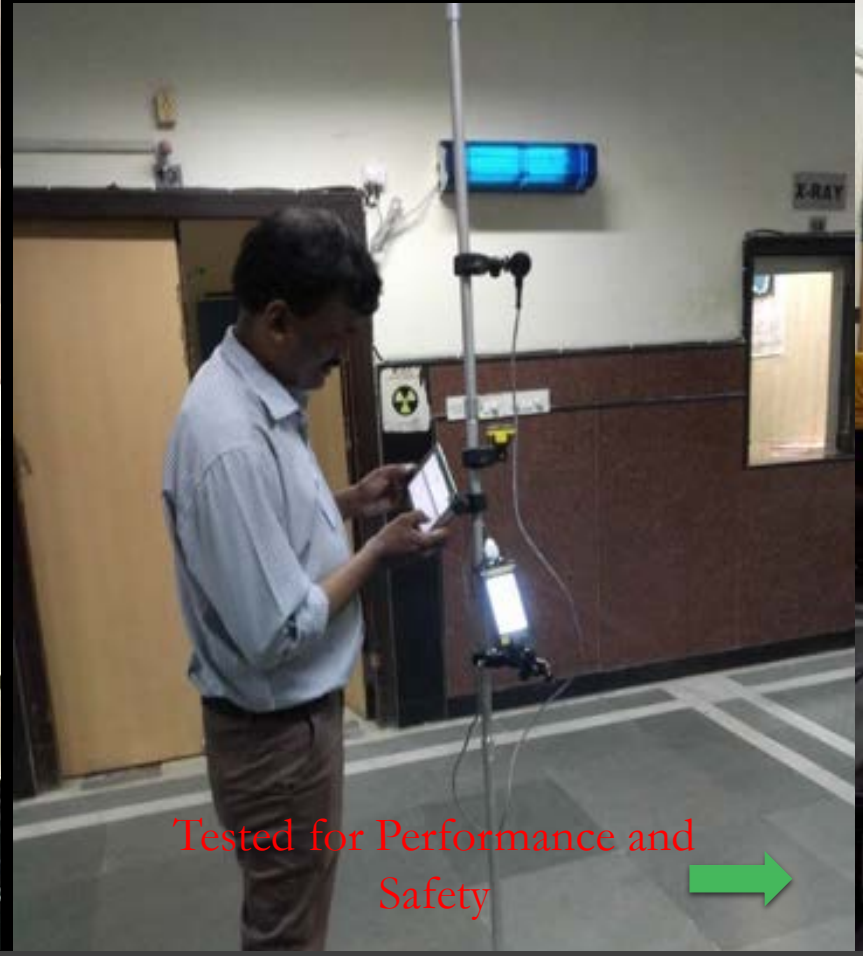


Kings County Hospital Waiting Room: Mechanical Ventilation: UVGI + Diffusers courtesy: Aeromed

Source: Aeromed

Where to apply?

- *Healthcare facilities*
  - *Waiting Rooms*
  - *Emergency Departments*
  - *Special aerosol procedures*
  - *Operating rooms*
  - *Autopsy*
  - *X-Ray*
  - *Dental*
  - *Nursing Homes*
- *Transportation Hubs*
- Retail
- Schools
- Houses of worship
- Pet Boarding/Care Centers
- Refuge Centers
- Homeless Shelters
- Military Barracks



GERMICIDAL UV AIR-MIXING SYSTEM
NATIONAL INSTITUTE OF TUBERCULOSIS RESPIRATORY DISEASES (NITRD), ROHIT SARIN, MD, DIRECTOR, NEW DELHI, INDIA

End Tuberculosis Transmission Initiative

ASHRAE GPC-37

Guidelines for the Application of Upper-Air (Upper Room) Ultraviolet Germicidal (UV-C) Devices to Control the Transmission of Airborne Pathogens

To provide minimum requirements for safe and effective implementation of upper room UVGI air-mixing systems for air disinfection in congregate settings, by

- best practices for assessing need in context of other airborne infection control measures
- understanding what is necessary for : design, installation, commissioning, maintenance & operation.

Acknowledgements

- Collaborators:
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Resources in following slides

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https://labs.icahn.mssm.edu/vincentlab/

Safety of Upper-Room Ultraviolet Germicidal Air Disinfection for Room Occupants: Results from the Tuberculosis Ultraviolet Shelter Study

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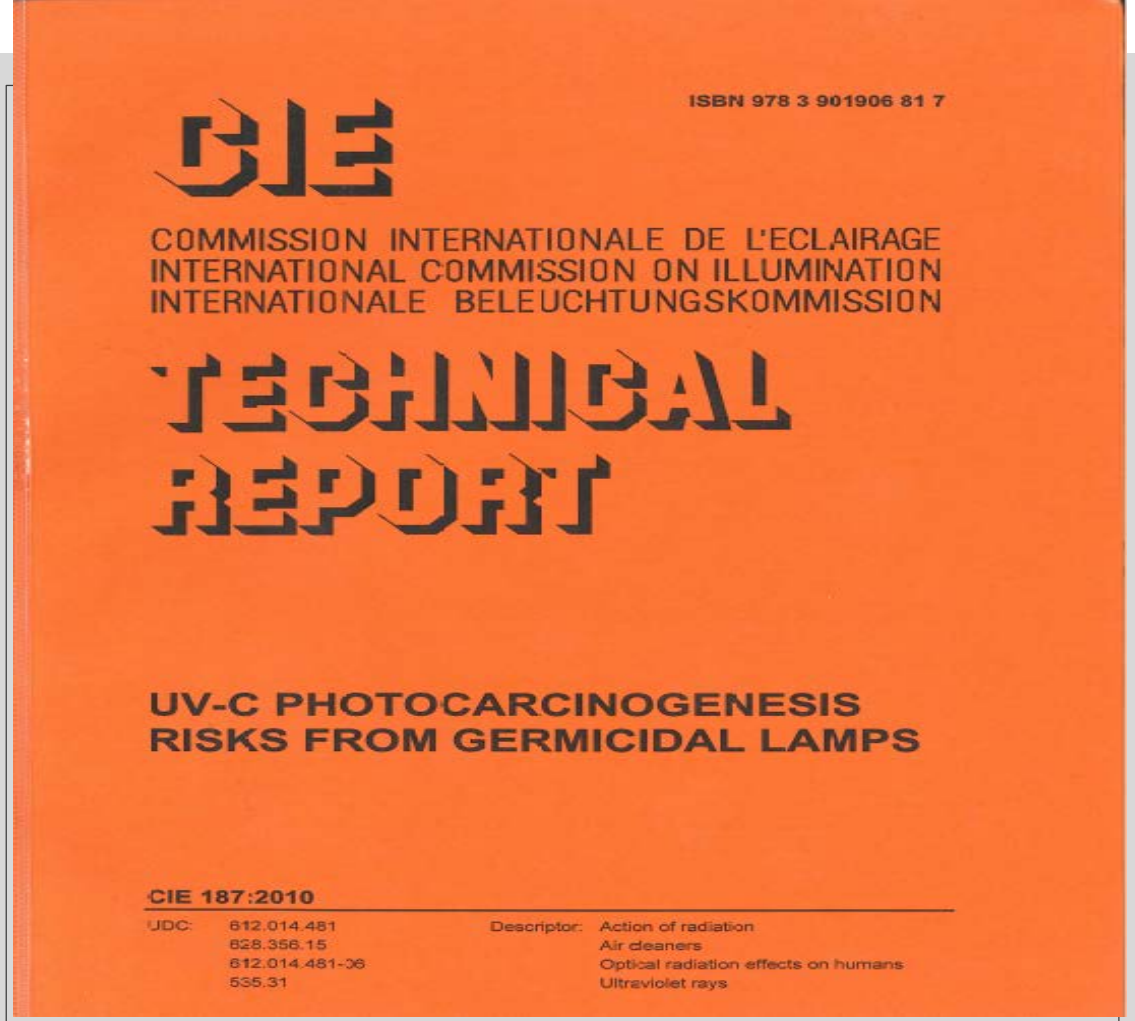
SYNOPSIS

Objectives. We evaluated the safety of room occupants in the Tuberculosis Ultraviolet Shelter Study (TUSS), a double-blind, placebo-controlled field trial of upper-room ultraviolet germicidal irradiation (UVGI) at 14 homeless shelters in six U.S. cities from 1997 to 2004.

Methods. Data collection involved administering questionnaires regarding eye and skin irritation to a total of 3,611 staff and homeless study subjects.

Results. Among these subjects, there were 223 reports of eye or skin symptoms. During the active UV period, 95 questionnaires (6%) noted such symptoms, and during the placebo period, 92 questionnaires (6%) did so. In the 36 remaining cases, either the UV period when symptoms took place was unknown or the symptoms spanned both periods. There was no statistically significant difference in the number of reports of symptoms between the active and placebo periods. One definite instance of UV-related keratoconjunctivitis occurred, resulting from a placement of a bunk bed in a dormitory where a single bed had been used when the UV fixtures were first installed.

Conclusions. These findings demonstrate that careful application of upper-room UVGI can be achieved without an apparent increase in the incidence of the most common side effects of accidental UV overexposure.



UV Safety Review

- UV Germicidal irradiation can be safely and effectively used for upper air disinfection with out a significant risk for long term delayed effects such as skin cancer. (CIE 187:2010)

◦ ETTi Guidance on Measurement and Maintenance of GUV Systems

www.StopTB.org/wg/ett

ETT | End TB Transmission Initiative

MAINTENANCE OF UPPER-ROOM GERMICIDAL ULTRAVIOLET (GUV) AIR DISINFECTION SYSTEMS FOR TB TRANSMISSION CONTROL

USAID FROM THE AMERICAN PEOPLE

Partner of the Stop TB Partnership

TABLE OF CONTENTS

End Tuberculosis Transmission Initiative

TECHNICAL INFORMATION SHEET

Disinfecting room air with upper-room (UR) germicidal UV (GUV) systems

Count the Cost!

STOPTB.ORG/wg/ett

UR GUV costs

(all costs presented in USD)

Initial costs	Estimated unit cost	EXAMPLE Unit cost	Lifecycle cost: 1 unit	Lifecycle cost: 10 units	Lifecycle cost: 50 units
UR GUV fixture(s): This price will vary depending on the volume of purchased units and taxes. Efforts are underway to develop negotiated prices through the GDF along with listing of pre-qualified fixtures (10% discount ≥10 units; 20% discount ≥50 units)	**200 – 2,000** USD	**1,000** USD	**1,000** USD	**9,000** USD	**40,000** USD
Shipping, customs, taxes: The price will vary by country depending on the volume purchased and local taxes.	**0 – 100%** of unit price	**200** USD (20%)	**200** USD	**1,800** USD	**8,000** USD
Air Mixing system (fans, etc.): a method of air-mixing is required. In naturally ventilated space, eithers ceiling or wall fans can provide this function.	**20 – 100** USD	**30** USD	**30** USD	**300** USD	**1,500** USD
Layout design: Includes site visits, GUV fixture selection and specification, architectural, mechanical & electrical drawings showing GUV fixture locations and model number.	**0 – 50** USD	**0** USD	**0** USD	**0** USD	**0** USD
Installation (fixture, fans, electrical, etc.): Electrical conduit to each fixture location. Individual electrical switch per location. Electric panel(s) & circuit breakers as required. Added facility electric capacity as necessary. UV fixture mounting & electric hookup at each location specified.	**10 – 40%** of unit price	**200** USD (20%)	**200** USD	**1,800** USD	**8,000** USD
Acceptance testing (UR GUV performance): Each installed GUV unit is assessed for functionality, placement & orientation. UV radiometric evaluation is performed to ensure each unit is both safe and effective (that adequate germicidal UV is present in the irradiated zone above room occupants and that only safe levels of UV are present in the occupied area near the unit). UV output adjustment as required. Prepare and document acceptance report.	**5 – 10%** of unit price	**75** USD (7.5%)	**75** USD	**675** USD	**3,000** USD
GUV Meter: at least one UV radiometer with a 254 nm detector is required for operating and maintaining a GUV system. If a facility has over 100 units it may require an additional meter as a backup. (for lifecycle cost, the cost will be divided by the total number of fixtures purchased)	**1,500 – 2,500** USD	**2,000** USD	**2,000** USD	**2,000** USD	**2,000** USD
Total initial costs			**3,505** USD	**15,575** USD	**62,500** USD

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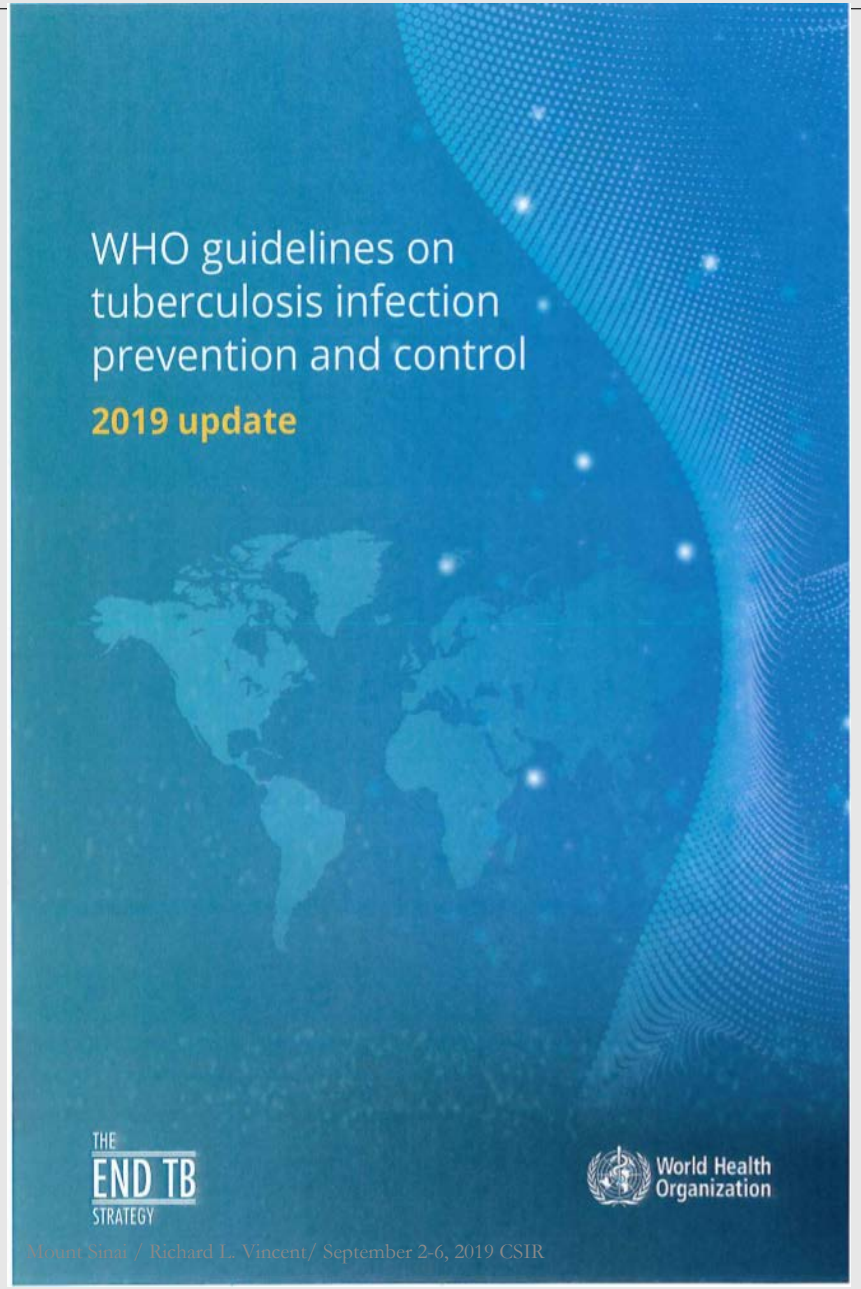

WHO guidelines on tuberculosis infection prevention and control
2019 update
THE END TB STRATEGY
World Health Organization

Enquiry Draft

Sent to BA/D6/D2 for commenting:
2020-07-03

Deadline for BA/D6/D2 commenting:
2020-09-03

LBs BA2024, D06-2006

cie

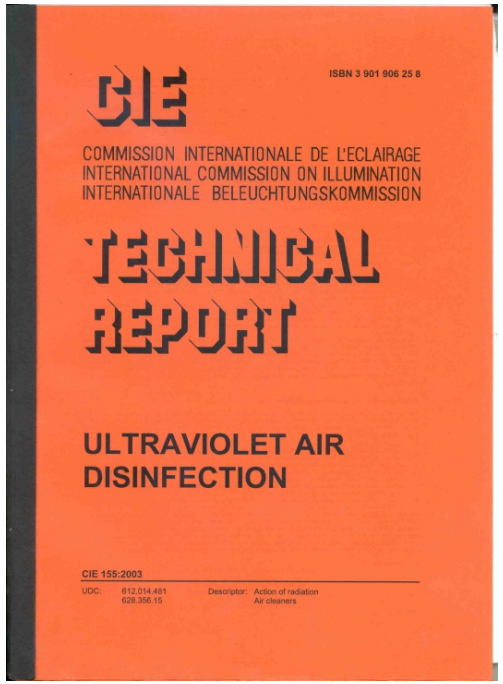
International Commission on Illumination
Commission Internationale de l'Eclairage
Internationale Beleuchtungskommission

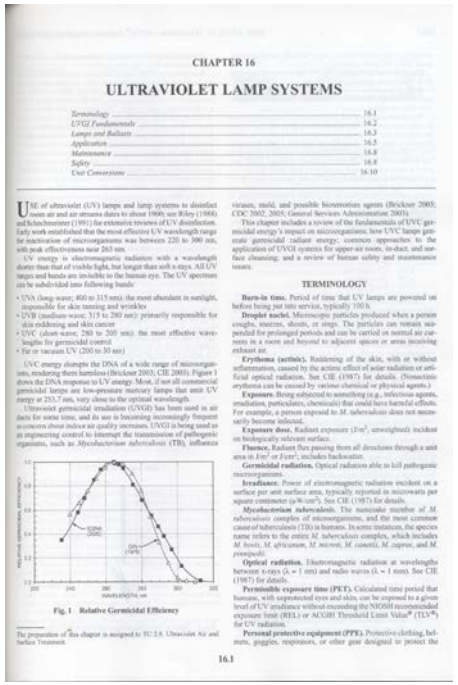
TECHNICAL REPORT

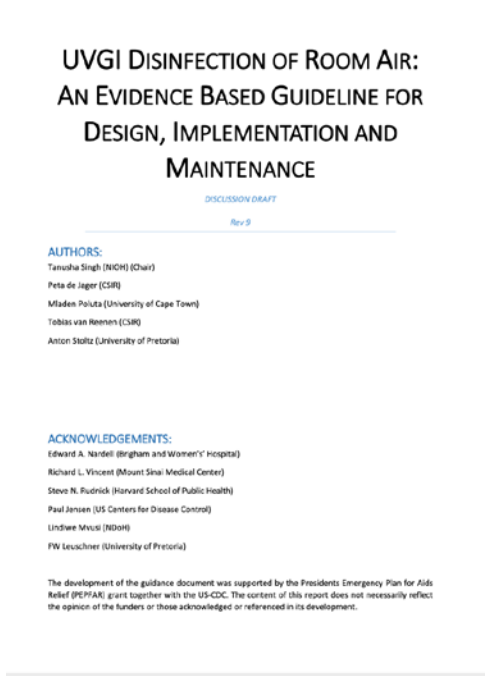
CIE Guide for the Measurement of Upper Air Ultraviolet Germicidal Irradiation Luminaires Using Low Pressure Germicidal UV-C Lamps

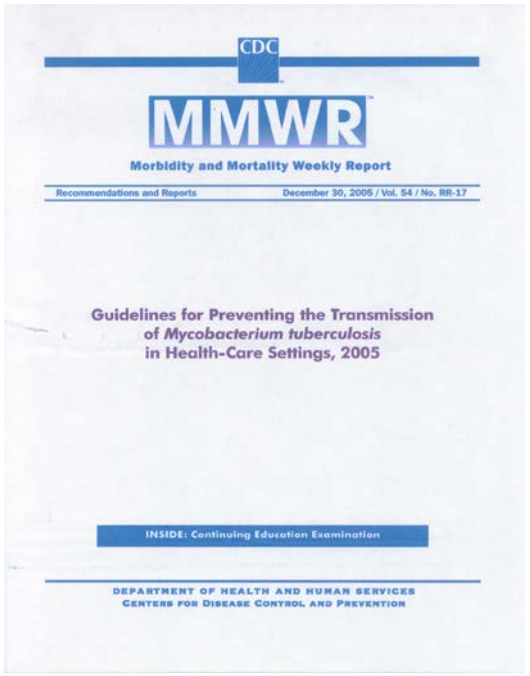
ED/TR TC 6-52

UDC: 612.014.481-06 Descriptor: Optical radiation effects on humans









Guidance Documents
Groups working on UVGI Guidelines and Standards