GUIDELINES FOR ULTRAVIOLET GERMICIDAL IRRADIATION (UVGI) REQUIREMENTS IN HEATING, VENTILATION, AND AIR CONDITIONING (HVAC) SYSTEMS IN HOSPITALS

MINISTRY OF HEALTH
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PREFACE

The COVID-19 pandemic has highlighted the critical importance of effective ventilation and airborne infection control in healthcare facilities. As an airborne infectious disease, COVID-19 has underscored the need for enhanced measures to reduce the transmission of pathogens within indoor environments, particularly in hospitals where patients and healthcare workers are at increased risk. Ensuring safe air quality through appropriate ventilation and disinfection strategies is therefore essential to safeguard both patient outcomes and staff wellbeing.

Ultraviolet Germicidal Irradiation (UVGI) has emerged as a valuable adjunct technology for airborne disinfection within Heating, Ventilation, and Air Conditioning (HVAC) systems. However, the implementation of UVGI systems involves significant capital investment and ongoing maintenance requirements. Without proper design, installation, and operation, such systems may not achieve optimal performance and may result in inefficient resource utilization.

This guideline is intended to be used in conjunction with other relevant technical documents, including national and international standards on ventilation, infection prevention and control (IPC), and healthcare facility engineering. It should not be applied in isolation, but rather as part of an integrated approach to airborne infection control within Ministry of Health hospitals and medical institutions.

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1.0 Introduction

1.1. Hospitals are high-risk environments where robust infection prevention and control (IPC) measures are crucial to prevent healthcare-associated infections (HAIs). Ultraviolet germicidal irradiation (UVGI) is a proven adjunctive disinfection technology particularly against airborne pathogens. However, it must always be integrated with ventilation and other IPC measures and must comply with national and international standards to ensure both efficacy and safety for end users.

1.2. The objective of this guideline is to assist hospital managers, clinicians, engineers and others in understanding UVGI requirements in HVAC systems in hospital settings.

2.0 Principles of UVGI Use

2.1 Ultraviolet germicidal irradiation (UVGI) employs ultraviolet (UV) energy to inactivate microorganisms, including viruses, when it is correctly designed and installed. Ultraviolet energy is germicidal within the range of 200–320 nm, with UV-C (200–280 nm) being the most effective spectrum. UVGI inactivates microorganisms by damaging the molecular structure of nucleic acids and proteins, rendering them incapable of replication. UVGI should serve as a supplementary measure and not as a replacement for other control mechanisms such as mechanical ventilation and air filtration. It is effective at reducing the transmission of airborne bacterial and viral infections in hospitals, although its effectiveness is limited against fungal spores. When installed, UVGI system must be integrated into the overall heating, ventilation, and air conditioning (HVAC) system.

2.2 In-duct ultraviolet (UV) air disinfection systems are intended to reduce or inactivate airborne microorganisms within ventilation systems. These systems operate by treating the airflow as it passes through ductwork and are designed to achieve a targeted level of air disinfection. System performance and configuration may vary depending on application requirements, with reference to established standards and commonly recognized airborne pathogens.

2.3 The system shall be capable of achieving a high level of microbial inactivation in the air stream, as demonstrated through appropriate performance testing using recognized surrogate microorganisms.

2.4 Thus, in-duct UVGI guidelines emphasize the optimization of UV-C dose by balancing UV lamp intensity with the following factors:

- Dose (irradiance × time)
  The effectiveness of UVGI depends on the UV dose delivered to microorganisms. This is determined by the product of the lamp's irradiance (average intensity) and the exposure time.

- Air velocity
  For testing and commissioning purposes, the air velocity shall be maintained at 500 feet per minute (FPM). In the event that the operational air velocity exceeds this threshold, the quantity of UVGI lamps or the system's radiant power must be increased accordingly to compensate for the reduced exposure time and ensure germicidal effectiveness.

- Relative humidity (RH)
  Effectiveness decreases when RH exceeds 60%, as moisture can create a barrier on airborne particulates, reducing UV penetration.

- Temperature

  Higher duct temperatures may improve UVGI performance, whereas lower temperatures may cause overcooling and reduce lamp output.

- Sterilization sizing calculation
  Calculated based on UVGI lamp length and quantity to meet the predefined target inactivation rate of microorganisms during the pre-installation stage.

3.0 Recommended Areas for UVGI Placement in Hospitals

3.1 The placement of UVGI should be prioritized in core hospital areas where it can provide the greatest impact in preventing airborne transmission.

3.2 Priority areas include airborne isolation rooms, particularly:

- Tuberculosis treatment and monitoring areas
- Treatment and monitoring areas of patients with high-risk respiratory pathogens, such as COVID-19, Influenza, immunocompromised patients such as patients undergoing organ transplant

3.3 Other clinical and support areas where it can be considered but not limited to:

- Emergency Department
- Intensive Care Unit (ICU), Neonatal ICU, High Dependency Ward (HDW), and Special Care Nursery (SCN)
- Burn, Oncology, and Hematology Unit
- Operating Theatres, including Ultraclean Operating Theatres
- Isolation rooms with negative pressure
- Endoscopy suites
- Hemodialysis Units
- Forensic/Mortuary areas
- Pathology labs (BSL-2/clinical): In-duct UVGI can be considered as a supplement but not a substitute to good ventilation, filtration and source controls.

3.4 Hospitals should conduct a structured risk assessment to determine the need for UVGI installation in the future, based on the level of transmission risk within different clinical areas.

4.0 Design and Installation

4.1 Reference shall be made to the Guidelines on Ventilation in the Healthcare Setting to Reduce the Transmission of Respiratory Pathogens (First Edition, Ministry of Health Malaysia and University Malaya Medical Centre) for the types of UVGI available and their respective applications.

4.2 The UVGI lamp can be positioned in either the return, supply and/or exhaust duct.

4.3 Safety interlock switches are to be installed on all access doors where UV intensity may be present. CAUTION LABELS to be installed on these access doors.

5.0 Basic Technical Specifications of UVGI Components

5.1 UVGI specifications depend on the intended application as follows:

i) Application 1: HVAC System Surface Treatment (Coil and Drain Pan Irradiation)

Objectives:

a) To prevent the formation of bacterial biofilm and fungal growth on surface
b) To reduce the frequency of coil cleaning
c) To sustain the coil performance

Table 1: HVAC System Surface Treatment (Coil and Drain Pan Irradiation) Requirement and Specification

Requirement	Specification	Supplementary data
UV-C lamp	200–280 nm	Design Qualification Test evidence from local 3rd party laboratory - UV wavelength - Irradiance at 1 meter - Actual UV lamp output
UVC Proven Efficacy	≥99% inactivation of MS2 bacteriophage surrogate k-value on surface: MS2 bacteriophage (0.0106 - 0.58 m^2/J)*, Serratia marcescens (0.1 – 0.9 m^2/J)**, Bacillus subtilis (0.02 m^2/J - 0.07 m^2/J)**, Cladosporium sphaerospermum (0.0008 – 0.002 m^2/J)** *ASHRAE 241:2023 **ISO 15714-2019	Design Qualification Test evidence from manufacturer Acceptance test based or ASHRAE 185.2 or ISO 15714-2019 or nationally recognized standard
Irradiance at Surface (e.g. Coil/drain pan)	50 W/cm^2 *typical values published by ASHRAE are between 50 – 100W/cm^2 However, there are cases where 200 W/cm^2 irradiance value were applied	Operation Qualification Single point irradiance measured at selected point against proposed configuration

Requirement	Specification	Supplementary data
Relative Humidity	40 - 60% for optimal efficiency	Operation Qualification Actual RH value during operation

ii) Application 2: Airstream treatment/ In-duct system

Objective: To inactivate the microorganisms in the air stream (kill "on-the-fly") for safe air supply.

Table 2 : Airstream treatment/ In-duct system Requirement and Specification

Requirement	Specification	Supplementary data
UV-C lamp	200–280 nm	Design Qualification Test evidence from local 3rd party laboratory - UV wavelength - Irradiance at 1 meter - Actual UV lamp output
UVC Proven Efficacy	≥99% inactivation of MS2 bacteriophage surrogate k-value in air: MS2 bacteriophage (0.0106 - 0.58 m^2/J)*, Serratia marcescens (0.1 – 0.9 m^2/J)**, Bacillus subtilis (0.02 m^2/J – 0.07 m^2/J)** *ASHRAE 241:2023 **ISO 15714-2019	Design Qualification Test evidence from manufacturer. Acceptance test based on ASHRAE 185.1 or ISO 15714-2019 or nationally recognized standard Operation Qualification and Performance Qualification Acceptance test based on ASHRAE Standard 62.1 or ASHRAE Guidelines 11: Field testing of HVAC component
Air Velocity	≤ 500 feet per minute (FPM) for optimal exposure (to allow for a minimum of 0.25 s of UV exposure per pass)	Operation Qualification Actual air velocity data
Relative Humidity	40 - 60% for optimal efficiency	Operation Qualification Actual RH value

Requirement	Specification	Supplementary data
Equivalent Air Changes per hour (eACH)	In between 6 to 15 ACH or any value recommended by CDC guidelines **KKM Guidelines on Ventilation in the Healthcare Setting to Reduce the Transmission of Respiratory Pathogens, 2021* **CDC*	Performance Qualification Acceptance test with actual eACH value

5.2 Validation stages for the installation and its operation can be based on the qualification of each part.

Table 3 : Type of Qualification at Various Stage

Type of qualification	Stage	Evidence
Design Qualification (DQ)	During tender process	DQ Evidence - Vendor-supplied specifications (e.g. wavelength, lamp wattage, total bulb counts, dimension of lamp, etc.) - Test evidence of UV lamp and its system (from KKM recognized laboratory) - Propose UVGI configuration in the system
Installation Qualification (IQ)	During installation	IQ Evidence - System description - Delivery and environment document - Inventory list - Evidence of proper UVGI installation
Operation Qualification (OQ)	During and after installation	OQ Evidence - UVGI Function tests - Acceptance test (Holistic or modular, with fixed parameters & acceptance criteria) **changes/repairs may require requalification.*
Performance Qualification (PQ)	Post installation	PQ Evidence - Verification based on typical UVGI application for hospital setup - On site - Periodic review **changes/repairs may require requalification.*

6.0 Maintenance

6.1 Inspection/Maintenance Task:
Minimum maintenance activity and its frequency of all engineering controls while in use should be stated by vendors for all associated components. Performance and safety of the systems should be maintained and verified as per manufacturer's instructions in accordance with ANSI/IES RP-44-21 and ANSI/IES RP-27.1.22 or equivalent. All the equipment should be adjusted, clean, and replaced as needed.

6.2 Frequency:
Assessment and maintenance of the system for its performance and safety should be conducted quarterly or per manufacturer's recommended interval.

6.3 The power supply ballast box shall be mounted outside the duct. Each ballast box shall incorporate electronic control systems with visual indicators to monitor the operational status of each lamp.

6.4 Warranty coverage shall be provided to ensure the availability of spare parts for the equipment.

7.0 Certification and Verification

7.1 All UVGI installations should undergo performance verification. Physical pre-installation verification should be conducted by Agensi Nuklear Malaysia (ANM) to ensure the UV lamps meet design and safety specifications.

7.2 Performance verification must be carried out in accordance with nationally or internationally recognized standards such as ANSI/ASHRAE or ISO or CDC, which specify microbial testing requirements. This process assesses the system's effectiveness and can be conducted by any laboratory that complies with the ANSI/ASHRAE or ISO standards for microbial testing.

7.3 Verification should confirm that:

- The system delivers the required UV dose under worst-case operational conditions.
- The installation complies with recognized safety exposure limits for healthcare workers, patients, and visitors.

References

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