Designing Healthcare Facilities to Maximize the Effectiveness of UV Disinfection

Using computer simulations to better understand UV-C distribution in hospital rooms

1. Problem Statement

Portable UV disinfection devices are gaining acceptance in healthcare facilities. However, for the following reasons, the effectiveness of these devices may be sub-optimal:

- Poor placement of the device in the room.
- Non-ideal treatment time – either longer than necessary or too short to be effective.
- Insufficient UV-C dose on some surfaces due to the design of the room - size, shape, materials, etc.

Objectives of this project

- Understand how UV-C light is distributed in a room, especially to shadowed surfaces, as a function of device location and the design/layout of the room.
- Evaluate a simulation tool based on methods used in computer graphics to predict UV-C intensity throughout any 3-dimensional space.
- Create a set of design rules and operating guidelines that allow healthcare facilities to maximize the effectiveness of their UV-C device. Ultimately, create a tool that can be used by designers of new facilities to optimize patient rooms for UV-C disinfection.

2. Approach

1. A 3D Computer-Aided Design (CAD) model of the room to be studied was created.

Often these models already exist as they are used by designers and facilities personnel. Otherwise a new model can be easily created based on measurements of the room's dimensions. 3D models of the objects in the room (patient bed, tables, etc.) are also included.

2. A model of the UV-C device of interest was added to the model to serve as the light source.

3. Software which uses physics-based illumination algorithms was used to simulate the distribution of UV-C light based on the 3D model and known properties of the surfaces in the room.

4. Using radiometric sensors, the UV-C intensity was measured at numerous locations throughout the room and compared to those values predicted by the model.

5. Once validated, the simulation tool can be used to study

  1. Device location: What is the optimal location(s) of the device?
  2. Treatment time: How much time is needed to deliver an effective dose?
  3. Room design: How do size, shape, material selection influence UV-C intensity?

3. Initial Study

This methodology was used to simulate a standard hospital room at UNC which was also the site of our previous UV-C disinfection research. To validate the method, a series of measurements of UV-C irradiance were taken using a commercially-available portable UV-C disinfection system.

4. Detailed Validation

Additional validation experiments were conducted at a second facility. This study consisted of measuring UV-C intensity at 20 locations throughout the room, with the device positioned in 5 separate locations.

5. Conclusions

- A novel simulation tool was evaluated to determine how effectively it can model the UV-C intensity on various surfaces of a patient room.
- The results of the simulation were validated experimentally using radiometric sensors.
- This methodology can be used to optimize the location of a device in a room and to determine the treatment times necessary to achieve a target dose.
- In the future, this approach could help designers maximize the effectiveness of UV-C disinfection for new or remodeled facilities.

Acknowledgements

The authors acknowledge Tru-D, LLC and Ultraviolet Devices, Inc., who loaned the devices used in this study, and Lumacopt, Inc., who provided the UV-C reflective coating.

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