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:**

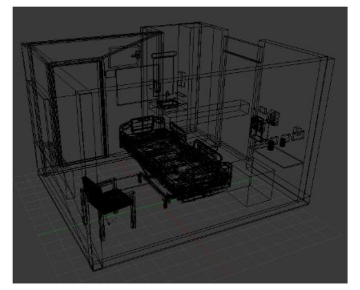
- Poor placement of the device in the room.
- Non-ideal treatment time – either longer than necessary or too short to be effective.
- Insufficient UV-C dose on some surfaces due to the design of the room- size, shape, materials, etc.

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.

ILT1700 from International Light Technologies.
Used with the SED240/NS254/W detector.

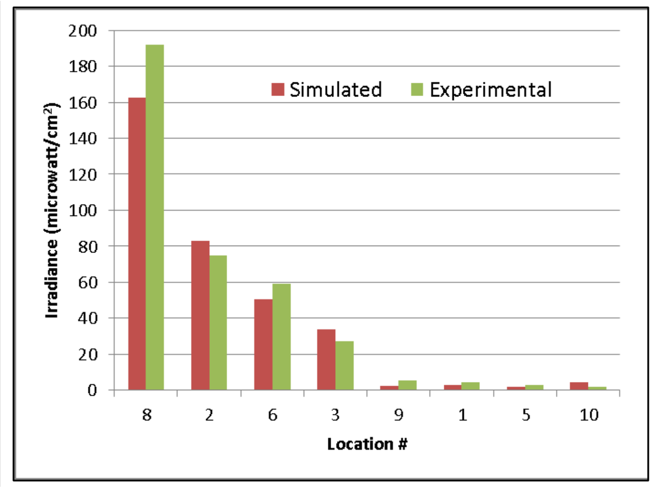
5. Once validated, the simulation tool can be used to study
   1. **Device location**- What is the optimal location(s) of the device?
   2. **Treatment time**- How much time is needed to deliver an effective dose?
   3. **Room design**- How do size, shape, material selection influence UV-C intensity?

3. Initial Study

UNC Memorial Hospital
Chapel Hill, NC
Site of initial studies

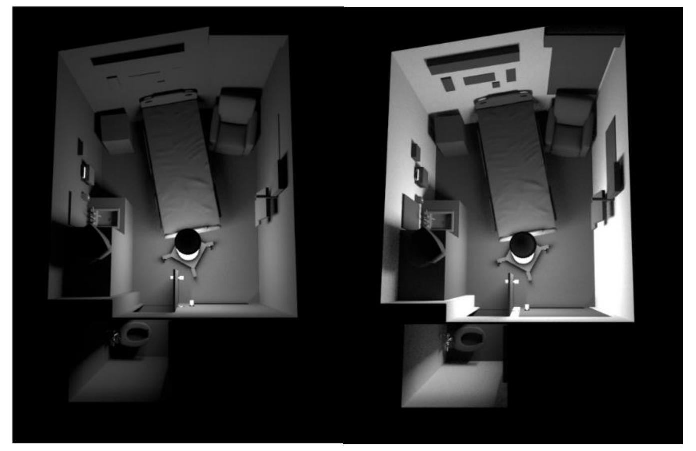
This methodology was used to simulate a standard hospital room at UNC which was also the site of our previous UV-C disinfection research[1]. To validate the method, a series of measurements of UV-C irradiance were taken using a commercially-available portable UV-C disinfection system.

A model of the room indicating the locations where UVC intensity was measured.



A comparison of UV-C intensity predicted by the model with values measured experimentally.

Effect of Wall Reflectivity



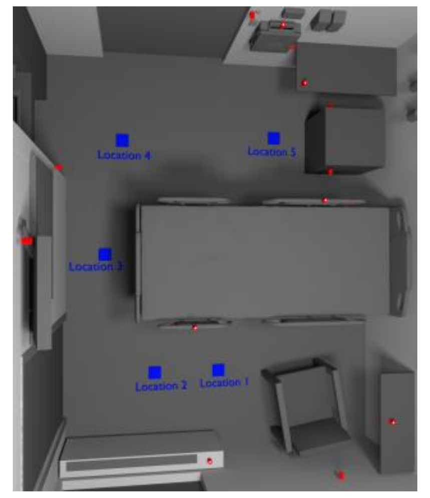
On the left, a model of the room with UV-C absorbing walls. On the right, the same room with walls reflecting over 50% of the UV-C light.

1. Rutala, W.A., Gergen, M.F., Tande, B.M., Weber, D.J. Rapid hospital room decontamination using ultraviolet (UV) light with a nanostructured UV-reflective wall coating (2013) Infection Control and Hospital Epidemiology, 34 (5 SPL), pp. 527-529.

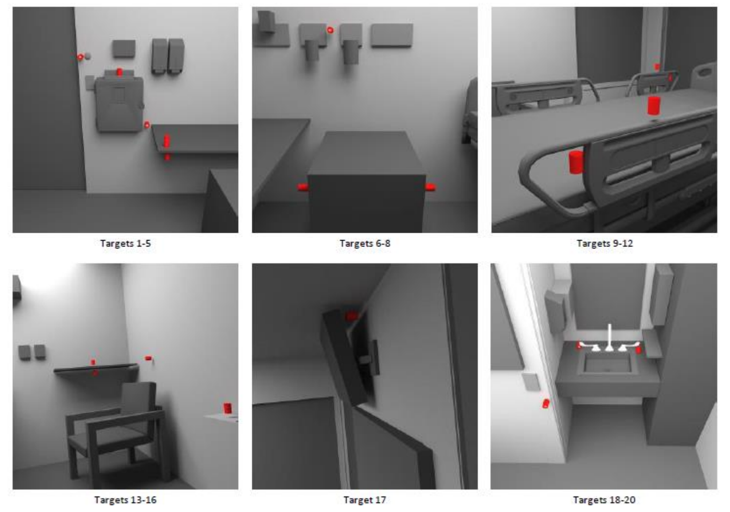
4. Detailed Validation

Sanford Hospital – South University
Fargo, ND
Site of detailed validation studies

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.

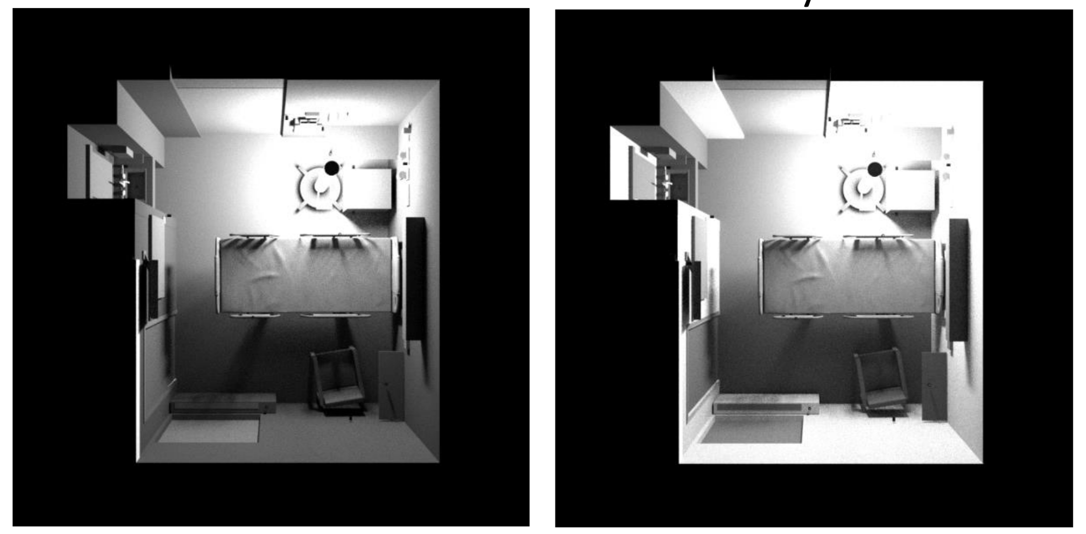


Device Locations

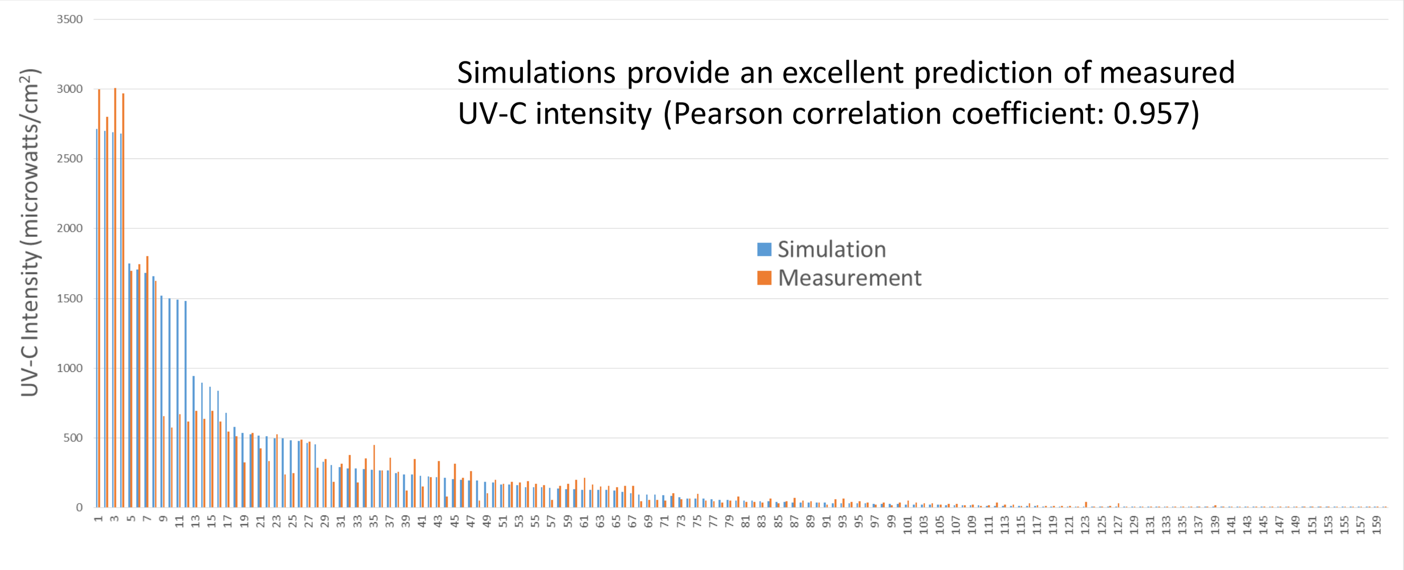


Detailed locations of sensors.

Effect of Wall Reflectivity



UV-C absorbing walls (left) compared to UV-C reflecting walls (right) with the device in location #5. Simulations confirmed previously reported results that the reflectivity of the walls has a significant effect on the intensity of UV-C on surfaces not in the line-of-sight of the device.



The data shown above includes locations 1 and 5 with four levels of wall UV reflectivity.

Authors

Brian M. Tande, PhD
Associate Professor of Chemical Engineering,
University of North Dakota, Grand Forks, ND
brian.tande@engr.und.edu

William Rutala, MS, MPH, PhD, CIC
Director, Hospital Epidemiology; Professor,
UNC School of Medicine, Chapel Hill, NC

Dubert M. Guerrero, MD
Chair, Infection Prevention and Control
Sanford Health
UND School of Medicine and Health Sciences
Fargo, ND

Paul Carson, MD
Director of Infection Prevention
Sanford Health, Fargo, ND
Professor, MPH Program
North Dakota State University, Fargo, ND

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.

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