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### **NIOSH-Funded Study Simulates Hospital Room to Test UV System for Employee TB Protection**

It looks very much like a hospital room. Under a hanging IV drip, a patient sits quietly. In reality, the "patient" is a mannequin and the room is a special laboratory chamber in the engineering department at the University of Colorado, Boulder.

Here, with funding from the National Institute for Occupational Safety and Health (NIOSH), researchers conducted a six-year study whose results will help NIOSH and others in ongoing efforts to protect employees in health-care and other industries from job-related tuberculosis infection. NIOSH, a part of the U.S. Centers for Disease Control and Prevention (CDC), performs research and makes recommendations to prevent occupational illnesses, injuries, and deaths.

Recreating a hospital setting, the NIOSH-funded study investigated the effectiveness of ultraviolet light as a key component of controls used to reduce health-care employees' exposure to TB. Although the NIOSH-sponsored study used a "hospital" room as a model, the findings are also applicable to other workplaces such as correctional facilities, homeless shelters, residential care facilities, and nursing homes.

TB usually is spread from person to person as a direct result of breathing air contaminated with airborne TB bacteria released by an infectious person, usually through coughing or sneezing. Once airborne in a room, TB bacteria may remain airborne for hours due to their small size. Although TB cases have declined in recent years after resurgence in the late 1980s, the disease still poses an occupational risk to healthcare personnel.

To reduce the potential for TB transmission in healthcare facilities, CDC guidelines recommend that a number of controls be used. Currently, many facilities use ultraviolet germicidal irradiation, referred to as UVGI, as an auxiliary control measure when their ventilation systems in hospital rooms are unable to provide air exchange rates recommended by CDC. In addition, UVGI is used for air disinfection in other areas such as waiting rooms. The UVGI lamps are suspended from or located near the ceiling, or are placed in ventilation ducts.

The genesis for the study occurred in 1992, when NIOSH

recognized that it did not have adequate information for making recommendations involving the use of UVGI as an engineering control for preventing TB transmission. Although it was known that UV light renders bacteria inactive, thereby limiting their ability to grow and multiply when inhaled, most of the experimental data that led to the development of UVGI systems were decades old. UVGI systems apply this principle to controlling TB bacteria. However, most of the experimental data that led to the development of UVGI systems are many decades old. Aside from anecdotal observations, little subsequent information existed about the actual performance of these systems in hospital rooms.

NIOSH was asked to conduct research on the in-room distribution of airborne TB bacteria, and the effects of room air circulation, ventilation, and humidity on the efficacy of UVGI to kill or inactivate airborne TB bacteria. Results of the research would give employers, employees, and facilities managers better data for answering key questions: Is a combination of ventilation and UVGI reliable for controlling TB transmission in a given facility? Would an employer need to invest in potentially more costly, time-consuming upgrades to the ventilation system to be safe? Is UV irradiation effective only above a specific intensity?

"To help fill those gaps, the NIOSH-funded studies were conducted in a physically realistic setting under controlled conditions," said NIOSH Director John Howard, M.D. "As a result, we have a high level of confidence that the studies will provide a reliable basis for assessing the real-life performance of UVGI systems. In conjunction with other information, the findings will help NIOSH develop practical, effective recommendations for UVGI use in hospitals. They will also help employers and employees achieve the best results in their individual workplaces."

In the replicated hospital setting, the NIOSH-funded study investigated the effectiveness of UVGI to kill or inactivate two different TB-like bacteria that were released into the room air. The study looked at environmental factors that could either enhance or diminish the effectiveness of UVGI, such as high versus low levels of relative humidity, high versus moderate ventilation in the room, and air-mixing effects, as well as the actual UV levels coming from the UVGI lamps. The researchers also examined UVGI effectiveness when the lamps were placed at different locations within the room.

The researchers used newly designed, commercially available UVGI fixtures consisting of five lamps. Four of the lamps were mounted in each corner of the room. The fifth was mounted from the center of the ceiling.

The mannequin in the test chamber (called "Manny" by the staff) was heated to approximate human body temperature. Heat from the body is one of the subtle factors that influence the movement of air near a person inside a room, affecting the

amount of tiny particles such as bacteria that come into the person's breathing zone.

Findings from the studies included these:

- Increasing the irradiance level of the UVGI lamps increased the effectiveness of inactivating the TB-like bacteria. The relationship was linear up to a certain level. Further increasing the irradiance above this high level resulted in little increase in the inactivation of the airborne TB-like bacteria.
- High relative humidity above 75 percent lowered the effectiveness of UVGI to inactivate the TB-like bacteria.
- Mostly, ventilation and UVGI worked together to remove or inactivate the airborne TB-like bacteria at a greater rate than either system working alone. Low to moderate levels of ventilation in the room did not negatively affect UVGI effectiveness.
- The study clearly demonstrated that the air in a room must be mixed for UVGI to effectively inactivate the TB-like bacteria. When warm air entered the room via a duct close to the ceiling (which may occur in the winter when the heating system is turned on), the warm air simply "rested" on the much cooler air below and the efficacy of the UVGI system was dramatically diminished. No mixing fans were on during this experiment but moderate ventilation was present.
- The findings of the NIOSH-funded study provided new data to help scientists in future research projects to evaluate a novel three-dimensional measurement approach to measuring UV radiation.

NIOSH is assessing the findings to help develop up-to-date recommendations on the ability of UVGI systems to help protect health-care employees from TB. The findings are being evaluated for inclusion in subsequent updates to the CDC guidelines on controlling TB transmission. They are also being used to develop a comprehensive NIOSH technical report on the application of UVGI systems.

Researchers from the University of Colorado and colleagues have reported on the studies in several technical articles, the most recent of which is "Efficacy of Ultraviolet Germicidal Irradiation of Upper-Room Air in Inactivating Airborne Bacterial Spores and Mycobacteria in Full Scale Studies" by Xu et al., in the journal *Atmospheric Environment*, Vol. 37, 405-419 (2003).

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