Ultraviolet Germicidal Irradiation for HVAC Systems

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Overview

Ultraviolet germicidal irradiation (UVGI) has been utilized in HVAC systems for a number of years in an attempt to reduce airborne microbial contamination. The fundamental concept of operation is that the UVGI disinfects the air as it passes through the HVAC system—whether in the return ducts or by the coils, resulting in the return of "clean" air to the room. Some manufacturers additionally claim that by "cleaning" the air, the UVGI systems also impact surface contamination as some contaminants in the air can settle out of the air and onto surfaces.

Microbial Reduction

Ultraviolet light's ability to deactivate pathogens is highly dependent on both the specific pathogen and the conditions under which the UVGI is used. Some studies have shown UVGI to be effective in reducing airborne microorganisms, though the National Air Duct Cleaners Association (NADCA) cautions that "organisms vary dramatically in how quickly they deactivate from UVGI…[and] some bacteria and mold spores are resistant to UVGI."[1] NADCA also points to a paucity of studies evaluating UVGI in commercial HVAC systems, citing only one study that found airborne bacteria was reduced by just 25-30 percent when used in an office system HVAC.[1] Further, the Air-Conditioning and Refrigeration Technology Institute (ARTI), the global association of the manufacturers of HVAC and water heating equipment, advises to "Be extremely cautious regarding claims about UVGI systems' high levels of inactivation of pathogenic bioaerosols…. It would be irresponsible to claim a high inactivation rate for a pathogenic bioaerosol without substantial testing. Even with substantial testing, design failures may occur." [2]

A Point in Time Intervention

A limiting factor for UVGI is that it exerts its effect only on the air that passes by the lamps. As soon as that treated air is returned to the room, it is subject to the inevitable recontamination that occurs in any occupied space, whether it be from an individual sneezing or shedding skin squames. And while that contaminated air will ultimately be recirculated through the HVAC system and exposed to the UVGI, the rate of disinfection is very dependent on the number of air changes, or times per hour that the room's air is replaced with "new" outside air, provided by the HVAC system—a number that can vary widely both within a facility and between types of facilities. In most commercial buildings, this number is usually 4, which translates into ample opportunity for re-contaminated air to present a risk to a room's occupant before the air is recirculated and retreated.

Efficacy as a Function of Multiple Parameters

NADCA states that UVGI's efficacy is dependent on a number of factors, including:[1]

1. Intensity of lamp(s).
2. Length of time of exposure.

3. An organism's ability to withstand UVGI.
4. The presence of particulates that may protect the organism from exposure by providing shadows or a shielding effect.
5. Increased humidity which may protect the organism.
6. Location of the UVC lamp(s).
7. Number of lamps.
8. Reflectivity of surrounding surfaces.

These parameters require careful consideration of installation and maintenance procedures, including the number and placement of bulbs as improper placement can result in not only safety hazards but reduced efficacy.[1]

Safety

Because the UVGI units are housed inside the HVAC system, safety is generally not a concern for room occupants; however, UVGI units that produce ultraviolet light at wavelengths below 185 nanometers do generate ozone which is damaging to lungs.[3-4] This is of particular concern for UVGI systems with natural or synthetic quartz materials.[3] Additionally, because UV-C is photo carcinogenic, only highly trained technicians can handle installation and maintenance.[1,3,5] This includes bulb replacement which must be treated as hazardous waste.[5] Monitoring of HVAC system components may be necessary as both the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) and International Society for Pharmaceutical Engineering (ISPE) caution that UVGI can cause rapid and severe degradation to a variety of components including gasket foams, insulation, sealants, cables, and certain filter media.[5] Polyester and lofted fiberglass filters are especially vulnerable to degradation from UV-C exposure.[3] Lofted fiberglass can disintegrate into loose fibers that become airborne in the ductwork, causing eye irritation.[3]

Dry Hydrogen Peroxide for Air and Surface Microbial Reduction

Hydrogen peroxide has long been established as a molecule that demonstrates potent antimicrobial activity against a broad range of pathogens, including bacteria, viruses, and spore-forming organisms.[6] Dry hydrogen peroxide (DHP) delivers hydrogen peroxide in a novel form—as a true, non-aqueous gas. Synexis® technology utilizes oxygen and humidity in the ambient air of a room to safely and naturally produce DHP molecules which can then diffuse throughout a treated space, actively reducing microbial contamination in the air and on surfaces.

Microbial Reduction

DHP has a broad spectrum of activity against microorganisms, including clinically relevant pathogens associated with infectious disease.[6-7] DHP is drawn to vulnerable polar functional groups on microbes, where it then denatures the functional group, impairing the infectivity of viruses and causing rifts to form in membrane or cell walls, resulting in microbial death. DHP has been utilized to reduce microbial contamination in a wide range of settings including food processing facilities, office complexes, the hospitality industry, and the maritime industry. It has also been shown to significantly reduce microbial contamination in air and on surfaces in the healthcare setting for which the risk of environmental transmission is arguably critical.[7]

A Continuous Intervention

The greatest benefits of DHP in the environment are its ability to continuously reduce microbial contamination 24/7/365 and its ability to act on microbes both in the air and on surfaces. Rather than treating a certain volume of air in a point of time, DHP technology is continuously producing DHP molecules that spread out into every corner of a room by means of convective air flows and simple diffusion. In fact, every cubic centimeter of air in a room treated with DHP will contain 125 to 625 billion molecules of DHP, each of which can diffuse into the remotest of recesses in a room—from ceiling to floor---where it can target a microbe in the air or on a surface. This means that, unlike UVGI, DHP can actively address the inevitable ongoing recontamination of an occupied space.

A Simple Solution

DHP devices can be installed in HVAC systems or used as standalone units, requiring only a standard 120V/50-60Hz outlet. Because DHP is a near ideal gas, it can diffuse anywhere and is not impeded by shadowing, shielding, or reflectivity parameters.

Safety

DHP is a safe and natural gas,[7] utilized at a concentration well below the safety threshold established by the Occupational Safety and Health Administration for hydrogen peroxide.[8] In fact, the concentration of hydrogen peroxide achieved by DHP systems is lower than the concentration of hydrogen peroxide naturally maintained by enzymes in the human respiratory tract.[9] DHP also interacts safely with materials in the environment with no risk of degradation and, because there are no toxic components, there are no safety risks for device handling.

References: 1. National Air Duct Cleaners Association. NADCA White Paper on Ultraviolet Lighting Applications in HVAC Systems. https://nadca.com/sites/default/files/images/2016/nadca_white_paper_on_uv_lighting_applications.pdf **2.** VanOsdell, D. and K, Foarde. 2002. Defining the effectiveness of UV lamps installed in circulating air ductwork. Final Report, Air-Conditioning and Refrigeration Technology Institute 21- CR Project 610-40030. **3.** International Society for Pharmaceutical Engineering. Air disinfection—UVGI disadvantages. **4.** Environmental Protection Agency. Indoor air quality: ozone generators that are sold as air cleaners. https://www.epa.gov/indoor-air-quality-iaq/ozone-generators-are-sold-air-cleaners **5.** American Society of Heating, Refrigerating, and Air-Conditioning Engineers. 2016 ASHRAE Handbook, Chapter 17: Ultraviolet Lamp Systems. https://www.ashrae.org/file%20library/technical%20resources/covid-19/si_s16_ch17.pdf **6.** Falagas ME, Thomaidis PC, Kotsanis IK, Sgouros K, Samonis G, Karageorgopoulos DE. Airborne hydrogen peroxide for disinfection of the hospital environment and infection control: a systematic review. J Hosp Infect 2011; 78: 171-77. **7.** Ramirez M, Matheu L, Gomez M, Chang A, Ferrolino J, Mack R, Antillon-Klussmann F, Melgar M. Effectiveness of dry hydrogen peroxide on reducing environmental microbial bioburden risk in a pediatric oncology intensive care unit. Am J Infect Control 2020. https://doi.org/10.1016/j.ajic.2020.08.026 **8.** Centers for Disease Control and Prevention. Toxic substances portal-hydrogen peroxide. Available from: https://www.atsdr.cdc.gov/mmg/mmg.asp?id=304&tid=55 **9.** El-Chemaly S, Salathe M, Baier S, Conner GE, Forteza R. Hydrogen peroxide–scavenging properties of normal human airway secretions. Am J Respir Crit Care Med 2003; 167 (3): 425-430.