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technical BRIEF

Biological Inactivation Efficiency of HVAC In-Duct Ultraviolet Light Devices

Background

One potential method of terrorism is the intentional introduction of biological warfare agents (BWAs) into the heating, ventilation, and air-conditioning (HVAC) systems of target structures in order to distribute pathogenic organisms. The introduction of BWAs into a building's HVAC system could harm many people, depending on the size of the building. This potential threat indicates a need to identify and test devices that could be used to destroy BWAs as they move through a building's air handling system.

U.S. EPA's Homeland Security Research Program (HSRP) develops products based on scientific research and technology evaluations. Our products and expertise are widely used in preventing, preparing for, and recovering from public health and environmental emergencies that arise from terrorist attacks. Our research and products address biological, radiological, or chemical contaminants that could affect indoor areas, outdoor areas, or water infrastructure. HSRP provides these products, technical assistance, and expertise to support EPA's roles and responsibilities under the National Response Framework, statutory requirements, and Homeland Security Presidential Directives.

One category of technology that may meet this need uses a configuration of ultraviolet (UV) lights that can be deployed inside the building's air ducts. Short-wave ultraviolet radiation in the "C" band (UV-C) has wavelengths of 200 to 280 nanometers. This type of ultraviolet germicidal irradiation (UVGI) has been used for over 100 years to inactivate microorganisms.

Early research in this area was directed at the control of highly infectious pathogens in medical facilities. UVC was shown to be effective at killing *Mycobacterium tuberculosis*, the causative agent of tuberculosis, and other bacteria including mycoplasma, as well as viruses and fungi.

In testing and evaluating homeland security related technologies, EPA provides unbiased, third-party performance information that can supplement vendor-generated information. This information is useful to decision makers in purchasing and applying the tested technologies. EPA's evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and high quality are generated.

Bioaerosol Inactivation Devices

EPA has conducted evaluations on the ability of the following devices to inactivate bioaerosols inside HVAC systems:

In-Duct System (Abracair, LLC)

ACP-24/HO-4 and **AeroLogic Model AD24-4** (American Ultraviolet Corporation)

Bio-Fighter 4Xtreme, Model 21 (Dust Free)

ADPL-60-8 (Lumalier)

BioProtector BP114i (Novatron, Inc.)

UV Bio-Wall 50 Outwardly Projecting Air Purifier (Sanuvox Technologies Inc.)

Model SE1 VO with GTS 24 Emitter (Steril-Aire, Inc.)

Altru-V V-Flex (UltraViolet Devices, Inc.)

Test Design

The nine UVC devices evaluated are designed to be mounted inside an HVAC system to inactivate bioaerosols as they migrate through the air handling system. The devices were tested separately in a laboratory-based test duct with state-of-the-art aerosol and microbiological generation and measurement equipment.

The testing was conducted using one spore-forming bacteria, *Bacillus atrophaeus* (*B. atrophaeus*), one vegetative bacteria, *Serratia marcescens* (*S. marcescens*), and one virus, *Escherichia coli* phage MS2 (MS2 bacteriophage). The structural characteristics and susceptibility to UVC inactivation make these reasonable surrogates for BWAs.

Each device was tested three times, once for each test microorganism. During testing, the test microorganisms were generated and introduced into the test duct upstream from the installed device. As air flowed through the duct, the bioaerosols passed through the device where they were exposed to UVC.

Airborne Inactivation Efficiency

The ability of each device to destroy the bioaerosols as they passed through the test air duct is reported as the *airborne inactivation efficiency*. The greater this percentage, the more effective was the UVC device.

To determine the efficiency, samples of the bioaerosols were taken from the duct upstream and downstream from the device. These samples were cultured, and the number of bacterial colony forming units (CFUs) or viral plaque forming units (PFUs) were counted.

The efficiency of the device was then calculated as a percentage from the ratio of the upstream to the downstream counts. This number is the percentage of microorganisms that did not survive UVC exposure corrected for the number of microorganisms that died from the rigors of traveling through the duct without being irradiated and for the number of microorganisms that did not completely pass through the duct due to deposition on the duct walls.

The correction factor used for the inactivation efficiency was determined by conducting a test for each microorganism without the UVC source in the device turned on. All nine devices were tested in this fashion.

Performance and Results

All nine UVC devices were ≥ 99 percent efficient at inactivating the vegetative bacteria.

- Three UVC devices were ≥ 93 percent effective for all three microorganisms.
- Five devices had ≤ 46 percent efficiency for inactivation of the spore form of the bacteria
- Two devices had ≤ 46 percent efficiency in destroying the virus.

The following table shows the airborne inactivation efficiencies of each device for each test organism.

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UVC Device	Lamps	Measured Dosage [a] (µW-s/cm2)	Power (w)	Airborne Inactivation Efficiencies (%)		
				Spore form of bacteria (*B. atrophaeus*)	Vegetative form of bacteria (*S. marcescens*)	Virus (MS2 bacteriophage)
Abracair, LLC	12	447 (376 – 550)	6480 – 6720	6.9	99.8	59
American Ultraviolet Corporation ACP-24/HO-4	4	582 (490 – 716)	169	9	≥99.96 [b]	75
Atlantic Ultraviolet Corporation AeroLogic Model AD24-4	4	295 (249 – 363)	94	0	≥99.8 [b]	46
Dust Free Bio-Fighter 4Xtreme, Model 21	1	247 (208 – 304)	53	4	99	39
Lumalier ADPL-60-8	8	3180 (2678 – 3914)	568	40	≥99.98 [b]	82
Novatron, Inc. BioProtector BP114i	6	> 42,342 (35,656 – 52,113)	748	≥99.9[b]	≥99.94[b]	≥99.9 [b]
Sanuvox Technologies Inc. UV Bio-Wall 50 Outwardly Projecting Air Purifier	5	16,439 (13,843 – 20,223)	944	93	≥99.97 [b]	99
Steril-Aire, Inc. Model SE1 VO with GTS 24 Emitter	6	19,826 (16,696 – 24,401)	421	96	≥99.96 [b]	99
UltraViolet Devices, Inc. Altru-V V-Flex	12	7,651 (6,443 – 9,416)	755	71	≥99.98 [b]	98

[a] The systems were run at 0.93 m3/sec (1970 CFM), except for the Novatron device, which was run at 0.14 m3/sec (300 CFM).
[b] These values are based on the upper 95 percent confidence limit for the mean downstream count of the test organism. There were no downstream counts measured.

In addition to airborne inactivation efficiency, other attributes of each device were assessed. These included dosage measurements, power consumption, single measurement intensity, pressure drop across the device, and air temperature rise through the device. Homeland security research studies using ultraviolet light are listed at this link.

For more information, visit the EPA Web site at www.epa.gov/nhsrc.

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