ESP-DLux® Ultraviolet Air Cleaner Performance Analysis

By Wladyslaw Kowalski, June 5, 2025

Executive Summary

The ESP-DLux® is a unique application ultraviolet (UV) light technology that facilitates the use of UV in diverse environments to both clean the air and disinfect surfaces in indoor environments. This shutter operated system is intended to operate in unoccupied rooms to disinfect the air and surfaces. The system has a relatively high Luminaire efficiency compared to typical Upper Room UV units. The disinfection of room air is rapid and high equivalent air change rates (EACs) are achieved against a variety of indicator pathogens. The internal airflow component delivers a Clean Air Delivery Rate of approximately 50 cfm which represents 2.6 ACH equivalent air changes in the model test room volume of 1152 ft^3, based on the test pathogen MRSA. The In-room UV exposure component performs as an Upper Room UV system and produces an equivalent of 53 ACH equivalent in the model test room with MRSA as the test pathogen. The projected EACs for all test pathogens greatly exceed the proposed recommendation of 6 EAC per ASHRAE 241P. During operation the system produces an average irradiance in the room of 0.157 W/m^2, which will be maintained for as long as the system operates, producing continuous disinfection of air and surfaces. The disinfection times for a variety of airborne pathogens are computed under various operating conditions. The system is shown to have a very high UV output (0.295 W/m^2) when the enclosure is removed and rooms are exposed to naked lamps.

About the Author

Dr. Kowalski holds a BS in Mechanical Engineering, Illinois Institute of Technology, and an MS and PhD in Architectural Engineering from The Pennsylvania State University. He has authored numerous articles on the topic of airborne disease control technologies including the widely cited Ultraviolet Germicidal Irradiation Handbook. He was previously chairman of the Air Treatment Group of the International Ultraviolet Association (IUVA) and works on UV standards in collaboration with ASHRAE, ASTM, and other professional societies. He has authored one standard, ASTM E3286-21 and two UV technology patents. Dr. Kowalski has previously assisted the US Army, the DoD, and the NYPD during the post-911 anthrax attacks and designed a UV system for NASA that is aboard the ISS. He currently serves on the IUVA Education Committee, the IUVA Industry Working Group, and the Underwriters Laboratories UL 8800 Photobiological Safety Committee. See Appendix C for Dr. Kowalski's complete curriculum vitae (CV).

Introduction and Background

ASHRAE Standard 241P, Control of Infectious Aerosols, establishes minimum requirements for HVAC-related technologies in buildings to reduce the risk of transmission of airborne diseases in homes, offices, schools, hospitals during periods of high risk. The standard provides minimum requirements for Equivalent Air Changes (EACs) due to the combined effect of ventilation, filtration, and air cleaning for use during Infection Risk Mitigation Mode. The standard addresses characterization of filter and air cleaner effectiveness.

The relevance to the UV industry is that a target value for EAC will be set for indoor environments and that target EAC will establish a design basis for UV implementations. Many previously published UV studies indicate that Upper Room and In-room UV air disinfection systems can produce very high EACs, relative to some tested species. Analysis indicates that outside airflow combined with UV can produce high EACs but that UV is considerably more effective and fast-acting than the typical outside airflow rates being discussed by ASHRAE (i.e. 6 ACH or EAC). Therefore, increasing outside air is not the answer and reliance on air cleaning technology will be more effective. Analysis also suggests that low levels of outside air will improve overall UV system disinfection efficiency.

The cost of using outside air is high and may entail energy costs in Winter and Summer. The use of UV is considerably more economical in terms of $/EAC. Both UVC and Far-UV can be implemented with cost savings to facilities.

The industry should embrace ASHRAE 241P in that it is the only document which gives specific, workable guidelines. The end result of ASHRAE 241P will be the assignment of EACs to all UV systems as a basis for comparison, and for performing energy and economic analysis. This will be a positive development for the UV industry.

The performance standards set by ASHRAE will depend on performance test results. For Upper Room UV and In-Room Far-UV devices several model room test protocols are available and examples are presented in Table 1. Both ASTM E3273 and ASHRAE 185.3 are appropriate for testing Upper Room systems and these require measurement of the removal efficiency (disinfection efficiency) and the airflow. Based on these results the EAC can be computed depending on whether the test was a Transient of Steady State test.

Table 1: In-Room UV Air Disinfection & Filtration Performance Tests and Standards

Subject	Org	Standard No.	Test Setup	Measured Parameters	Reference
UV Air Cleaners	AHAM	AC-5	Model Room	Removal efficiency & airflow	AHAM 2022
UV Air Cleaners	ASTM	E3273-1	Model Room	Removal efficiency & airflow	ASTM 2021
UV Air Cleaners	ASHRAE	185.3P	Model Room	Removal efficiency & airflow	ASHRAE 2023
Air cleaners	ASHRAE	185.5	Model Room	Removal efficiency & airflow	ASHRAE 2022

Summary of System Performance

Analysis of the equivalent air change (EAC) rate of the ESP-Dlux shows superb performance when compared against the guideline recommendations, easily exceeding the proposed 6 ACH equivalent. Compared with CDC guidelines for Upper Room UV systems, the system provides over twice the recommended input power for a patient-sized room (200 ft^2) and delivers the irradiance more efficiently than a typical Upper Room unit. The ESP-DLux® system specifications and positioning of the unit in the model room are shown in Table 2. The Luminaire Efficiency was estimated to be 24% as explained later.

Table 2: System Specifications

Lamp Model	ozone free	G30T5LU
Input Power	32	W
UV Power	11	W
Length	353	mm
Base	B36	
OD	15	mm
Total UV Power	22	W

Luminaire Efficiency of the Enclosure

The enclosure is modeled as a rectangular box with an outlet area equivalent to the rectangular outlet area just above the lamps. The equivalent rectangular dimensions are shown in Table 3. The internal spherical irradiance was modeled with a detailed finite-element UV lamp model and this irradiance proved to be 72.9 W/m^2. The spherical irradiance defines the UV exposure of spherical microbes and can differ from cosine-corrected photosensor measurements which measure irradiance on a flat plane. The irradiance across the open hole area where the light exits was divided by the total irradiance exiting the four lamps, and this ratio represents the luminaire efficiency (LE), or what fraction of light exits the luminaire. The ratio proved to be 0.24 or a **24% Luminaire Efficiency**, which is much higher than typical Upper Room UV systems that measure out at about 10%-15% LE. UV Safety testing performed by Intertek Labs verified the lower room irradiance levels did not exceed NIOSH Threshold Limit Values (TLVs) at the fan outlets.

Establishing the LE allows for the system to be more accurately modeled and the first component to be modeled is the internal UV air cleaning component consisting of fans moving the air through the enclosure at 50 cfm. The exposure times of 0.87 seconds produces a UV dose of 63 J/m^2. By itself, the 50 cfm airflow component produces in excess of 99% kill rate against the test microbes and so the clean air delivery rate (CADR) is approximately 50 cfm and the EAC computes to be 2.6 ACH equivalent.

Table 3: Enclosure Model Specifications

Airflow	50	cfm
	1.41585	m3/min
Exposure Time	0.87	sec
W	17.70	cm
H	66.00	cm
L	17.70	cm
Area Side	52.27	in2
Volume	1150.04	in3
	0.02	m3
Square side equivalent	7.23	in
Open Hole Area	0.06	m2
Surface Area	0.53	m2
Luminaire Efficiency	0.24	
Average Irradiance	72.9	W/m2
UV Dose	63.423	J/m2
URV Rating	17	
EAC	2.60	1/hr

The Box Model is an evaluation of the irradiance inside the Dlux enclosure. The irradiance at the box outlet was evaluated to confirm that the luminaire efficiency was at least 0.24. The average irradiance inside the box was found to be 83 W/m^2 with an assumed internal reflectivity of 0%.

The Room Model

The model room for testing is 12'x12'x8' or 1152 ft^3 (32.6 m^3). This is an appropriate volume for the room test and is larger than the 21 m^3 model room used by ASHRAE, the 24 m^3 model room used by ASTM, and the 28.5 m^3 model room used by AHAM. The CDC TB guideline uses a 200 ft^2 room with an 8' ceiling for a total volume of 45.3 m^3. This 32.6 m^3 model room sits appropriately within the range of model test rooms.

The unit is located at 7 ft. height in the 12'x12'x8' model room which has dimensions as shown in Table 4. The reflectivity of the room surfaces is assumed to be zero for the baseline condition. The reflectivity is assumed to be 25% in a second analysis for comparison. A third analysis is performed to evaluate the effects of removing the enclosure completely and allowing naked UV lamps to operate on the room air and surfaces.

Table 4: Room Model Dimensions

Width	12	ft
	365.76	cm
Length	12	ft
	365.76	cm
Height	8	ft
	243.84	cm
Volume	32.621007	m3
Unit Location		
y	7	ft
	213.36	cm
x	6	ft
	182.5	cm
z	0	ft
	0	cm

Table 5 shows the Time in minutes for the indicated kill rates (99% & 99.9%) for pathogens where it can be seen that 99.9% disinfection of MRSA would occur within 8 minutes. Table 6 shows the time to kill 99% & 99.9% of the indicated pathogen species when 25% room surface reflectivity is assumed and this shows further reduction in disinfection times. Tables 7 shows the results for naked lamps and the time to kill the pathogens is significantly reduced over the baseline.

Table 5: Time (Minutes) for % Kill Rate - 24% Luminaire Efficiency

UV Irradiance, W/m2		0.157	
% Kill Rate	**UV k, m2/J**	**99%**	**99.90%**
Coronavirus (SARS)	0.35	1.40	2.10
MRSA	0.0929	5.26	7.89
Pseudomonas aeruginosa	0.0751	6.51	9.76
Clostridium difficile spores	0.01215	40.24	60.35
Candida auris	0.0108	45.27	67.90

Table 6: Time (Minutes) for % Kill Rate - 25% Room Reflectivity

UV Irradiance, W/m2		0.199	
% Kill Rate	**UV k, m2/J**	**99%**	**99.90%**
Coronavirus (SARS)	0.35	1.10	1.65
MRSA	0.0929	4.15	6.23
Pseudomonas aeruginosa	0.0751	5.14	7.70
Clostridium difficile spores	0.01215	31.74	47.62
Candida auris	0.0108	35.71	53.57

Table 7: Time (Minutes) for % Kill Rate - Naked Lamps

UV Irradiance, W/m2		0.295	
% Kill Rate	**UV k, m2/J**	**99%**	**99.90%**
Coronavirus (SARS)	0.35	0.74	1.12
MRSA	0.0929	2.80	4.20
Pseudomonas aeruginosa	0.0751	3.46	5.20
Clostridium difficile spores	0.01215	21.41	32.12
Candida auris	0.0108	24.09	36.14

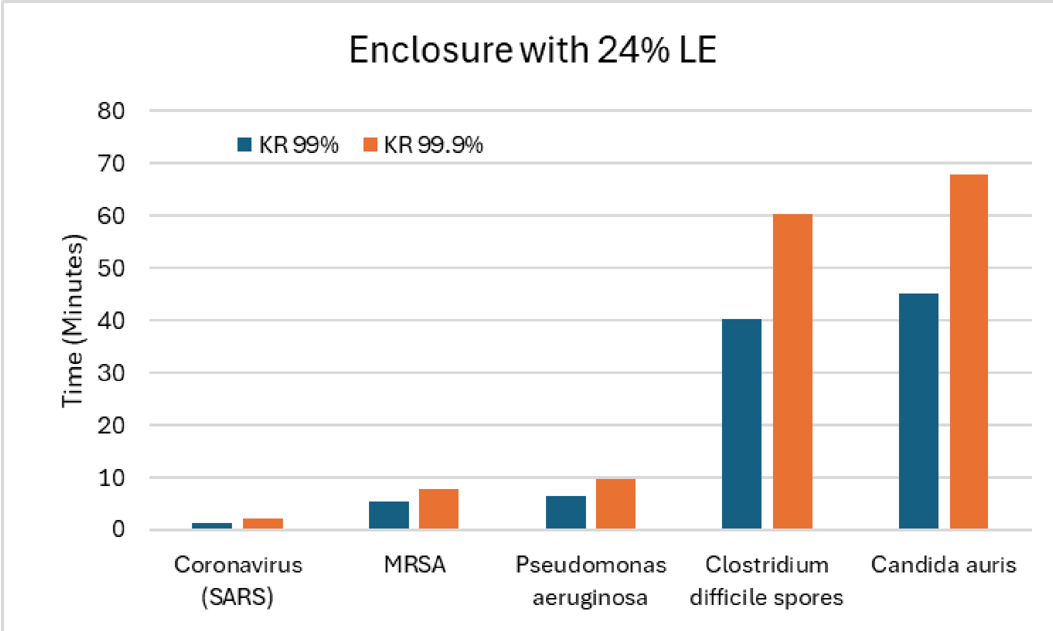

Figure 1: Enclosure with 24% Luminaire Efficiency. Baseline condition with no room reflectivity.

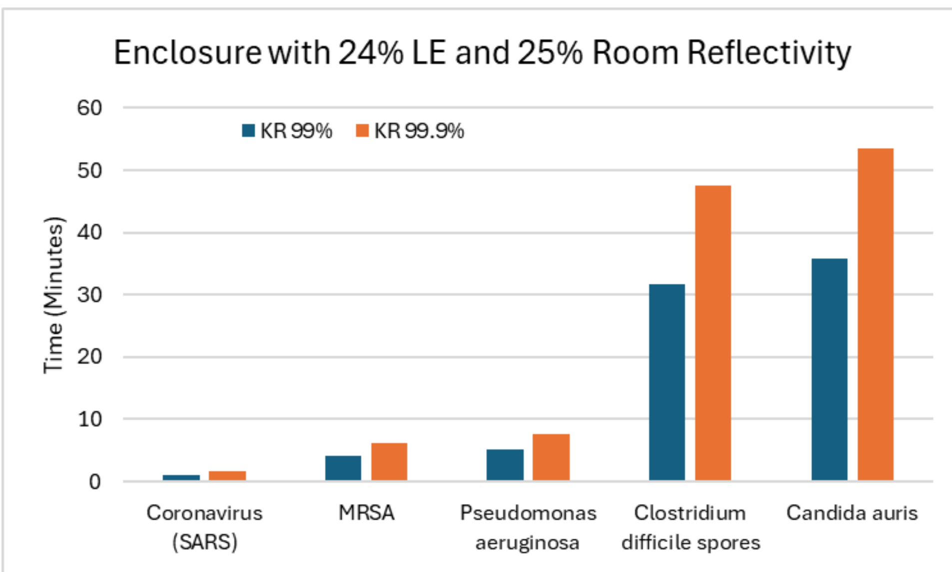

Figure 2: Enclosure with 24% Luminaire Efficiency and 25% Room Reflectivity.

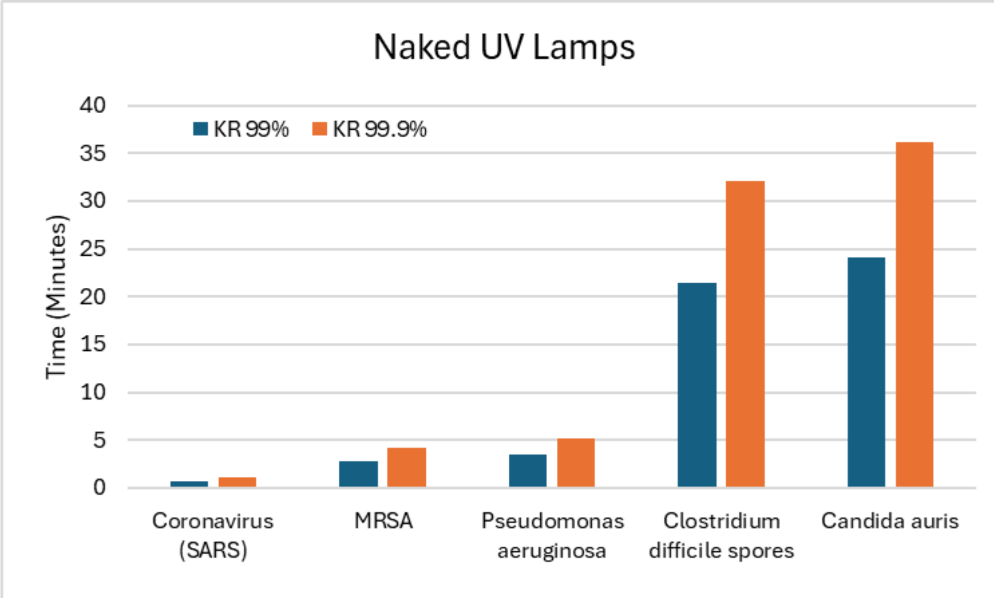

Figure 3: Evaluation of naked lamps without the enclosure and with zero room reflectivity.

Table 8 summarizes the estimated EAC values based on the computed average irradiance and the rate constant for MRSA, under each of the three configurations. These EACs are relative to the indicated species MRSA only. More resistant microbes will produce lower EACs.

Table 8: EAC Estimates from Irradiance Levels

Condition	Baseline	25% Room Refl	Naked Lamps
Luminaire Efficiency	24	24	24
Box Reflectivity	0	0	0
Room Reflectivity	0	0	25
Species	MRSA	MRSA	MRSA
k, m2/J	0.0929	0.0929	0.0929
Iavg, W/m2	0.157	0.199	0.651
Volume, m3	32.62	32.62	32.62
EAC (1/hr)	53	67	218

References

[1] ASHRAE Standard 241P, Control of Infectious Aerosols, ASHRAE, Atlanta (2023).

[2] ASHRAE Epidemic Task Force, Core Recommendations for Reducing Infectious Aerosol Exposure. ASHRAE. Atlanta, GA (2021).

[3] ASHRAE Position Document on Infectious Aerosols. ASHRAE. Atlanta, GA (2020).

[4] EPA Clean Air in Buildings Challenge. USEPA, U.S. Environmental Protection Agency, Ft. Meade, MD (2022).

[5] ASHRAE Epidemic Task Force Building Readiness Guide, 02 Feb 2021 (Updated 02-17-2022) ASHRAE. Atlanta, GA (2022).

[6] ANSI/ASHRAE Standard 62.1-2016: Ventilation for acceptable indoor air quality. ASHRAE, Atlanta, GA (2016).

[7] EPA Test Report: EPA 600/R-06/053. Biological Inactivation Efficiency by HVAC In-Duct Ultraviolet Light Systems: Sanuvox Technologies, Inc., U.S. Environmental Protection Agency (2006).

[8] IEC/AWI 63086-2-3, Household and similar electrical air cleaning appliances — Methods for measuring the performance — Part 2-3: Particular requirements for reduction of microorganisms. Belgium, International Electrotechnical Commission: 37 (2020).

[9] ASHRAE Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size. ANSI/ASHRAE Standard 52.2-2017. Atlanta, GA, American Society of Heating, Refrigerating and Air-Conditioning Engineers (2017).

[10] AHAM Standard AC-5, Method for Assessing the Reduction Rate of Key Bioaerosols by Portable Air Cleaners Using an Aerobiology Test Chamber. Association of Home Appliance Manufacturers, Washington, DC (2022).

[11] ASTM E3273-21: Standard Practice to Assess Microbial Decontamination of Indoor Air using an Aerobiology Chamber. American Society of Testing and Materials, West Conshohocken, PA, U.S.A. (2021).

[12] ASHRAE Standard 185.3P, Method of Testing In-Room Devices and Systems for Microorganism Removal or Inactivation in a Chamber, ASHRAE. Atlanta, GA (2023).

[13] ASHRAE SPC 185.5P, Method of Testing HVAC-duct mounted Devices and Systems and In-Room devices for Particle and Microorganism Removal or Inactivation in a Chamber with a Recirculating Duct System, ASHRAE, Atlanta (2022).

[14] W.J. Kowalski, Ultraviolet Germicidal Irradiation Handbook: UVGI for Air and Surface Disinfection. New York, Springer (2009).

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Professional Experience:

2021 Dec -2023 Sep, Chief Scientist of Sanuvox: Dr. Kowalski works on air cleaning design and construction for hospitals and commercial facilities and develops products and testing standards. He speaks at international conferences on infection control and biodefense. He serves on several committees in ASHRAE, IUVA and ASTM. He is currently engaged in R&D for ultraviolet germicidal irradiation systems for hospital infection control and research on UV genomics.

Prior 2017 Nov -2021 Jun, Chief Scientist of PurpleSun of New York, and also Vice-president of Immune Building Systems, Inc. (IBSI) of New York, he was chairman and secretary of the Air Treatment Group of the International Ultraviolet Association (IUVA) with whom he developed a series of guidelines for air and surface treatment systems.

1978-1995 Mechanical Engineer/Project Engineer/Senior Engineer for various companies in the Nuclear Power Industry. Specialized in the Design and Testing of Nuclear Air Cleaning Systems, Radioactive Contamination Control Systems, Building Pressurization and Isolation Systems, HVAC & Cooling Water Systems.

2000-2011 Designed and installed air cleaning systems in commercial buildings and health care facilities. Consulted on projects involving biodefense retrofits, mold remediation, hospital infection control, and residential air cleaning systems. Assisted various equipment manufacturers with the design and testing of UVGI, filtration, ozone, ionization, and other air disinfection systems. Has provided support for various private, commercial, and government projects internationally, including hospital and biodefense projects, and has performed air contamination investigations in a variety of health care facilities and commercial buildings.

Education:

B.S. Mechanical Engineering, 1978, Illinois Institute of Technology
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Licensed Professional Engineer State of Illinois, ASHRAE Graduate Grant-In-Aid, 1997, UVDI Research Grant 1999, Kissinger Fellowship Award for Scholarship 1999, Laraine and Jack Beiter Excellence Endowment in AE 2001.

Published Books:

Kowalski, W.J. (2009). "**Ultraviolet Germicidal Irradiation Handbook: UVGI for Air and Surface Disinfection**." Springer, New York.
Kowalski, W.J. (2011). "**Hospital Airborne Infection Control**." CRC Press/Taylor & Francis, Boca Raton, FL.
Kowalski, W.J. (2006). "**Aerobiological Engineering Handbook**: A Guide to Airborne Disease Control Technologies." McGraw-Hill, New York.
Kowalski, W.J. (2021). **Lighting Science for Medical Marijuana: Indoor and Outdoor Growing**. Aerobiological Engineering (planned).
Kowalski, W.J. (2013). "**Pet Owners Handbook of Airborne Dog Diseases**." ebook, Aerobiological Engineering.
Kowalski, W.J. (2003). "**Immune Building Systems Technology**." McGraw-Hill, New York.
Rosaler, R.C. (2004). **HVAC Handbook**, McGraw-Hill, New York. (contributed Chapter on Aerobiological Engineering).
ASHRAE (2003). **HVAC Design Manual for Hospitals and Clinics**. American Society of Heating, Ventilating, and Air Conditioning Engineers, Atlanta. (contributed chapter).
ASHRAE (2006). **ASHRAE Green Guide**, American Society of Heating, Ventilating, and Air Conditioning Engineers, Atlanta. (contributed sections).
ASHRAE (2008). "**UVGI Air Disinfection**." (contributed to chapter in Handbook of Systems and Equipment, American Society of Heating, Ventilating, and Air Conditioning Engineers, Atlanta.
Kowalski, W.J. (2001). "**Design and Optimization of UVGI Air Disinfection Systems**." Doctoral Thesis, The Pennsylvania State University.
Kowalski, W.J. (1997). "**Technologies for Controlling Respiratory Disease Transmission in Indoor Environments: Theoretical Performance and Economics**." Master's Thesis, The Pennsylvania State University.

Published Articles and Papers:

Kowalski, WJ, D. Saputa, D. Jones. (2021). **Achieving MERV-13: UV-C Can Help Less Efficient HVAC Filters Get There**, HPAC Engineering 93(6):38-44.
Kowalski, W., R. Moeller, T. J. Walsh, V. Petraitis and F. J. Passman (2022). "**Ultraviolet disinfection efficacy test method using bacteria monolayers**." J Microbiol Methods 200: 106541.
Kowalski, W. J., T.J. Walsh, V. Petraitis (2020). **2020 COVID-19 Coronavirus Ultraviolet Susceptibility**. ResearchGate online, PurpleSun.
Kowalski WJ, Bahnfleth WP, Raguse M, Moeller R. (2020). **The cluster model of ultraviolet disinfection explains tailing kinetics**. J Appl Microbiol 128,1003-1014.
Mayor-Smith, I., W. Kowalski and M. R. Templeton (2014), **A Genomic Exploration for Viral Surrogates for UV Biodosimetry**, IUVA Americas Regional Conference, New York, October 27, 2014.

Kowalski, W.J. (2011). "**Ultraviolet Genomic Modeling: Current Research and Applications**." 2011 May 23-27, Paris, France, Proceedings, Ozone and Ultraviolet World Congress & Exhibition.

Kowalski, WJ, WP Bahnfleth, M Hernandez (2009), **A Genomic Model for the Prediction of Ultraviolet Susceptibility for Viruses and Bacteria**. IUVA Conference Proceedings, Amsterdam, Netherlands, September 21-25.

Kowalski, WJ (2009), **A Genomic Model for the Ultraviolet Susceptibility of Viruses**. IUVA News, June.

Kowalski, WJ, WP Bahnfleth, M Hernandez (2009), **A Genomic Model for the Prediction of Ultraviolet Inactivation Rate Constants for RNA and DNA Viruses**. IUVA Conference Proceedings, Cambridge, MA.

Kowalski, WJ (2009), **UVGI for Cooling Coil Disinfection, Air Treatment, and Hospital Infection Control**, American Air & Water, Inc.

Kowalski W. (2008). **Operating Room Aerobiology in the Alaska Native Medical Center: Air and Surface Sampling Results and Recommendations for Reducing Surgical Site Infection Rates.** Anchorage, Alaska: Alaska Native Medical Center.

Kowalski W. (2008). **UVGI for Hospital Applications**. IUVA News 10(4):30-34.

Kowalski WJ. (2008). **Airborne Disease Control.** Action Bioscience November, 2008.

Kowalski WJ. (2007). **Air-Treatment Systems for Controlling Hospital-Acquired Infections**. HPAC Engineering 79(1):28-48.

Kowalski WJ. (2007). **Airborne Superbugs: Can Hospital-Acquired Infections Cause Community Epidemics?** Consulting Specifying Engineer 41(3):28-36, 69.

Kowalski, W. J. (1997). "**Technologies for controlling respiratory disease transmission in indoor environments: Theoretical performance and economics**.," M.S. Thesis, The Pennsylvania State University.

Kowalski, W. J., Bahnfleth, W. P., and Whittam, T. S. (1998). "**Bactericidal effects of high airborne ozone concentrations on *Escherichia coli* and *Staphylococcus aureus***." *Ozone Science & Engineering*, 20(3), 205-221.

Kowalski, W., and Bahnfleth, W. P. (1998). "**Airborne respiratory diseases and technologies for control of microbes**." *HPAC Engineering*, 70(6).

Kowalski, W. J., W. P. Bahnfleth, T. S. Whittam. (1999). "**Filtration of Airborne Microorganisms: Modeling and prediction**." *ASHRAE Transactions*, 105(2), 4-17.

Kowalski, W. J., and Bahnfleth, W. P. (2000). "**UVGI Design Basics for Air and Surface Disinfection.**" *HPAC Engineering*, 72(1), 100-110.

Kowalski, W. J., and Bahnfleth, W. P. (2000). "**Effective UVGI system design through improved modeling**." *ASHRAE Transactions,* 106v2:4-15.

Kowalski, W. J. (2000). "**Shedding Light on Moldy Ductwork**." *Home Energy*, 17(3), 6.

Kowalski, W. J. (2000). "**Indoor mold growth: Health hazards and remediation**." *HPAC Engineering*, September, 2000.

Kowalski, W. J. (2001). "**Air Cleaning Technologies for Animal Research Laboratories**." Presented at the ACLAM Annual Conference, April 2, in Pointe Claire, AL.

Kowalski, W. J. (2001). "**Design and Optimization of UVGI Air Disinfection Systems**.," PhD Thesis, The Pennsylvania State University.

Kowalski, W. J., W.P. Bahnfleth, D.L. Witham, B.F. Severin, and T.S. Whittam, (2000). "**Mathematical modeling of UVGI air disinfection**." *Quant. Microb. 2 :249-270.*

Kowalski, W. J. and E. Burnett. (2001). "**Technical Brief: Mold and Buildings.**" The Pennsylvania Housing Research Center.

Kowalski, W. J. and D. Witham. (2001). "**UVGI Systems for Air and Surface Disinfection**." *IUVA Journal.* 3(5):4-7.

Kowalski, W. J., and W. P. Bahnfleth**.** (2002). "**Airborne-Microbe Filtration in Indoor Environments.**" *HPAC Engineering. January, 57-69.*

Kowalski, W.J. and W.P. Bahnfleth (2002). "**MERV Filter Models for Aerobiological Applications**." Air Media, Summer 13-17.

Kowalski, W.J. and C. Dunn (2002). "**Current Trends in UVGI Air and Surface Disinfection**." INvironment 8(6):4-6.

Kowalski, WJ, WP Bahnfleth (2002). "**Innovative Strategies to Protect Hospitalized Premature Infants against Airborne Pathogens and Toxins.**" Hershey Medical Center Neonatal Intensive Care Unit.

Kowalski, W. J., W. P. Bahnfleth, and D. D. Carey. (2002). "**Engineering control of airborne disease transmission in animal research laboratories**." *Contemporary Topics in Laboratory Animal Science. 41(3):9-17*.

Musser, A., Kowalski, W., and Bahnfleth, W. (2002). "**Stack and mechanical system effects on dispersion of biological agents in a tall building**." International Mechanical Engineering Congress and Exposition, New Orleans.

Kowalski, W.J., (2003). "**Defending Buildings Against Bioterrorism**." Engineered Systems 2002, p61-68.

Kowalski, W. J. and W. P. Bahnfleth. (2003). "**Immune-Building Technology and Bioterrorism Defense**." *HPAC Engineering. 75(1)57-62.*

Kowalski, W. J., W. P. Bahnfleth, and T. S. Whittam**.** (2003). "**Demonstration of a hermetic airborne ozone disinfection system: Studies on *E. coli*.**" *American Industrial Hygiene Association Journal*. 64:222-227.

Kowalski, W. J., W. P. Bahnfleth, and J. L. Rosenberger. (2003) "**Dimensional Analysis of UVGI Air Disinfection Systems**" *HVACR Journal*. 9(3):347-362.

Kowalski, W. J., W. P. Bahnfleth, and A. Musser. (2003) "**Modeling Immune Building Systems for Bioterrorism Defense**." Journal of Architectural Engineering. June:86-96.

Kowalski, W.J. (2005). "**Retrofitting Buildings for Bioterrorism Defense**." HPAC Engineering.

Kowalski, W.J. and W.P. Bahnfleth (2004). "**Clearing the Air on UVGI Systems**," RSES Journal.

Bahnfleth, W.P. and Kowalski, W.J. (2005). "**Indoor-Air Quality: Issues and Resolutions**," HPAC Engineering, June, 2-11.

Bahnfleth, W.P., W.J. Kowalski, and J. Friehaut (2005). "**Standard and Guideline Requirements for UVGI Air Treatment Systems**." Proceedings Indoor Air 2005.

Kowalski, W.J. (2006). **IUVA Guidelines for UVGI Air and Surface Disinfection**, International Ultraviolet Association, iuva.org.

Armellino D, Walsh TJ, Petraitis V, Kowalski W. (2019). **Assessing the Feasibility of a Focused Multivector Ultraviolet System Between Surgery Cases with a Parallel Protocol for Enhanced Disinfection Capabilities**. Am J Infect Control 47,1006-1008.

Armellino D, Walsh TJ, Petraitis V, Kowalski W. (2019). **Assessment of focused multivector ultraviolet disinfection with shadowless delivery using 5-point multisided sampling of patient care equipment without manual-chemical disinfection**. Am J Infect Control 47,409-414.

Presentations and Seminars:

Kowalski, WJ, (2023). **Infection Prevention and Ultraviolet Air Disinfection – Performance and Economics**, IUVA Seminar, Sep. 12, 2023, Dubai, UAE.

Kowalski, W.J. "**Infection Prevention and Ultraviolet Air Disinfection Technologies**: Performance and Economics." Paper presented at the First International Far-UV Conference, Columbia University, New York, 2023.

Kowalski, WJ. "**Ultraviolet Air Cleaning and Decarbonization**." Live video presented at the CUVA / IUVA Asia Symposium, Chinese Ultraviolet Association Annual Conference, Tsinghua University, China, (2023).

Kowalski, WJ, (2023). **UV101 – Ultraviolet Science**, IUVA Seminar, Sep. 10, 2023, Dubai, UAE.

Kowalski, WJ, (2023). **Ultraviolet Science**, Roseland Podcast Seminar, Aug. 23, 2023, online webcast.

Kowalski, W.J. (2023). **Ultraviolet Science and History**. Online Webinar UV Air Safety Series. May 28th, 2023.

Kowalski, WJ. (2023). **Can Widespread Application of Air Disinfection Technology Immunize Entire Communities and Suppress Epidemics?** Quebec ASHRAE Meeting, Feb. 13th, 2023, Quebec City, QC.

Kowalski, W.J. (2022). **Ultraviolet Air Disinfection and Validation**, International Ultraviolet Association Fundamentals of UV Process and Equipment Validation Workshop, 2022 IUVA Americas Conference, Cincinnati, Sep. 25th.

Kowalski, W.J. (2022). **Can Widespread Application of Air Disinfection Technology Immunize Entire Communities and Suppress Epidemics?** 2022 IUVA Americas Conference, Cincinnati, Sep. 27th.
Kowalski, W.J. (2022). **Applications of Ultraviolet Technology in Cannabis Growing Facilities.** Montreal Cannabis Expo 2022, Montreal, Quebec. Sep. 22nd.
Kowalski, W.J. (2003). "**UVGI Applications for Commercial and Health Care Facilities**." NIOSH Seminar, Cincinnati, July 15th.
Kowalski, W.J. (2003). "**UVGI Applications for Commercial and Health Care Facilities**." CDC Seminar, Atlanta, September 11th.
Kowalski, W. J. (2001). "**Air Cleaning Technologies for Animal Research Laboratories**." Presented at the ACLAM Annual Conference, April 2, in Pointe Claire, AL.
Kowalski, W.J. (2001). "**Bioterrorism and Immune Building Technology**." Energy Solutions / Lumalier Seminar. Dec.13-14, Memphis, TN.
Kowalski, W.J. (2002). "**Bioterrorism and Immune Building Technology**." National Air Filtration Association Technical Seminar, April 19, Nashville, TN.
Kowalski, W.J. (2002). "**Defending Building against CBW Terrorism**." National Environmental Health Association conference, July 1st, Minneapolis, MN.
Kowalski, W.J. (2002). "**Bioterrorism and Preparedness for Hospital Facilities**" HAZMAT Annual Conference, December 2nd, Las Vegas, NV.
Kowalski, W.J. (2003). "**Bioterrorism and Immune Building Technologies**." 2003 NEBB Annual Education and Recertification Seminar. April 11, Washington, DC.
Kowalski, W.J. (2003). "**Bioterrorism and Building Protection**." 2003 ASHRAE Meeting. April 17, Austin, TX.
Kowalski, W.J. (2003). "**Proposed Standards and Guidelines for UVGI Air Disinfection**," International Ultraviolet Association Conference, Nov. 5, Chicago, IL.
Kowalski, W.J. (2003). Television Appearance: "**American Environmental Review**," hosted by Morley Safer, May-June 2003, PBS.
Kowalski, W.J. (2004). **"Modeling the Dispersion of Chemical or Biological Contaminants**," 2004 ASHRAE Winter Meeting, Anaheim, CA.
Kowalski, W.J. (2004). "**Bioterrorism and Immune Building Technologies**," The Construction Industry Partnership of New York 7th Annual Winter Conference, Hollywood, FL.
Kowalski, W.J. (2004). "**Proposed Standards and Guidelines for UVGI Air Disinfection**," Ultraviolet Air Treatment Conference, Chicago, IL, November 6, 2003.
Kowalski, W.J. (2004). "**Modeling the Dispersion of Chemical of Biological Contaminants**," ASHRAE Winter Meeting, Anaheim, CA, January 25, 2004.
Kowalski, W.J. (2004). "**Building Protection and Decontamination**," Southeast Homeland Security Conference, Orlando, FL, July 8, 2004.
Kowalski, W.J. (2004), "**Proposed Standards and Guidelines for UVGI Air Disinfection."** IUVA 2nd Annual UV Air Treatment Conference, Chicago, IL, November 6.
Kowalski, W.J. (2004). "**Guidelines and Standards for UVGI Air & Surface Treatment Systems**," American Refrigeration Institute, Phoenix, AZ, November 15, 2004.
Kowalski, W.J. (2004). "**Proposed Standards and Guidelines for UVGI Air Treatment Systems."** Air Conditioning & Refrigeration Institute, Scottsdale, AZ, November 15, 2004
Kowalski, W.J. (2004), "**UVGI Air Treatment Systems: Experience with Retrofits for Commercial Office Buildings."** IUVA 2nd Annual UV Air Treatment Conference, Penn State, PA, December 10, 2004.
Kowalski, W.J. (2005), "**Progress on Standards and Guidelines for UVGI Air Treatment Systems**." IUVA Third International Congress on Ultraviolet Technologies, Whistler, British Columbia, May 25, 2005.
Kowalski, W.J. (2005), "**Building Protection Factors**." IUVA Third International Congress on Ultraviolet Technologies, Whistler, British Columbia, May 26, 2005.
Kowalski, W.J. (2005), "**Aerobiological Engineering: Controlling Airborne Disease by Designing Healthy Indoor Environments**." Montreal ASHRAE, September 12th, 2005.
Kowalski, W.J. (2006), "**Proposed UVGI Air Treatment Standards**." ASHRAE 2006 Winter Meeting, Chicago, IL, January 15-16, 2006.
Kowalski, WJ (2007). "**UVGI for Hospital Applications**." IUVA Air Treatment Symposium, Los Angeles, CA.

Kowalski, WJ (2008). “**UVGI in Ventilation Ducts and in Recirculating Room Air Disinfection Units**.” Engineering Methods for the Control of Airborne Infections, Harvard School of Public Health, Boston, MA.

Kowalski W, Bahnfleth W, Hernandez M. (2009). “**A Genomic Model for Predicting the Ultraviolet Susceptibility of Viruses and Bacteria,”** 2009 September 21-23; Amsterdam, The Netherlands. International Ultraviolet Association.

Kowalski W, Bahnfleth W, Hernandez M. (2009). **A Genomic Model for the Prediction of Ultraviolet Inactivation Rate Constants for RNA and DNA Viruses**,” 2009 May 4-5; Boston, MA. International Ultraviolet Association.

Kowalski W, Bahnfleth W, Hernandez M. (2009). **A Genomic Model for the Prediction of Ultraviolet Inactivation Rate Constants for RNA and DNA Viruses**. IUVA News June.

Kowalski, W.J. (2011). “**Ultraviolet Genomic Modeling: Current Research and Applications**.” 2011 May 23-27, Paris, France, IOA IUVA World Congress & Exhibition.

<u>Software:</u>

Kowalski, W.J. (2021). **GROMAX**: Grow lamp sizing software package, Aerobiological Engineering, Inc..

Kowalski, W. J. (2000). “**UVD: UVGI System Design Program**.” Proprietary software package developed for Ultraviolet Devices, Inc., Valencia, CA

Kowalski, W. J. (2001). “**UVH: Ultraviolet Air Treatment Application Guide**.” Proprietary software package developed for Honeywell, Inc.

Kowalski, W. J. (2001). “**BCT: Air Sampling Analysis Program**.” Proprietary software package developed for BioChem Technologies, LLC.

Kowalski, W. J. (2003). “**UVS: Specular UVGI System Design Program**.” Proprietary software package developed for Immune Building Systems, Inc., New York, NY.

Kowalski, W. J. (2003). “**Vmod: Modular Coil Irradiator Selection Guide**.” Proprietary software package developed for Ultraviolet Devices, Inc., Valencia, CA

Kowalski, W. J. (2003). “**V-Smart: Return on Investment Calculator**.” Proprietary software package developed for Ultraviolet Devices, Inc., Valencia, CA

Kowalski, W.J. (2013). “**UV3: Genomic Sequence Analyzer**.” Proprietary Software developed for Aerobiological Engineering, LLC.

<u>Other Activities</u>

- Dr. Kowalski was involved in the design of a UV LED system for NASA’s Microgravity Glovebox which was launched to the International Space Station in January of 2014. NASA lists Dr. Kowalski as a Subject Matter Expert in the area of ultraviolet germicidal irradiation (UVGI).
- Dr. Kowalski has been an expert witness in hospital litigation and has assisted in the resolution of patent infringement cases.
- Dr. Kowalski is a Certified Fallout Shelter Analyst (CFSA) and has designed retrofits for US Federal fallout shelters to incorporate UV air disinfection systems.
- Dr. Kowalski provided support to the US Army, the Pentagon and the NYPD during the post-911 anthrax attacks, providing information on biodefense systems and the disinfection of buildings contaminated with anthrax.
- Dr. Kowalski is a member of the Underwriters Laboratories UL8800 Committee for Ultraviolet Photobiological Safety.
- Dr. Kowalski was a participant in E35 and D37 Working Groups for ASTM Standards being developed for Air Disinfection, Bacteria Monolayers, and Cannabis (2020.2021).
- Dr. Kowalski has two patents, the Space-1 area disinfection systems (PurpleSun) and the Bacteria Monolayer Spray System (PurpleSun).
- Dr. Kowalski was a participating member of the ASHRAE 185.3 and 185.4 Technical Committees

- Participating member of the IUVA Canadian Regulatory Committee.
- Participating member of the IUVA Education Committee.