Alfa Laval
Pure Air case study

Pure Air liquid desiccant system

Surrogate testing — December 10 - 13, 2018

Abstract

A study was conducted at the Alfa Laval facility in Elizabethtown, NC during December 10th to the 13th 2018. The objective of this study was to evaluate and understand the effect of the Pure Air liquid desiccant system (LDS) on microorganisms most commonly attributed to healthcare acquired infections (HAIs). The organisms selected for this evaluation were:

- *Staphylococcus epidermidis*
- *Klebsiella aerogenes*
- *E. coli*
- *Enterobacter cloacae*
- *Salmonella Typhimurium*
- *Pseudomonas fluorescens*
- *Listeria innocua*

The results of the study verified an average 5.41 Net LOG reduction of the vegetative challenge aerosol within the test apparatus, detailed in the body of this report.

A previous study (Alfa Laval White Paper 4-22-2014) done in conjunction with the State University of New York at Buffalo, School of Medicine and Biomedical Sciences demonstrated complete destruction of six (6) similar microorganisms when tested invitro with LiCl and $CaCl_2$, the solutions utilized in the dehumidification process.

Introduction

HAIs impact millions of people globally and increase patient morbidity and mortality while attributing $36 to $45 billion annual costs within the US alone (Scott RD, 2009).

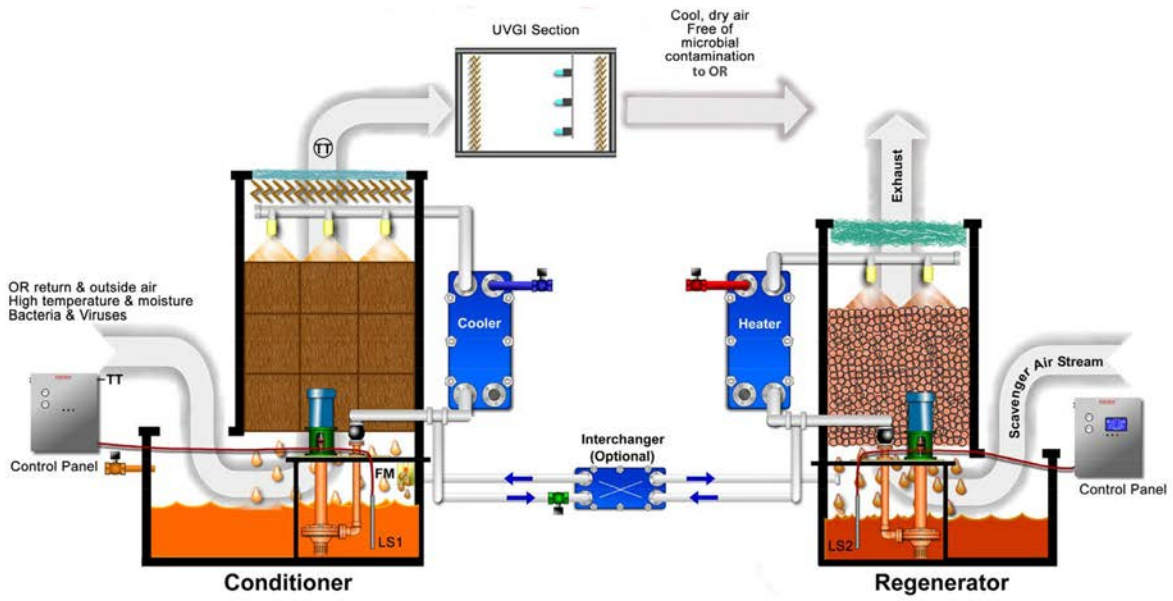
Hand washing has been a focus of Hospital Infection Preventionists to address the increasing HAI problem within Healthcare environments. The result of this focus has not changed the trajectory of the problem (Vincent JL, 2009). Airborne transmission of these pathogens is increasingly reported in the literature (Beggs CB, 2006. Roberts K, 2008). Additionally, these pathogenic bacteria have been isolated from Hospital HVAC (heating, ventilation and air conditioning) systems (Ryan RM, 2011).

The Alfa Laval Pure Air LDS technology employs a specific salt solution, LiCl, which removes moisture from air as the air moves through a conditioning spray chamber within the desiccant system, along with an ultraviolet germicidal irradiation (UVGI) section. This process precisely controls relative humidity (RH) within designated conditioned space to a range of 18-80%, RH at an accuracy of ±1% as well as sanitizing the air flow.

The solution is sprayed downwards over packing material as incoming counter-current airflow is distributed from beneath the packing material. The moisture laden solution collects within the unit sump reservoir after passing through the packing. It is transferred to a regenerator unit that removes

Introduction continued

the moisture, concentrating the solution, before transfer back to the conditioning unit. This cyclical process results in a stabilization of the space RH regardless of the condition present at the inlet of the conditioning section.



The premise that a combination of exposure to the LiCl solution and a germicidal energy field may result in a significant reduction of aerosolized microbial challenge was investigated.

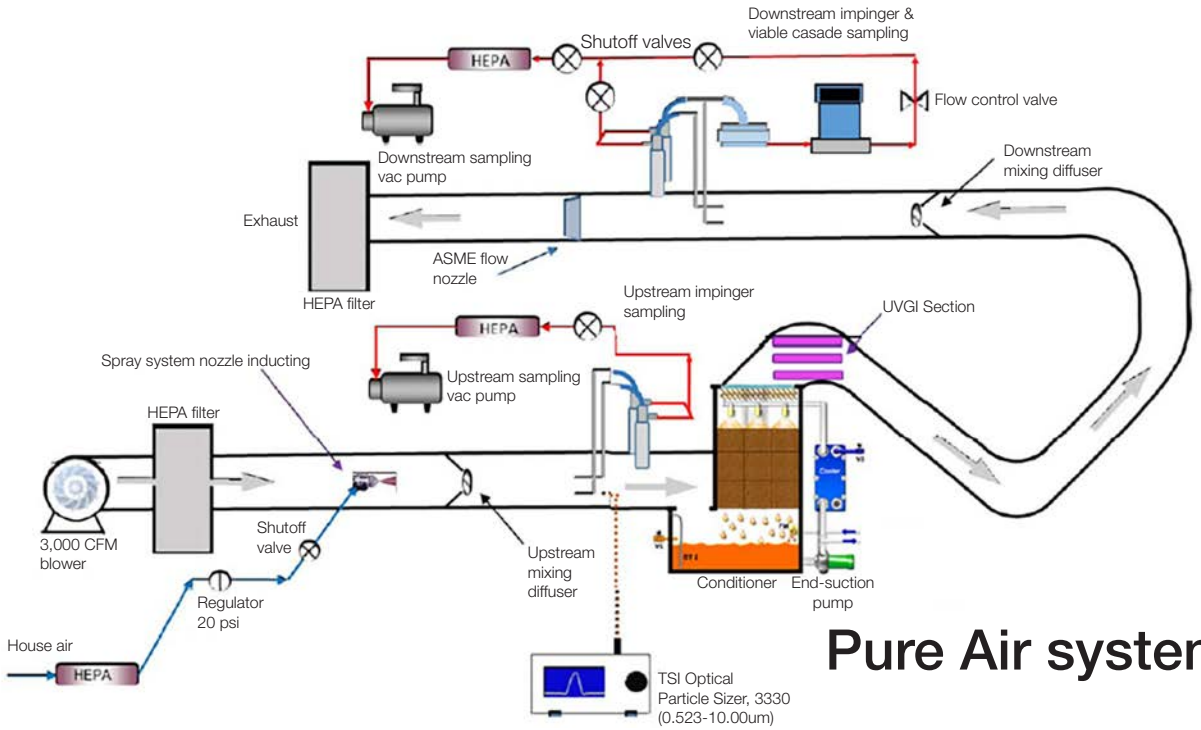
Methods

Aerosol testing was undertaken to understand the efficacy of the Pure Air LDS technology.

A total of seven (7) surrogate species, based on Biological Safety Level 1 (BSL1) for pathogenic microorganisms (BSL3), typically associated with HAI were generated via aerosolization at the Alfa Laval Elizabethtown, NC facility. A standardized ASHRAE 52.2 test air duct in conjunction with Alfa Laval Pure Air LDS technology were used in the testing.

The ASHRAE 52.2 test duct consisted of 24” x 24” SAE 304 stainless steel with inlet fan/motor, inlet HEPA filter section, aerosol injection section, upstream mixing diffuser, upstream sample location, liquid desiccant section, UVGI section, downstream mixing section, downstream sample location, ASME flow nozzle section and exhaust HEPA filter section.

Methods continued



Pure Air system

A 3,000 CFM fan/blower was positioned at the upstream end of the test duct driving an airstream through the entire system. The airstream immediately passed through an inlet HEPA filter, past the aerosolization injection port and mixing diffuser, past the sample ports for bio aerosolization upstream sample collection, and then into the Pure Air system.

Each set of organisms was aerosolized via high flow pneumatic gravity fed nozzle (flow rate, 22.3ml/min at 20psi) into the test duct individually and air samples collected upstream and downstream of the system.

Upstream sample location

Downstream sample location

Methods continued

Comparisons of the number of living organisms between the upstream and downstream air samples allowed for determination of the Pure Air system's efficacy at removing viable bioaerosols from an HVAC system.

Aerosol Research and Engineering Laboratories, an independent certified environmental testing laboratory, conducted culturing, generation, exposure, collection and counting of the seven (7) microorganism aerosol challenges.

A minimum concentration of bio-aerosol, (between $1x10^7$ cfu/L), was generated via aerosol spray nozzle device to challenge the operational Pure Air system. Seven (7) individual aerosol tests were run with the following microorganisms:

- *Staphylococcus epidermidis*
- *Klebsiella aerogenes*
- *E. coli*
- *Enterobacter cloacae*
- *Salmonella Typhimurium*
- *Pseudomonas fluorescens*
- *Listeria innocua*

Microbial samples in quadruplicate were collected upstream (with two (2) AGI impinger) and downstream (with one (1) AGI impinger and one (1) Anderson N-6 single stage impactor) of the Pure Air system.

All samples were sealed (impactor), plated and sealed (impinger) and then placed in an incubator on site for appropriate time to culture.

Collected bio-aerosol samples were incubated/inspected/serial diluted. All samples were read and counted for determination of efficacy.

Total count and enumeration were summarized via generated tables for each aerosolized species demonstrating:

Upstream data

- Upstream bioaerosol concentration, colony forming unit per liter (cfu/L)
- Total colony forming unit captured via impinger (cfu/imp)

Downstream data

- Downstream bioaerosol concentration (cfu/L)
- Total colony forming unit (cfu) captured via impinger (cfu/imp)
- Total colony forming unit (cfu) captured via impactor (cfu/impct)

Calculated efficacy

- Reduction of viable bioaerosol concentration = downstream concentration / upstream concentration with LOG_{10} of quotient

An optical particle sizer (OPS) Model 3330 (TSI Inc.) was connected to a sample port upstream of the Pure Air system. The OPS measured particles from 0.3 to 10 µm in 16 adjustable size channels. Data was recorded with the OPS during every test as well as control runs.

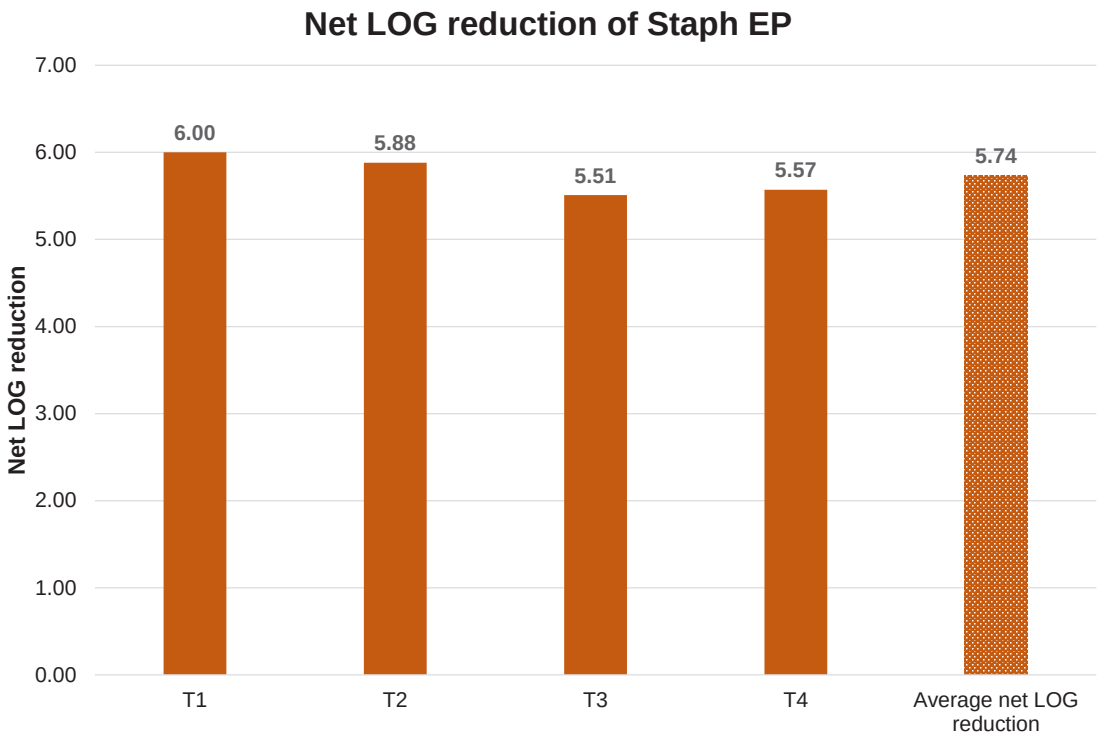
Methods continued

Pure Air LDS bioaerosol challenge test matrix									
	Challenge organism	Surrogate for	ATCC#	Gram	# of trials	sampling	Impinger sample times (min)	Viable casade sample times (min)	Total trial time (min)
1	*Methicillin Resistant Staphylococcus epidermidis*	*Methicillin Resistant Staph Aureus (MRSA)*	12228	pos	4	Viable casade, AGI Impingers, TSI OPS 3330	Upstream: 4 Downstream: 4	Upstream: n/a Downstream: 0.5 & 3	4
2	*E. coli*	*E. coli*	15597	neg	4	Viable casade, AGI Impingers, TSI OPS 3330	Upstream: 3 Downstream: 3	Upstream: n/a Downstream: 3	4
3	*Salmonella Typhimurium*	*Salmonella*	53648	pos	4	Viable casade, AGI Impingers, TSI OPS 3330	Upstream: 4 Downstream: 4	Upstream: n/a Downstream: 0.5 & 3	4
4	*Listeria innocua*	*Listeria Monocytogenes*	33090	pos	4	Viable casade, AGI Impingers, TSI OPS 3330	Upstream: 4 Downstream: 4	Upstream: n/a Downstream: 0.5 & 3	4
5	*Pseudomonas flourescens*	*Pseudomonas*	13525	neg	4	Viable casade, AGI Impingers, TSI OPS 3330	Upstream: 4 Downstream: 4	Upstream: n/a Downstream: 0.5 & 3	4
6	*Enterobacter cloacae subsp. Cloacae*	*Enterobacter*	13047	neg	4	Viable casade, AGI Impingers, TSI OPS 3330	Upstream: 4 Downstream: 4	Upstream: n/a Downstream: 0.5 & 3	4
7	*Kiebsiella aerogenes*	*Kiebsiella*	51697	neg	4	Viable casade, AGI Impingers, TSI OPS 3330	Upstream: 4 Downstream: 4	Upstream: n/a Downstream: 0.5 & 3	4

- ***Staphylococcus epidermidis*** (ATCC 12228) was the surrogate for Staphylococcus aureus, which has developed multi drug resistance (MRSA) and a major cause of hospital-acquired infections.
- The ***E. coli*** (ATCC 15597) was the surrogate for infectious strain of E. coli which is a cause of food poisoning.
- ***Salmonella typhimurium*** (ATCC 53648) was the surrogate for the pathogenic strain of Salmonella which is a leading cause of gastrointestinal infections.
- ***Listeria innocua*** (ATCC 33090) was the surrogate for the pathogenic strain of Listeria monocytogenes that cause the infection listeriosis.
- ***Pseudomonas fluorescens*** (ATCC 13525) was the surrogate for the drug resistant pathogenic strain P. aeruginosa that is a major concern in hospital-acquired infections.
- ***Enterobacter cloacae*** (ATCC 13047) was the surrogate for the pathogenic Genus relative that cause UTI and lower respiratory tract infections.
- ***Klebsiella aerogenes*** (ATCC 13048) was the surrogate for the infectious K. pneumoniae that cause pneumonia in humans.

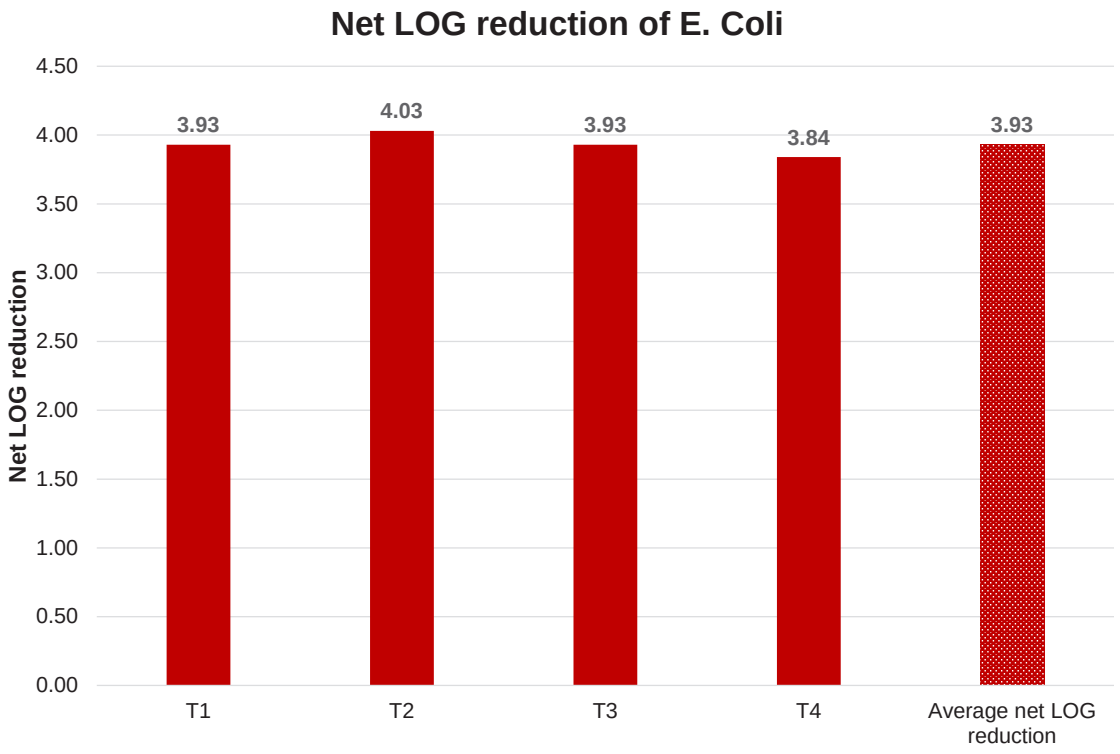
Results

The average Net LOG reduction of ***Staphylococcus epidermidis*** was 5.74 with limits of detection at 7.64.



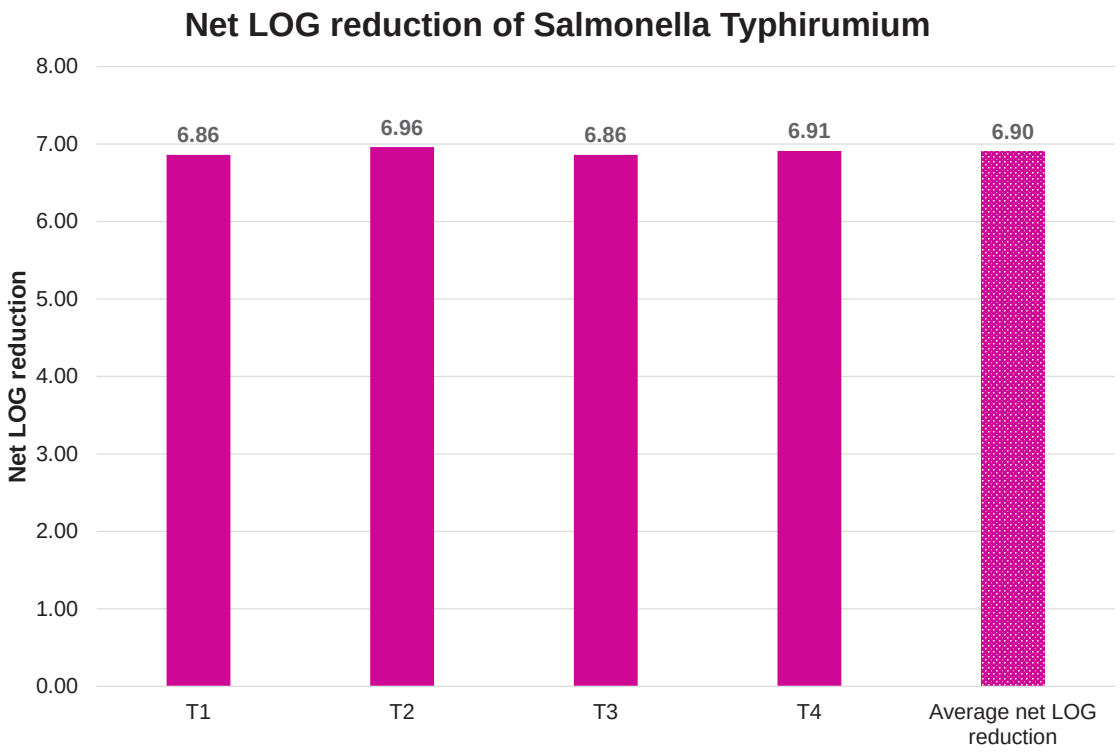
Results continued

The average Net LOG reduction of ***E.coli*** was 3.93 with the limit of detection at 6.06.



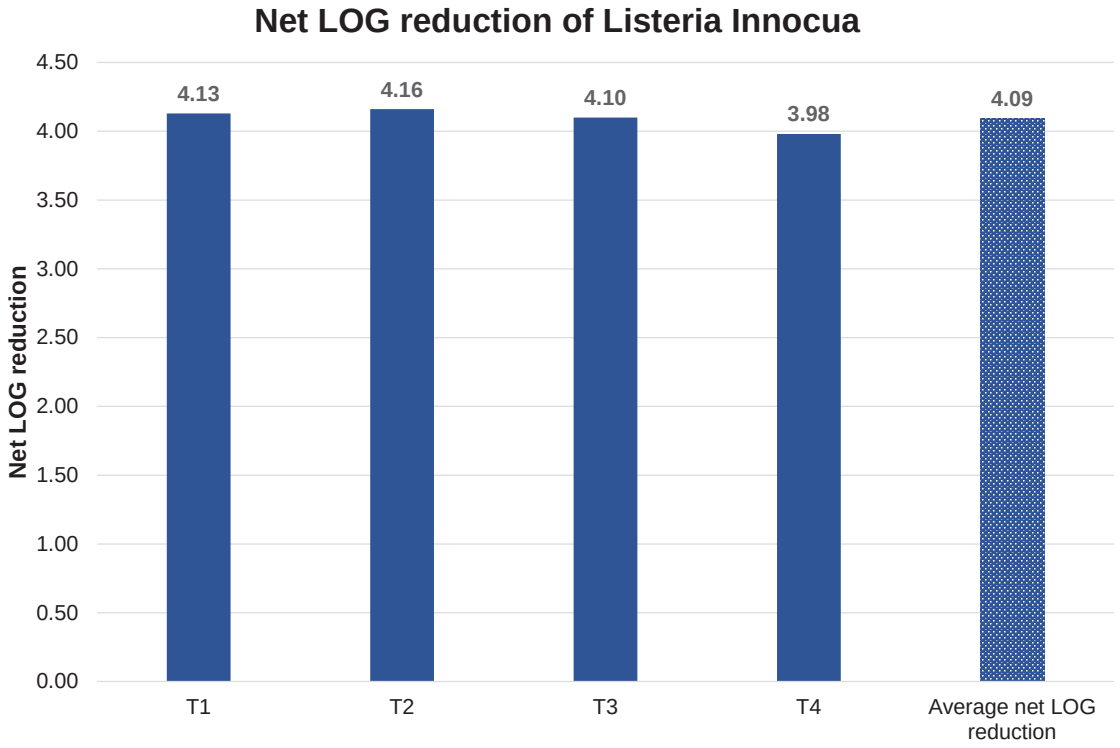
Results continued

The average minimum Net LOG reduction of ***Salmonella typhimurium*** was >6.90 with a limit of detection of 6.90. The Net LOG reduction is considered a minimum value because a single colony was artificially added to the downstream impinger non-dilution. There were, no growth on any of the downstream plates. However, if zeros were to be marked for the plates the logarithmic math does not calculate.



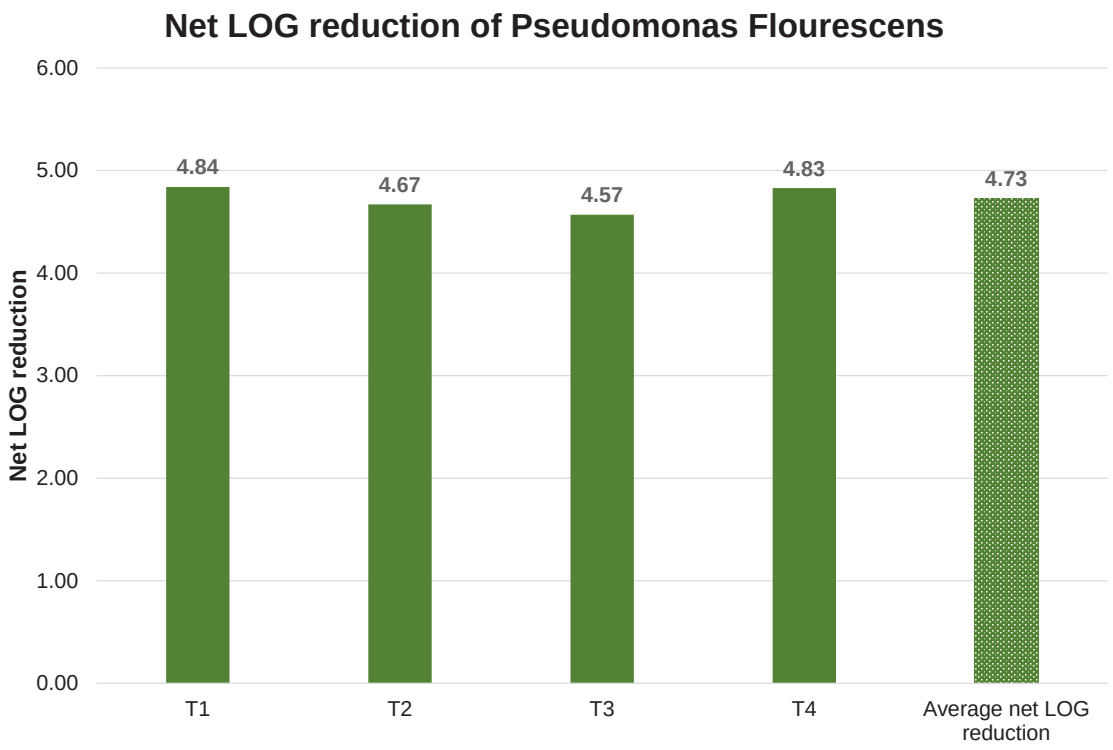
Results continued

The average Net LOG reduction of ***Listeria innocua*** was 4.09 with a limit of detection of 5.58.



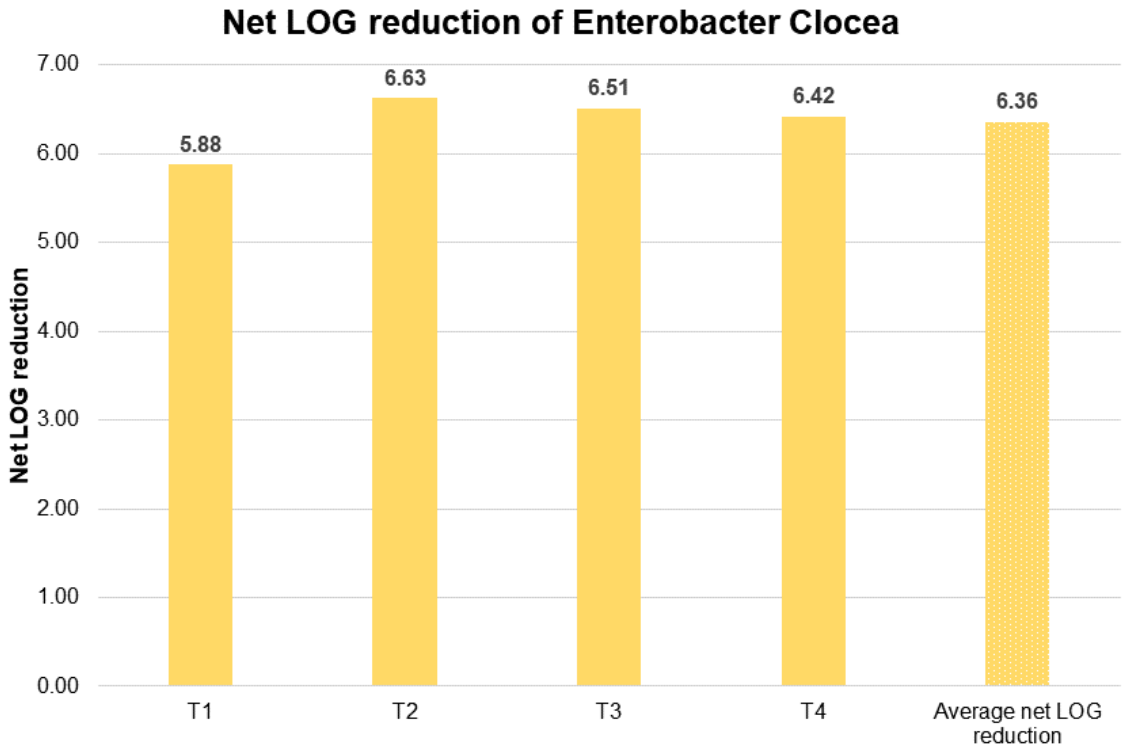
Results continued

The average minimum Net LOG reduction for ***Pseudomonas*** fluorescens was >4.73 with a limit of detection of 4.73. The Net LOG reduction is considered a minimum value because a single colony was artificially added to the downstream impinger non-dilution. There were, no growth on any of the downstream plates. However, if zeros were to be marked for the plates the logarithmic math does not calculate.



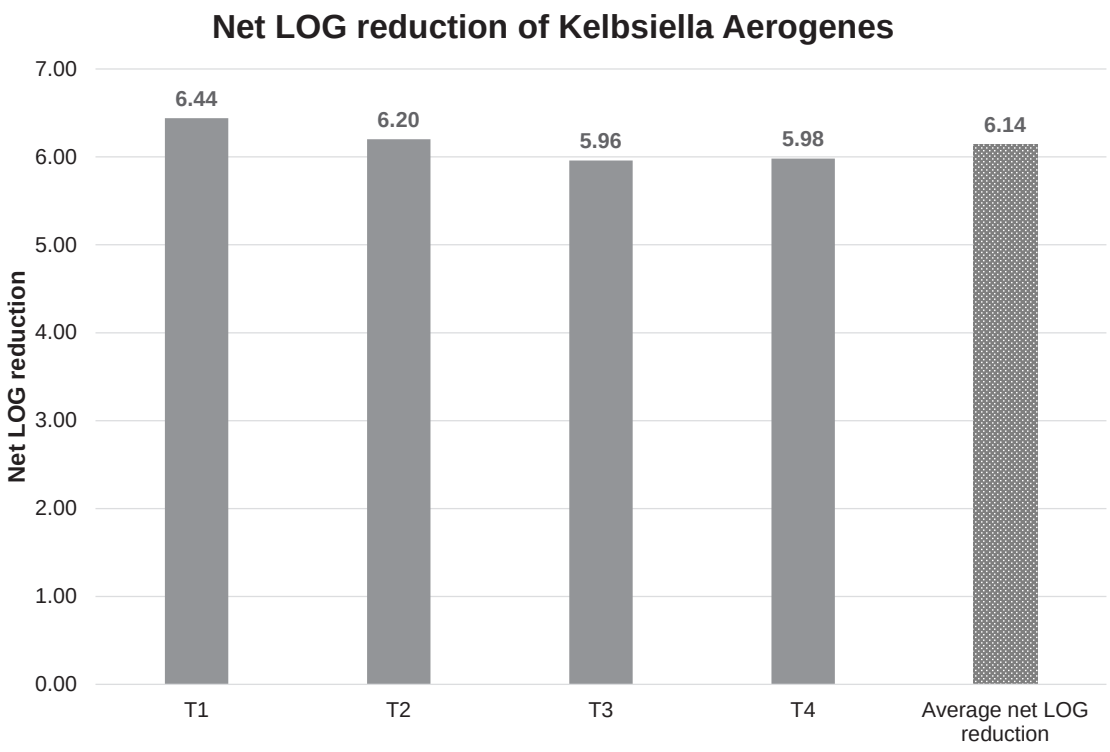
Results continued

The average Net LOG reduction for ***Enterobacter cloacae*** was 6.36 with a limit of detection of 6.51.



Results continued

The average minimum net LOG reduction for ***Klebsiella aerogenes*** was >6.14 with a limit of detection of 6.14. The Net LOG reduction is considered a minimum value because a single colony was artificially added to the downstream impinger non-dilution. There were, no growth on any of the downstream plates. However, if zeros were to be marked for the plates the logarithmic math does not calculate.



Results continued

	Pure Air LDS bioaerosol challenge summary				Results						Limits of detection
	Challenge organism	Surrogate for	ATCC#	Gram	T1	T2	T3	T4	Average Net log reduction	Stand. dev	
1	*Methicillin Resistant Staphylococcus epidermidis*	*Methicillin Resistant Staph Aureus (MRSA)*	12228	pos	6.00	5.88	5.51	5.57	5.74	0.24	7.64
2	*E. coli*	*E. coli*	15597	neg	3.93	4.03	3.93	3.84	3.93	0.08	6.06
3	*Salmonella Typhimurium*	*Salmonella*	53648	pos	>6.85	>6.96	>6.85	>6.90	>6.90	0.05	6.90
4	*Listeria innocua*	*Listeria Monocytogenes*	33090	pos	4.13	4.16	4.10	3.98	4.09	0.08	5.58
5	*Pseudomonas flourescens*	*Pseudomonas*	13525	neg	>4.84	>4.67	>4.57	>4.82	>4.73	0.13	4.73
6	*Enterobacter cloacae subsp. Cloacae*	*Enterobacter*	13047	neg	6.11	6.87	6.74	6.65	6.36	0.33	6.51
7	*Kiebsiella aerogenes*	*Kiebsiella*	51697	neg	>6.43	>6.19	>5.95	>5.97	>6.14	0.23	6.14

*Red text = at detection limits, calculated LOG reduction values represent a minimum

Discussion

The purpose for this study was exploration of the impact that liquid desiccant dehumidification technology and application of ultraviolet germicidal irradiation (Pure Air LDS) have on known concentrations of specific microorganisms aerosolized in a moving airstream.

Seven (7) vegetative surrogates for pathogens, of which (4) associated with HAIs, were aerosolized individually in quadruplicate trials.

Sampling via AIG impinger upstream and AIG impinger and single stage impactor downstream of an operational Pure Air system determined the efficacy levels for the experiment.

The resulting bioaerosol testing demonstrated an efficacy for the seven (7) microorganisms at an average Net LOG reduction of 5.41.

Conclusion

This study demonstrated the effect of two known independent technologies that when collectively used in a scientific method resulted in findings that exceeded the individually expected results for microbial efficacy.

The resulting Net LOG reductions were achieved:

- *Staphylococcus epidermidis at 5.74*
- *E. coli at 3.93*
- *Salmonella Typhimurium at 6.90*
- *Listeria innocua at 4.09*
- *Klebsiella aerogenes at 6.14*
- *Enterobacter cloacae at 6.36*
- *Pseudomonas fluorescens at 4.73*

Application of the Pure Air LDS technology for the Healthcare sector may address many issues within all critical care areas. Specifically, the requirements established by ASHRAE (American Society of Heating, Refrigeration and Air Conditioning Engineers) Standard 170; 20-60% RH and 68-75°F for operating rooms (OR), as well as other critical procedural spaces. Another issue of much greater concern is the ability to control microbial contamination that may impact patient outcomes.

The use of this novel technology for Healthcare facility implementation bodes well for improvement in multiple areas. The demanding requirements within the OR setting, temperature and RH, are easily attained and sustained to exacting parameters.

Additionally, and perhaps more significantly, this technology controls microbial contamination by sanitizing air flows that serve critical care environments. This equates to supplementation of bundling methods that can aid Infection Prevention in the role of reducing infection and ultimately realizing positive patient outcomes.

References

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Infection prevention

The implementation of the Alfa Laval Pure Air LDS technology for eliminating environmental microbial contaminants present within the conditioned air provided to the occupied Healthcare space is another tool that may be applied for the control of HAIs.

The advantages of using Pure Air LDS for Healthcare are many. This single technology is capable of providing and managing moisture levels in the most challenging of critical care areas, ORs, SPD, ICU, Burn and Trauma to a precise control level. More significantly, the ability to eradicate environmental microbial contamination throughout the Healthcare facility aids in the overall infection control scheme to help prevent HAI.

System advantages

Pure Air LDS technology

- Latent load easily controlled
- Energy efficient
- Low maintenance costs
- Standard humidification offering
- Unparalleled moisture removal capacity
- Small equipment footprint
- Germicidal-efficacy near sterilization

This is Alfa Laval

Alfa Laval is active in the areas of Energy, Food, Water and Marine, offering its expertise, products and service to a wide range of industries in some 100 countries. The company is committed to optimizing processes and creating responsible growth. We drive progress, always going the extra mile to support customers in achieving their business goals and sustainability targets.

Alfa Laval's innovative technologies are dedicated to purifying, refining and recycling material. They contribute to enhanced energy efficiency, improved heat recovery, responsible use of natural resources, better water treatment, and reduced emissions. Thereby not only accelerating success for our customers, but also for people and our planet. Making the world better, every day. It's all about ***Advancing better***™.

How to contact Alfa Laval

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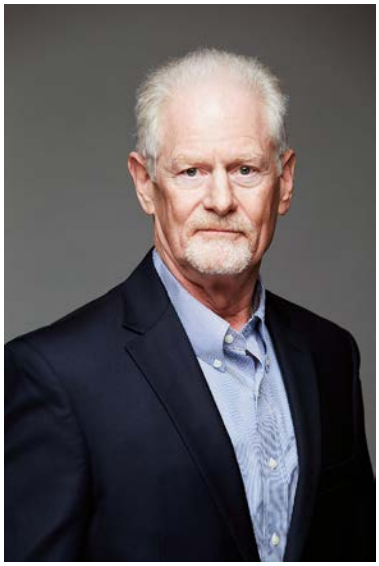
Patrick Leach
Alfa Laval — Pure Air



Patrick Leach is as an authority on the role of HVAC (heating, ventilation and air conditioning) in healthcare and bio-defense. He has been involved in the design and implementation of clinical studies demonstrating the reduction of Healthcare Acquired Infections (HAIs) through application of Ultra Violet Germicidal Irradiation in Hospital HVAC systems. These published studies include Women and Children's Hospital of Buffalo, NY and Georgetown University Hospital in Washington, DC.

Mr. Leach has functioned as an invited consultant with government agencies including The White House Office of Science and Technology, the GSA and Department of Homeland Security.

He has designed and overseen microbial exposure testing in collaboration with the State University of New York at Buffalo, Buffalo, NY, School of Medicine. The resulting study demonstrated the efficacy on pathogens associated with HAIs through exposure to desiccant solutions.

Additionally, he has undertaken design and implementation of a study demonstrating the near sterilization of a controlled airstream containing aerosolized surrogate pathogens via liquid desiccant and ultraviolet germicidal irradiation technologies.

He is a member of ASHE (the American Society for Healthcare Engineering) and APIC (the Association for Professionals in Infection Control and Epidemiology.)

Contact: pat.leach@alfalaval.com

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