

# **CONTAMINATED AIR: The Invisible Threat to Patients and Healthcare Workers**

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**Dr. Linda D. Lee, MBA**

April 7, 2020

# LEARNING OBJECTIVES

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- **Understand how air becomes contaminated in a hospital environment**
- **Explain how pathogenic particles travel on air currents**
- **Describe the dangers that pathogenic air particles pose to the patient and the healthcare worker**
- **Describe the relationship between positive and negative air pressure and how it affects the hospital environment**
- **Learn how ultraviolet light in the C spectrum (UV-C) air purification can reduce aerosols and minimize contamination on surrounding surfaces as a mitigation strategy.**



# BIOGRAPHY

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- Chief Medical Affairs and Science Officer, UV Angel
- Founding member of Stericycle
- MD Anderson Cancer Center, AVP Admin Facilities and Campus Operations
- Adjunct Faculty, UT Health School of Public Health, University of Houston, Walden University
- CH2M Hill, Global Public Health Director
- WM Healthcare Solutions, Director of Operations
- Speaker - SHEA, AIHce, IPAC-Canada, C. Diff Foundation, ASHAE, AHE, APIC
- Published author – AHA
- DrPH- The University of Texas Health Science Center Houston
- MS- University of Arkansas College of Engineering
- BS- Indiana State University Environmental Health Science

**Dr. Linda D. Lee, MBA**

Why we are here...

## HEALTHCARE ASSOCIATED INFECTIONS: THE UNKNOWN KILLER

“CDC estimates that 1 in 31 hospital patients gets a HAI (an infection while being treated in a medical facility).”

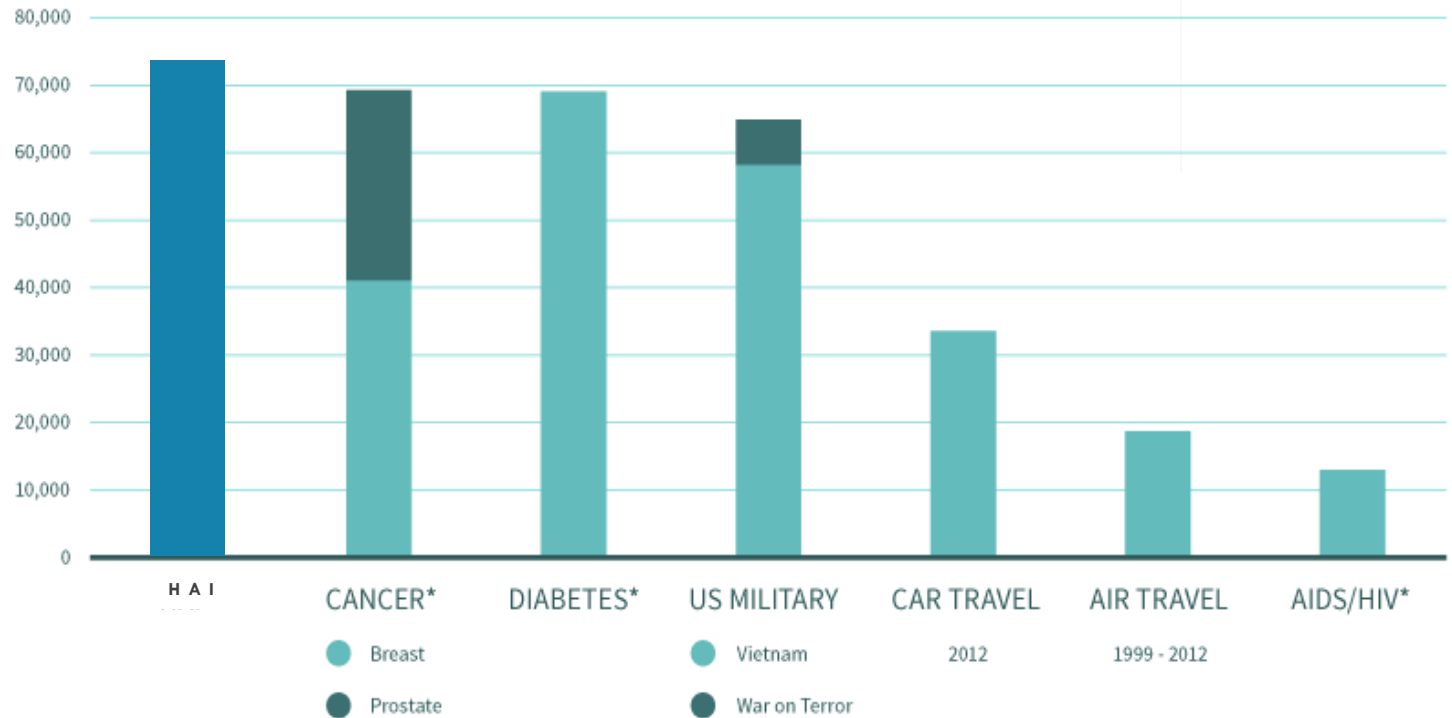
**+720,000**

US citizens that **contract** healthcare-associated infections annually

**+72,000**


US citizens that **die** from healthcare-associated infections annually

(Source: cdc.org)



# PENALTIES AND COSTS

## CMS - Centers for Medicare & Medicaid Services

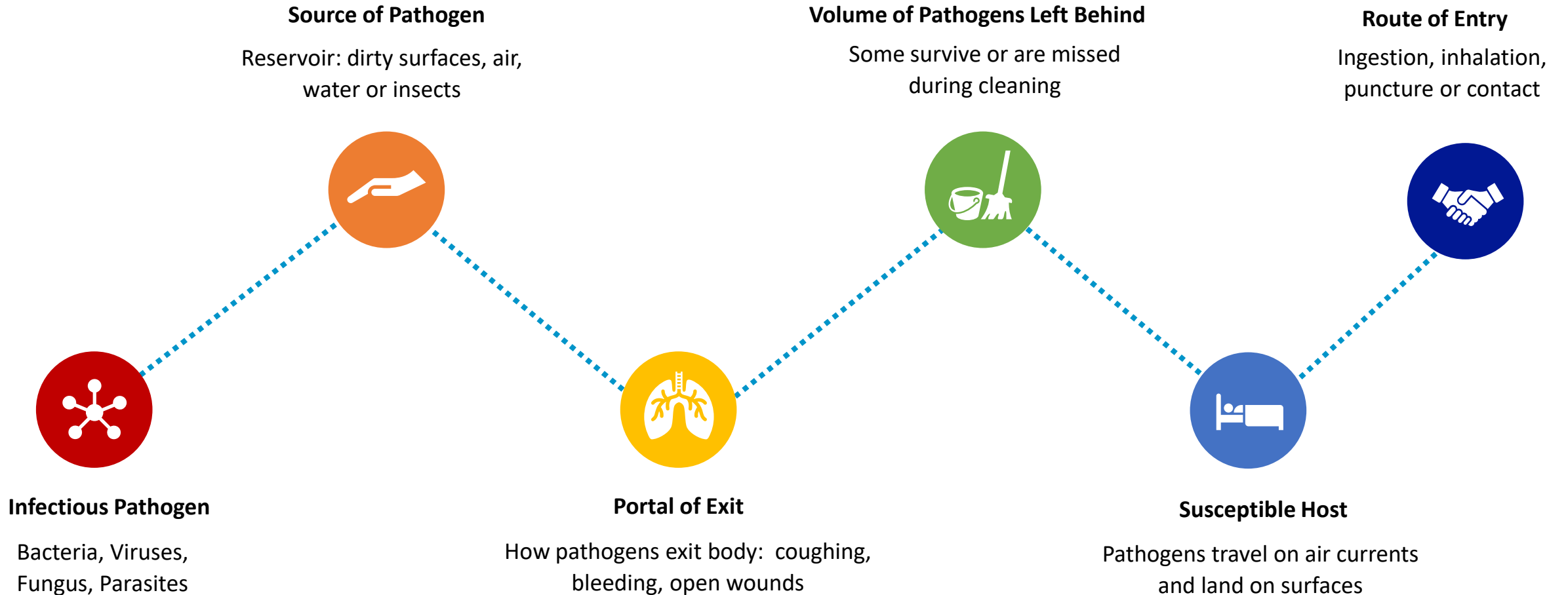
<p><b>\$35-45 Billion</b></p>	<p><b>Cost Annually Directly from Healthcare-associated infections (HAIs) in US</b> <small>(Source: cdc.org)</small></p>
<p><b>\$96-147 Billion</b></p>	<p><b>Total Cost Impact from direct, indirect, and nonmedical social costs of HAIs</b> <small>(Source: beckershospitalreview.com)</small></p>
	<p><b>Hospital-Acquired Condition Reduction Program</b> Medicare payments are significantly reduced for the worst performing hospitals with regards to Hospital Acquired Conditions</p>

## Typical Excess Costs Per Patient of Common HAIs

<p><b>CDI (Clostridium difficile Infection)</b></p> <ul style="list-style-type: none"> <li>• \$11,000</li> <li>• 3.3 extra days</li> </ul>	<p><b>VAP (Ventilator-Associated Pneumonia)</b></p> <ul style="list-style-type: none"> <li>• \$40,000</li> <li>• 13.1 extra days</li> </ul>
<p><b>SSI (Surgical Site Infections)</b></p> <ul style="list-style-type: none"> <li>• \$20,800</li> <li>• 23 extra days (w/ MRSA)</li> </ul>	<p><b>CLABSI (Central Line-associated Blood Stream Infection)</b></p> <ul style="list-style-type: none"> <li>• \$45,800</li> <li>• 15.7 extra days (MRSA)</li> </ul>
<p><b>CAUTI (Catheter-Associated Urinary Tract Infections)</b></p> <ul style="list-style-type: none"> <li>• \$1,000 extra per patient</li> </ul>	

# DISEASE TRANSMISSION

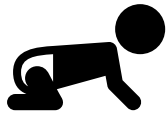
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# WHY IS THE AIR IMPORTANT?

SURFACE CLEANING EFFORTS ARE NOT ENOUGH

Well-child visits account for 700,000+ new influenza cases costing \$500m annually



2011 study of 150,000 people, 82% visited doctor or dentist prior to diagnosis, without visiting hospital



69% of infrequently touched (high-dust) surfaces positive for *C. difficile* in elderly ward



Is Alzheimer's caused by fungus?



380,000 die in LTCF annually (CDC)



MRSA and *C. difficile* survive for months on surfaces



Airborne dispersion plays role in non-respiratory infections

# HIERARCHY OF CONTROLS

CDC, EPA, OSHA

## ENGINEERING

UV Angel Air Handler,  
UV Angel surface disinfection device



## ADMINISTRATIVE

Surface cleaning, UV towers, hand hygiene, prevention/prophylaxis, UV Clean & Charge



## PPE

Masks, gloves, protective equipment





# HEALTHCARE: PRIMARY CURRENT CLEANING PROCEDURES

## Our workers clean... and clean... and clean...

HANDWASHING



CLEANING



TERMINAL CLEANING



HIGH TOUCH SURFACES



World Health Organization Patient Safety **SAVE LIVES** Clean Your Hands

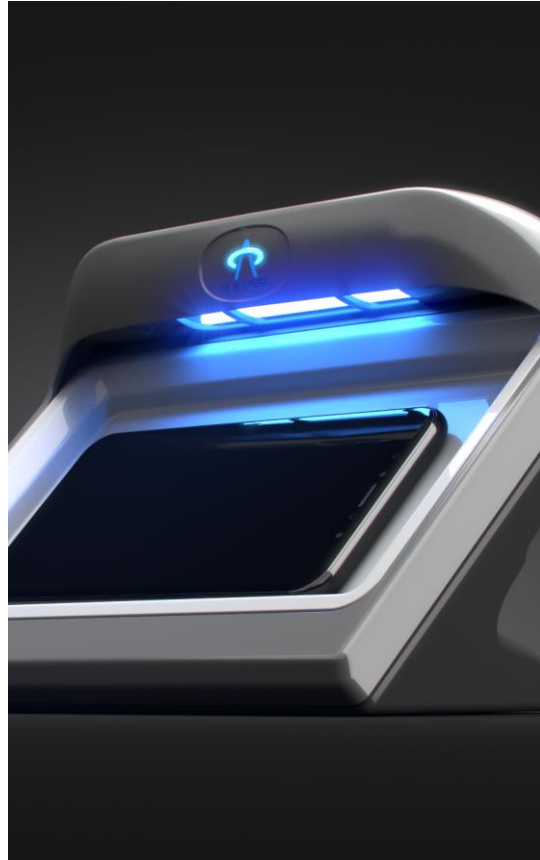


# TECHNOLOGY IS TAKING CHARGE

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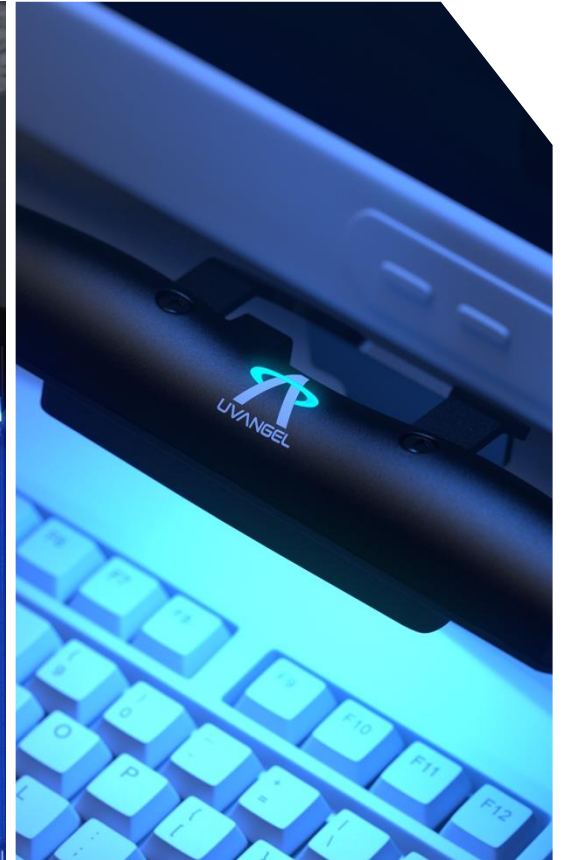
Portable Medical Carts



Mobile Disinfection



UV Air & Surface Disinfection



Integrated Technology

# UV technology has a long history in healthcare.



Upper room air disinfection



UV "robots"



Biological safety cabinet



Air handlers & air conditioning units



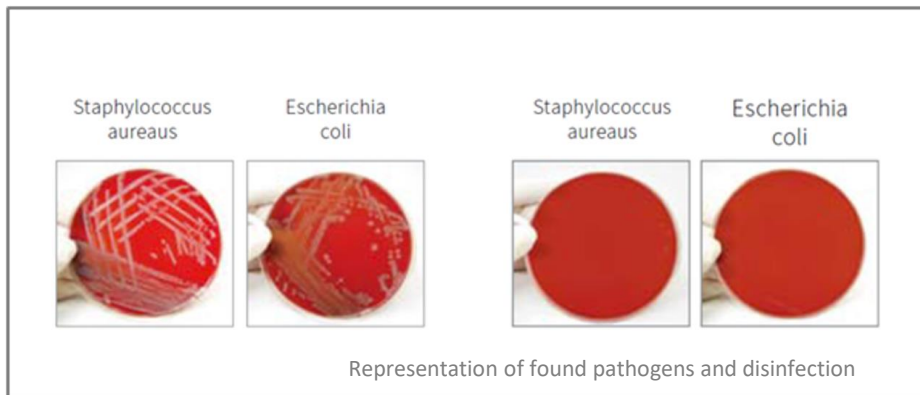
UV lamps in water treatment

# UV-C SURFACE AND AIR TREATMENT

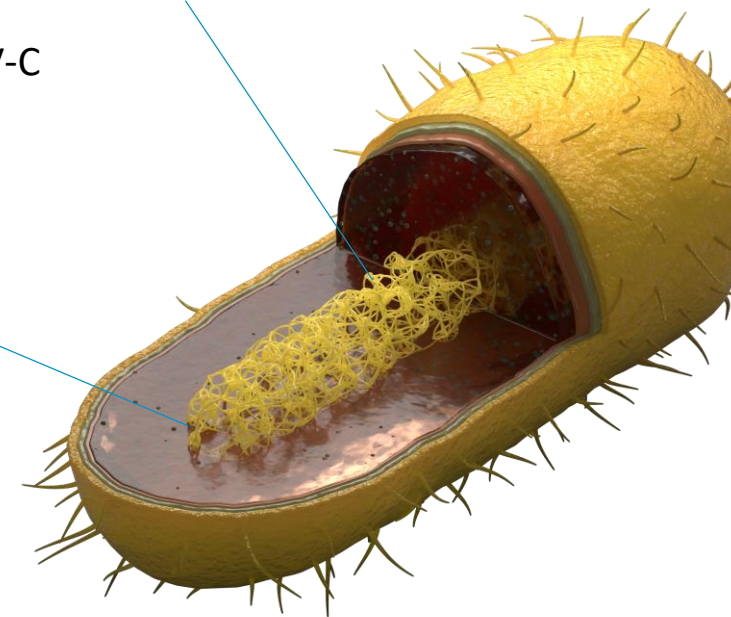
- UV-C light provides rapid, effective inactivation of microorganisms through a physical process.
- When bacteria, viruses, and fungi are exposed to the germicidal wavelengths of UV light, they are rendered incapable of reproducing and infecting.



Before UV-C



After UV-C



UV-C is proven to reduce Coronavirus



### PROVEN EFFECTIVE

- **Gram-negative pathogens** which can cause pneumonias, bloodstream infections, wound and surgical site infections
- **Gram-positive pathogens** such as staphylococcus, streptococcus, enterococci and listeria
- **Fungal pathogen surrogates** which could include pathogens such as aspergillus, yeasts and histoplasmosis

Results showed elimination rates up to **99.99%**

# THE INVISIBLE THREAT

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# PRIOR ROOM OCCUPANCY INCREASES RISK

WHERE DID THE PATHOGENS COME FROM IN TERMINALLY CLEAN ROOM?

Study	Healthcare-associated pathogen	Likelihood of patient acquiring HAI based on prior room occupancy (comparing previously 'positive' room with a previously 'negative' room)
Martinez 2003	VRE – cultured within room	2.6x
Huang 2006	VRE – prior room occupant	1.6x
	MRSA – prior room occupant	1.3x
Drees 2008	VRE – cultured within room	1.9x
	VRE – prior room occupant	2.2x
	VRE – prior room occupant in previous 2 weeks	2.0x
Shaughnessy 2008	<i>C. difficile</i> – prior room occupant	2.4x
Nseir 2010	<i>A. baumannii</i> – prior room occupant	3.8x
	<i>P. aeruginosa</i> – prior room occupant	2.1x

# Air Transports the Pathogens that Contaminate People and Surfaces



## Up to 8 times

- Hospital air samples, on average, are up to 8 times more contaminated than surfaces

## 15 minutes

- MRSA counts remain elevated up to 15 minutes after bed making

## 69% Untouched

- A hospital study on C. diff showed 69% of untouched areas in a C. diff patient's room were contaminated

## 66% Reduced Contamination

- Hospital evidence shows reducing pathogens from the air can reduce surface contamination by as much as 66%



# PATHOGEN SURVIVAL RATE

SOME PATHOGENS CAN HIDE FOR MONTHS

Organism	Survival period
Clostridium difficile	35- >200 days
Methicillin resistant Staphylococcus aureus (MRSA)	14- >300 days
Vancomycin-resistant enterococcus (VRE)	58- >200 days
Escherichia coli	>150- 480 days
Acinetobacter	150- >300 days
Klebsiella	>10- 900 days
Salmonella typhimurium	10 days- 4.2 years
Mycobacterium tuberculosis	120 days
Candida albicans	120 days
Most viruses from respiratory tract (eg: corona, coxsackie, influenza, SARS, rhino virus)	Few days
Viruses from the gastrointestinal tract (eg: astrovirus, HAV, polio- or rota virus)	60- 90 days
Blood-borne viruses (e.g.: HBV or HIV)	>7 days



# HAZARDS OF SHARED MEDICAL EQUIPMENT



## INCREASED RISK

- In 2017 AJIC study\*, hospitalized patients had **1.4 interactions** per hour with medication carts that traveled between patient rooms.



## TRANSMISSION

- Patients frequently had direct or indirect interaction with medical equipment or other fomites that were shared with other patients.



## PROOF

- Equipment was often found to be contaminated with healthcare-associated pathogens.
- **12%** of the cultures found MRSA, VRE or *C. difficile*.



*“Our findings suggest that there is a need for protocols to ensure effective cleaning of shared portable equipment”*

Suwantararat, et. al

# 10 HOSPITAL SITE ANALYSIS, N=2,079

Of the 2,079 samples 1,464 samples were positive for clinically relevant organisms (70%) Below are the average CFU for the organisms tested. (hospital group no-pass policy greater than 10 CFU)

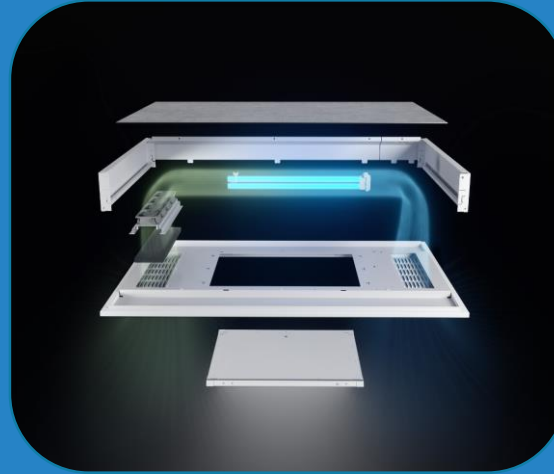
Organism	Average CFU
Total aerobes	111*
Staphylococcus aureus	34
Methicillin-resistant Staphylococcus aureus	35
Enterococcus	137
Vancomycin-resistant enterococcus	54
Gram-negative bacilli	196
Candida spp.	60
Clostridioides difficile	N/A
Too Numerous To Count (limit is 250 CFU)	38% (549)
Gram Negative	199
Enterococcus	42

- All surfaces sampled; WOW Work Surfaces, WOW Keyboard, Wall Arm Keyboard, Nurse Station Keyboard, Patient Vitals Monitor, Pyxis Machines, IV Pumps
- Surface with the highest number of samples positive for HAI Bacteria: Nurse Keyboard (26%), WOW Work Surface (25%), Wow Keyboard (23%)
- Most contaminated surface by avg CFU'S: Pyxis Machine (171 CFU), WOW Work Surface (114 CFU), WOW Keyboard
- Most clinically relevant surface contamination by percent: Wall arm keyboard (86%), WOW Work Surfaces (79%)

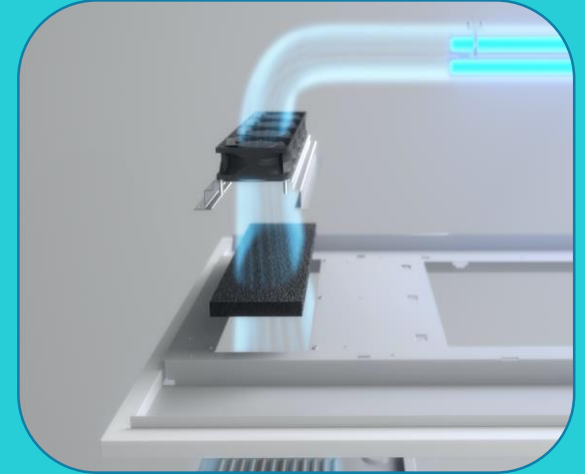
# HOW IN CEILING UV-C AIR PURIFICATION WORKS



Replaces conventional lighting systems so no staff intervention is required



A fully sealed UV-C chamber is enclosed above normal LED room lighting



Fans quietly draw air into the sealed UV-C chamber

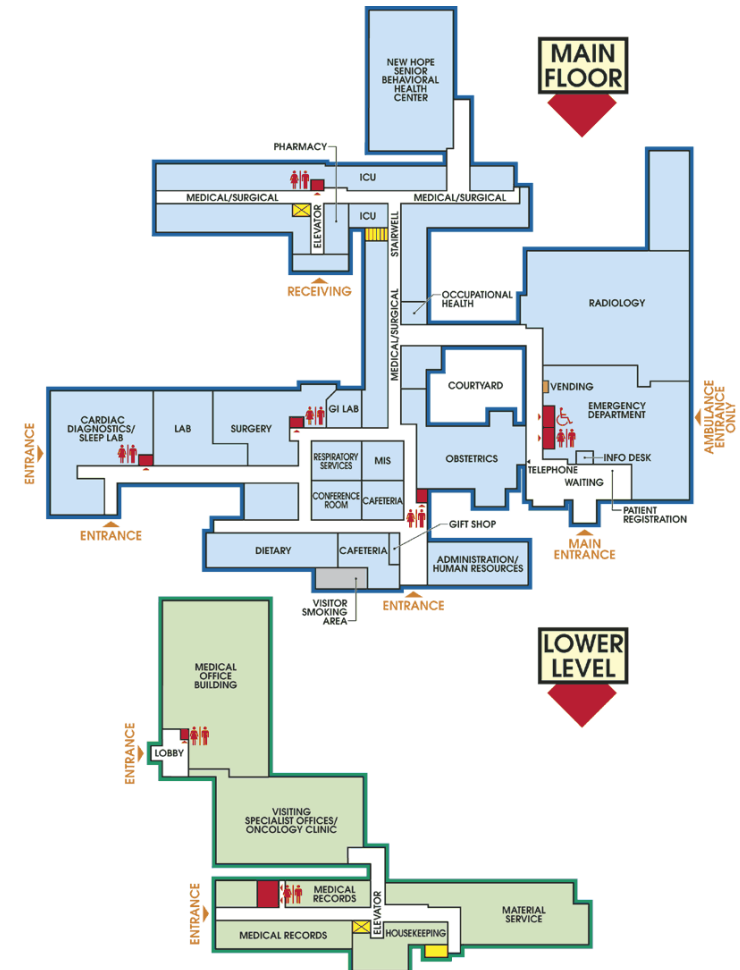
# WHERE CAN UV-C SOLUTIONS BE MOST EFFECTIVE IN A HOSPITAL?

High risk patients

High contamination areas

High density locations

- ICU
- NICU
- PICU
- SCU
- Geriatric
- Oncology
- Hematology
- Burn units
- BMT units
- Bronchoscopy Suites
- Areas surrounding the ORs
- Decontamination rooms
- Employee break rooms
- Soiled utility rooms
- Isolation rooms
- Toilet rooms
- TB-Isolation
- Emergency Dept.
- Nurses stations
- Clinics
- Corridors
- Waiting rooms
- Central supply
- Sterile core
- PACU



# Air Sampling Process



SAS 180 Sampler



Rodac Plates

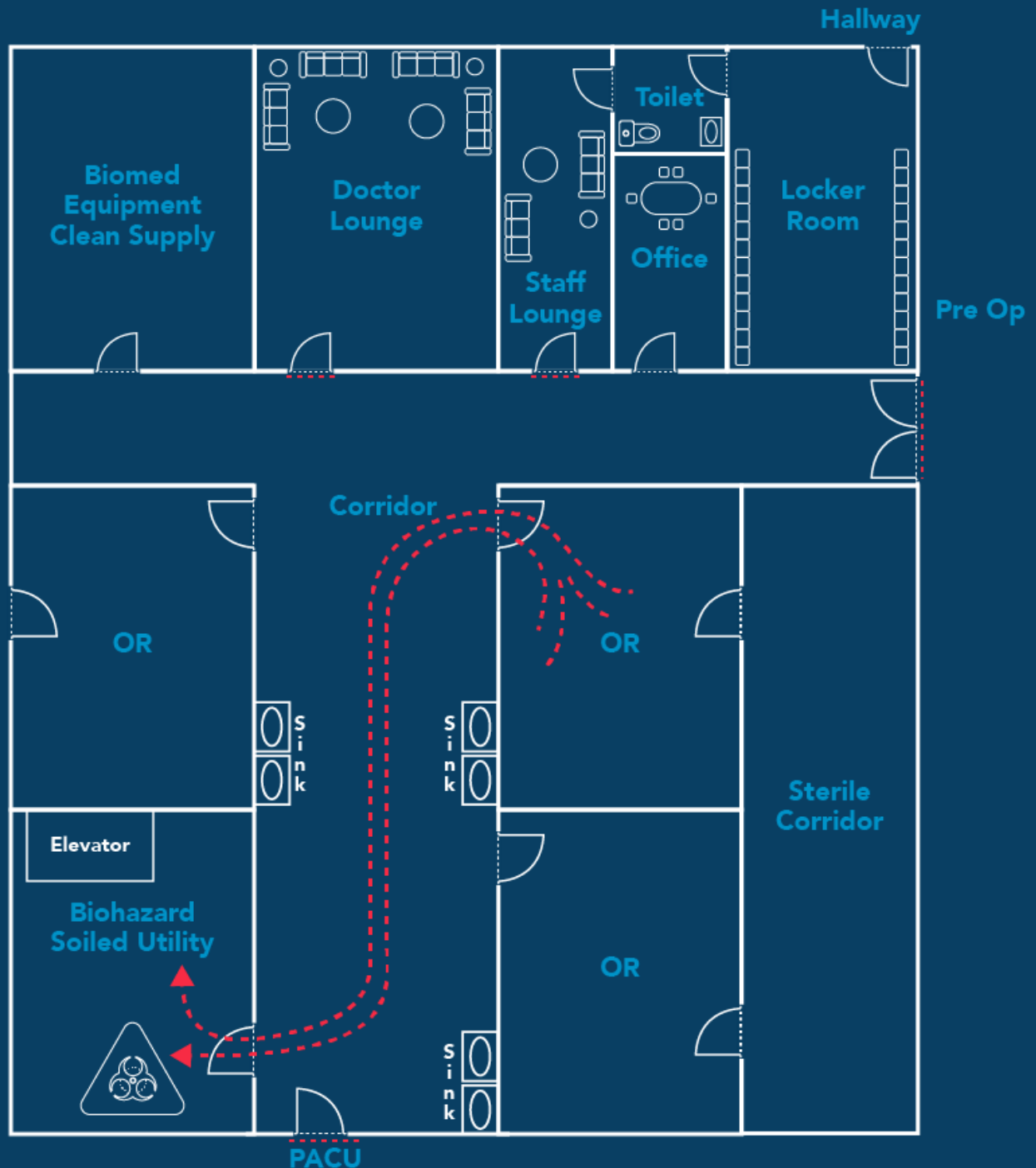


Blood Agar Plates



# Air Flow

The basis of design is not always operational reality



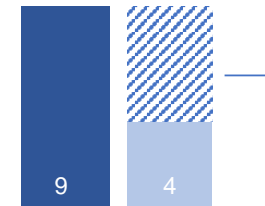


# Infection Reduction Results, KY

Hospital ICU in KY, 12-month study

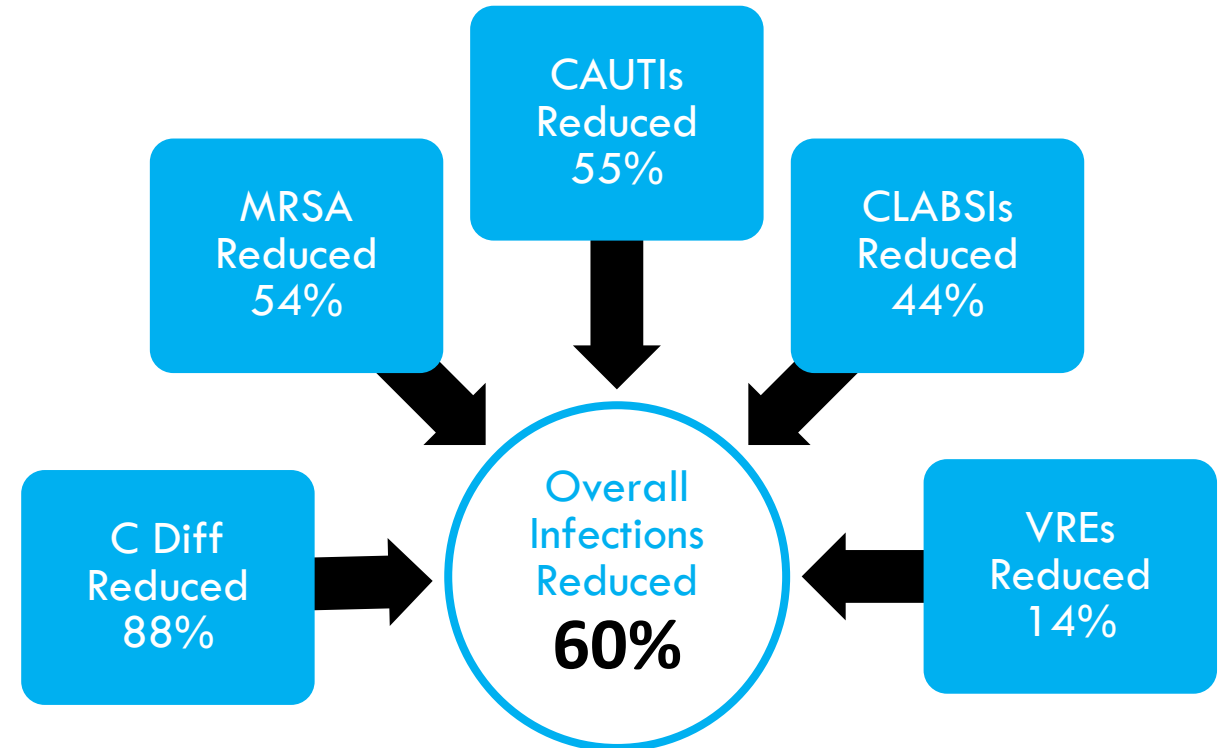
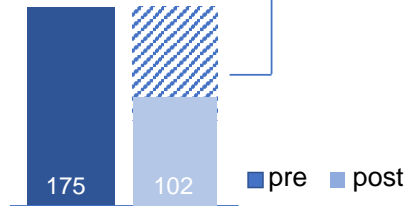
Infection Rate –  
All Infections

**60%**  
Reduction



Bacteria Air Sampling –  
Patient Rooms

**42%**  
Reduction



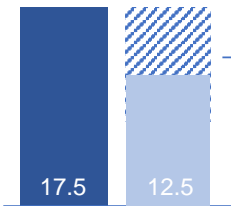
**Staff reported that allergy symptoms and odors were minimized, and absenteeism was lowest where UV-C systems were installed**

# Infection Reduction Results, TN

18 patient vent unit in TN, six-month study

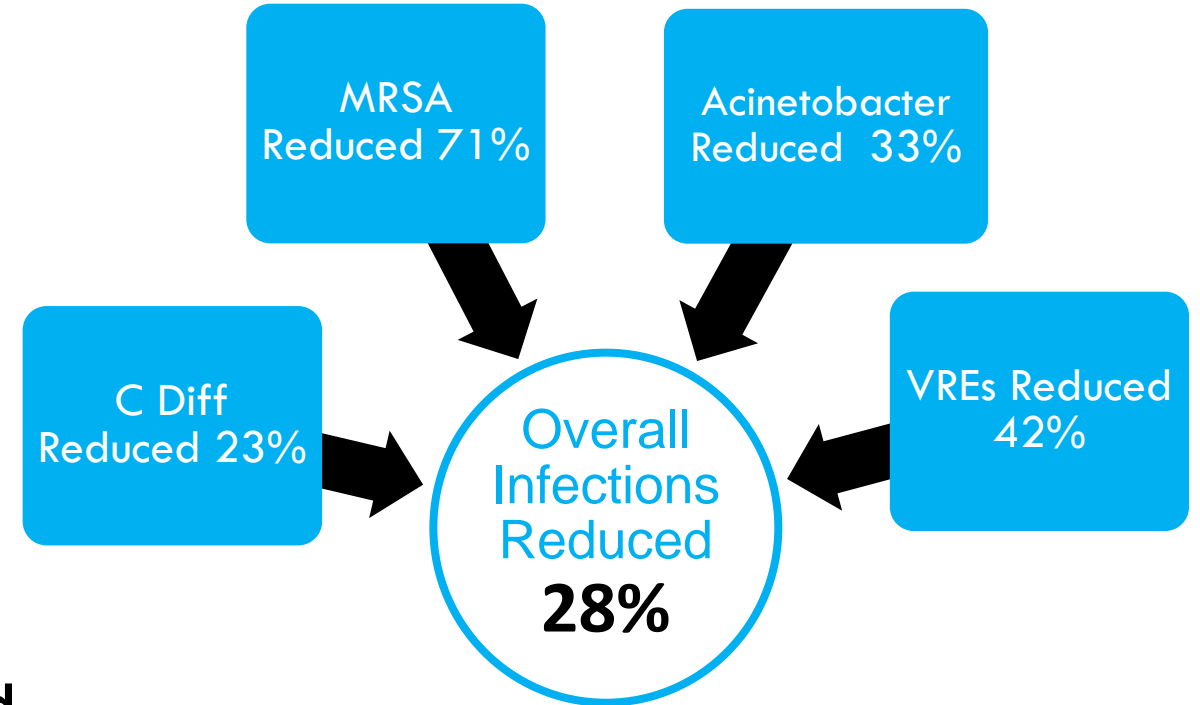
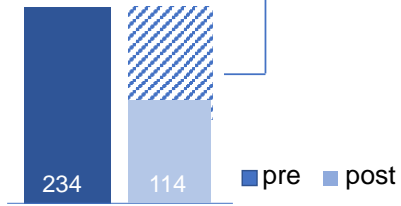
Infection Rate –  
All Infections

**28%**  
Reduction



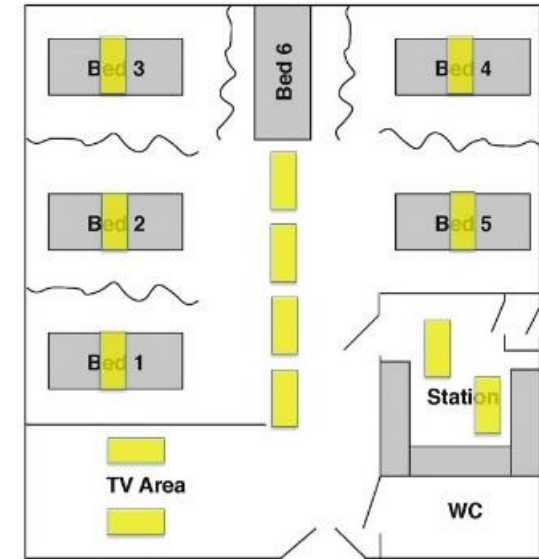
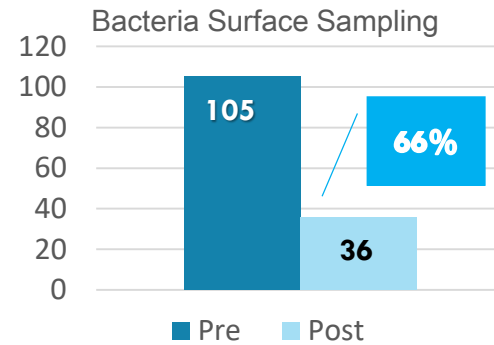
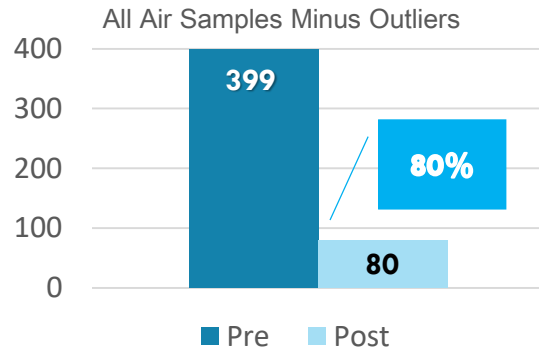
Bacteria Air Sampling –  
Patient Rooms

**51%**  
Reduction



**Nurses and staff report odors were reduced  
and the air felt cleaner and fresher**

# Acute Care Hospital, ED-Psychiatric Holding, Las Vegas

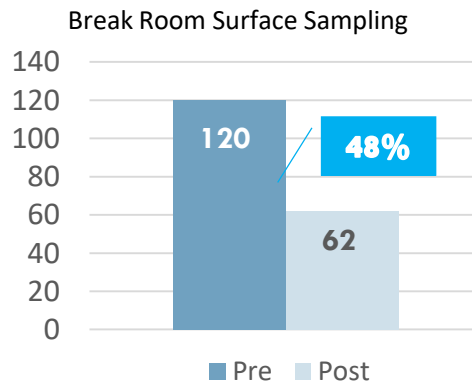
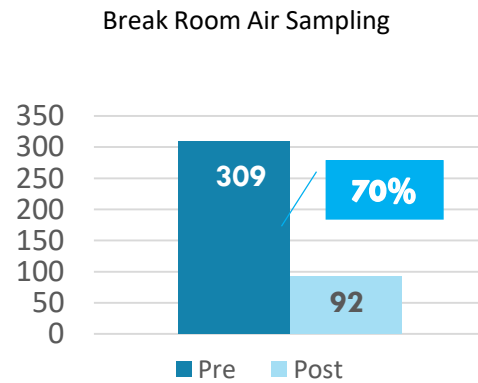
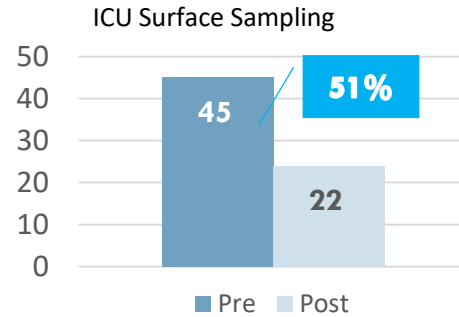
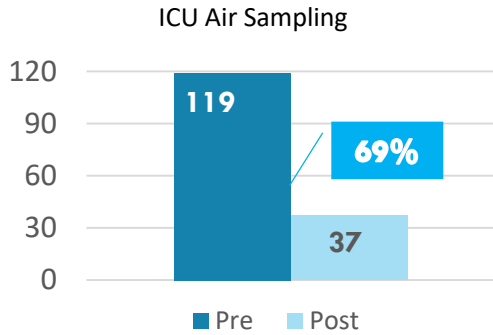


All units of measure are in colony forming units (cfu).

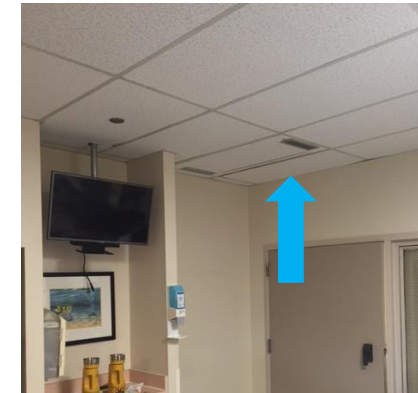
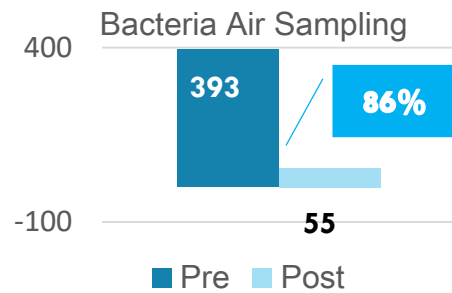
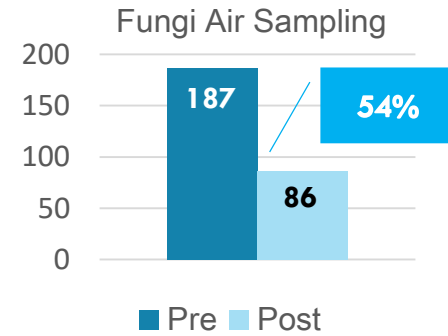
Reported short term study microbe reduction results may not be solely due to product and may not be representative of whole room product microbe reductions.

# Acute Care Hospital, MA

## ICU and OR break rooms

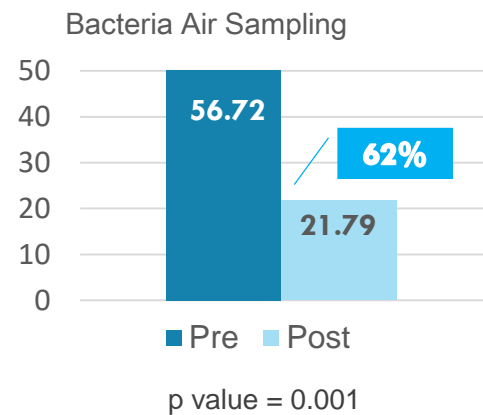
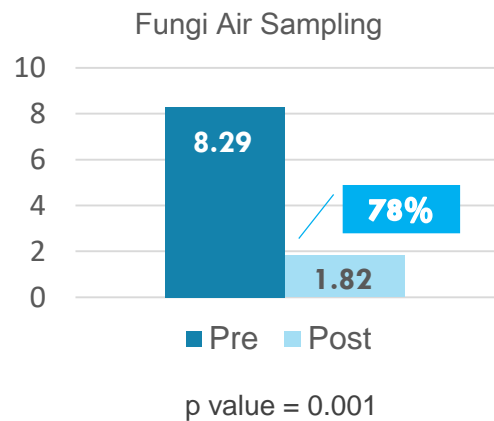


# Children's Hospital Oncology Unit, Texas



\*Post-sampling period, no terminal cleaning took place.

# Children's Hospital, Pharmacy, Memphis, TN



Compounding IV Room	Pre CFUs	Post CFUs	% Decrease
Fungi Air Sampling	3.25	0	100%
Bacteria Air Sampling	1.25	0.125	92%



# AIR: PUBLISHED DATA

## Study Departments – Pharmacy, OR, ICU, Nursing Home, Outpatient Clinic

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American Journal of Infection Control ••• (2017) •••

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American Journal of Infection Control

journal homepage: www.ajicjournal.org

ELSEVIER

Major Article

### Cleaning the air with ultraviolet contact infections in a long-term care facility

Tina Ethington MSN, RN, CEN, NE-BC<sup>a</sup>, St Jett Vaughn BSN, RN, MBA/MHA<sup>a</sup>, Linda D. Lee PhD, MS, MBA, Executive Vice President and Chief Science Officer, Vaidia<sup>b</sup>

<sup>a</sup>Kindred Hospital, Louisville, KY  
<sup>b</sup>American Green Technology, South Bend, IN

Key Words: UV-C, air disinfection, HAI, infection prevention, airborne bacteria

Background: UV-C air disinfection technology is a possible solution to reduce the amount of bacteria circulating in the air, but also been shown to reduce the amount of bacteria found on surfaces. We set to test this technology in a long-term care facility. Methods: We set up a UV-C disinfection system in a long-term care facility. Results: All patients remained free of infections. Conclusion: UV-C air disinfection technology is a possible solution to reduce the amount of bacteria circulating in the air.

INTRODUCTION

Ultraviolet germicidal irradiation (UV-C) in water treatment has been clearly demonstrated to reduce bacterial contamination. In 1877, Robert Koch showed that bacteria died when exposed to sunlight. In 1924, Cohen and Kohn published the germicidal effects of ultraviolet radiation. Sharp, et al. outlined the ultraviolet dosages needed to kill a variety of bacteria.

It has been known for decades that many diseases, such as tuberculosis and influenza, are spread via airborne and/or droplet transmission. More recently, studies have shown that pathogens thought to be spread through direct contact can also become airborne. Robert et al. demonstrated that *Clostridium difficile* (C. diff) spores could be disseminated through the air (4) as did Best et al. (5). Li et al. reviewed 40 studies to show a strong association between building ventilation and the transmission of airborne disease (6). Barnes et al. wrote similarly, but with a slighter focus on hospital acquired infection (HAI), including methicillin-resistant *Staphylococcus aureus* (MRSA) (7). Nazrofi's discussion of indoor bacterial dynamics lays out how the airflow in a space moves particulate matter, including microbes (8).

Knowing that disease could be spread through the air and that short-wave ultraviolet (UV-C) can render pathogens inert, it is logical that the medical community would turn to UV-C to reduce the amount of bacteria circulating in the air. Bolton and Cotton discussed how UV disinfection works generally (9) and Boyce discussed specific technologies for using UV-C in hospitals (10). Ritzala et al. studied how eliminate bacteria (11).

Over the decades, several technologies have been developed. These methods include water filtration systems, using a stand-alone, mobile prototype recommended in terms of also each one has drawbacks in the case of the mobile unit, the requirement that the space provided an excellent indoor air quality, and the use of UV-C. It is concluded that ultraviolet is a useful addition to the disinfection of the air. The potential for surface disinfection and standard cleaning methods that an important source of activity, such as entering and leaving a room, is the use of UV-C on the air and whether cleaning the surface bacteria.

METHODS

Environmental studies were conducted in a long-term care facility (Hospital A) and an outpatient clinic (Hospital C). In each case, the

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Major Article

### Effect of a shielded continuous ultraviolet-C air disinfection device on reduction of air and surface microbial contamination in a pediatric oncology outpatient care unit

Hana Hakim MD, MS, CIC<sup>a,b,c</sup>, Craig Gilliam BS, CIC, FAPIC<sup>a</sup>, Li Tang PhD<sup>a</sup>, Jiahui Xu MSPH<sup>a</sup>, Linda D. Lee DrPH, MBA<sup>a</sup>

<sup>a</sup>Department of Infectious Diseases, St. Jude Children's Research Hospital, Memphis, TN  
<sup>b</sup>Department of Pediatric Prevention and Control, St. Jude Children's Research Hospital, Memphis, TN  
<sup>c</sup>Department of Biostatistics, St. Jude Children's Research Hospital, Memphis, TN  
<sup>d</sup>Unit for Healthcare Contamination, LLC, Austin, TX

Key Words: air disinfection, ultraviolet-C, pediatric oncology

Background: For a clean hospital environment, we evaluated whether ultraviolet-C (UV-C) air disinfection devices reduce airborne and surface microbial contamination in an outpatient pediatric oncology unit. Methods: A pre- and post-intervention study compared 10 test locations, where continuous shielded UV-C air disinfection devices were installed, with 10 control locations without UV-C. Pre- and post-intervention air and surface samples were collected for bacterial and fungal cultures. Prevalence changes in colony forming units (CFU) counts in the test and control locations were compared. Results: Mean bacterial CFU count per cubic meter air and per surface contact plate decreased by 27% (P = .019) and 37% (P = .01), respectively, in test locations compared to 40% (P = .054) and 30% (P = .006) reductions in control locations. Mean fungal CFU count per cubic meter air and per surface contact plate increased by 14% (P = .156) and 10% (P = .048), respectively, in test locations compared to 24% (P = .407) and 21% (P = .34) increases in control locations. Conclusions: There were no consistent statistically significant differences in the air and surface culture results between test locations where UV-C devices were installed and control locations. The effectiveness of UV-C air disinfection in reducing air and surface microbial contamination in outpatient clinical areas where immunocompromised children are encountered was not proven.

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Major Article

### UV-C light and infection rate in a long term care ventilator unit

Douglas W. Kane, MD, Cynthia Finley, RRT, Diane Brown, RRT

Key Words: UV-C, air disinfection, ventilator, infection rate

Background: The use of continuous ultraviolet (UV-C) light in a long-term care ventilator unit may reduce the amount of bacteria circulating in the air, but also been shown to reduce the amount of bacteria found on surfaces. We set to test this technology in a long-term care ventilator unit. Methods: We set up a UV-C disinfection system in a long-term care ventilator unit. Results: All patients remained free of infections. Conclusion: UV-C air disinfection technology is a possible solution to reduce the amount of bacteria circulating in the air.

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### Effect of a shielded continuous ultraviolet-C air disinfection device on reduction of air and surface microbial contamination in a pediatric oncology outpatient care unit

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Key Words: air disinfection, ultraviolet-C, pediatric oncology

Background: For a clean hospital environment, we evaluated whether ultraviolet-C (UV-C) air disinfection devices reduce airborne and surface microbial contamination in an outpatient pediatric oncology unit. Methods: A pre- and post-intervention study compared 10 test locations, where continuous shielded UV-C air disinfection devices were installed, with 10 control locations without UV-C. Pre- and post-intervention air and surface samples were collected for bacterial and fungal cultures. Prevalence changes in colony forming units (CFU) counts in the test and control locations were compared. Results: Mean bacterial CFU count per cubic meter air and per surface contact plate decreased by 27% (P = .019) and 37% (P = .01), respectively, in test locations compared to 40% (P = .054) and 30% (P = .006) reductions in control locations. Mean fungal CFU count per cubic meter air and per surface contact plate increased by 14% (P = .156) and 10% (P = .048), respectively, in test locations compared to 24% (P = .407) and 21% (P = .34) increases in control locations. Conclusions: There were no consistent statistically significant differences in the air and surface culture results between test locations where UV-C devices were installed and control locations. The effectiveness of UV-C air disinfection in reducing air and surface microbial contamination in outpatient clinical areas where immunocompromised children are encountered was not proven.

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ARTICLE IN PRESS

American Journal of Infection Control ••• (2017) •••

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

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Major Article

### UV-C light and infection rate in a long term care ventilator unit

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Key Words: UV-C, air disinfection, ventilator, infection rate

Background: The use of continuous ultraviolet (UV-C) light in a long-term care ventilator unit may reduce the amount of bacteria circulating in the air, but also been shown to reduce the amount of bacteria found on surfaces. We set to test this technology in a long-term care ventilator unit. Methods: We set up a UV-C disinfection system in a long-term care ventilator unit. Results: All patients remained free of infections. Conclusion: UV-C air disinfection technology is a possible solution to reduce the amount of bacteria circulating in the air.

INTRODUCTION

Ultraviolet germicidal irradiation (UV-C) in water treatment has been clearly demonstrated to reduce bacterial contamination. In 1877, Robert Koch showed that bacteria died when exposed to sunlight. In 1924, Cohen and Kohn published the germicidal effects of ultraviolet radiation. Sharp, et al. outlined the ultraviolet dosages needed to kill a variety of bacteria.

It has been known for decades that many diseases, such as tuberculosis and influenza, are spread via airborne and/or droplet transmission. More recently, studies have shown that pathogens thought to be spread through direct contact can also become airborne. Robert et al. demonstrated that *Clostridium difficile* (C. diff) spores could be disseminated through the air (4) as did Best et al. (5). Li et al. reviewed 40 studies to show a strong association between building ventilation and the transmission of airborne disease (6). Barnes et al. wrote similarly, but with a slighter focus on hospital acquired infection (HAI), including methicillin-resistant *Staphylococcus aureus* (MRSA) (7). Nazrofi's discussion of indoor bacterial dynamics lays out how the airflow in a space moves particulate matter, including microbes (8).

Knowing that disease could be spread through the air and that short-wave ultraviolet (UV-C) can render pathogens inert, it is logical that the medical community would turn to UV-C to reduce the amount of bacteria circulating in the air. Bolton and Cotton discussed how UV disinfection works generally (9) and Boyce discussed specific technologies for using UV-C in hospitals (10). Ritzala et al. studied how eliminate bacteria (11).

Over the decades, several technologies have been developed. These methods include water filtration systems, using a stand-alone, mobile prototype recommended in terms of also each one has drawbacks in the case of the mobile unit, the requirement that the space provided an excellent indoor air quality, and the use of UV-C. It is concluded that ultraviolet is a useful addition to the disinfection of the air. The potential for surface disinfection and standard cleaning methods that an important source of activity, such as entering and leaving a room, is the use of UV-C on the air and whether cleaning the surface bacteria.

METHODS

Environmental studies were conducted in a long-term care facility (Hospital A) and an outpatient clinic (Hospital C). In each case, the

**THANK YOU!**

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**ANY QUESTIONS?**

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