The Integration of UVGI in Hospital HVAC Systems

SMSHE Meeting
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Tim Leach,
Director of Healthcare Solutions
Steril-Aire, Inc.
Steril-Aire – A Data Driven

Manufacture of Ultra Violet Germicidal Irradiation Systems for HVAC Reservoir & Room Disinfection
Studies of UVGI in HVAC – Reduced HAIs

- Women & Children’s Hospital of Buffalo
  - Reduced Ventilator Associated Pneumonia (VAP)
  - Published
- Washington, DC Hospital
  - Reduced VAP
  - Reduced Bloodstream Infections
  - Process of publication
- Teaching Hospital - South Carolina
  - Reduced VAP
  - Reduced Bloodstream Infections
  - Process of publication
Today’s Presentation

1. Hospital Acquired Infections (HAIs) - *Impacts*
2. Microorganisms, HAIs & Role of the HVAC – *ASHRAE*
3. Environmental & Clinical Results of UVGI Application in HVAC
4. UVGI System Performance Specification & Verification
Types of Hospital Acquired Infections

- Surgical site infections (SSI)
- Central line-associated bloodstream infections (CLABSI)
- Catheter-associated urinary tract infection (CAUTI)
- Ventilator-associated pneumonia (VAP)
Associated Costs of HAIs

$57,000
Average cost per incidence of VAP

$69,000
Average cost per incidence of CLABSI

Costs for HAIs are no longer reimbursable!
Lost Revenue Opportunity (LOS)

Average additional LOS/VAP = 15 Days

How much revenue would 15 ICU days of reimbursable dollars add to your facility bottom line?

Section 2.2: The Role of HVAC in Infection Control
- Identifies HVAC as a reservoir for microorganisms attributed to infections

Section 2.3: How the Human Body is Affected by Airborne Contaminants
- Chain of infection
The HVAC Role

Chain of Infection

Susceptible Host → Entry → Mode → Pathogen → Source
The Role of the HVAC System

The Building’s Respiratory System
Upstream Side of Intermediate Filter
Is it just dirt?

Is this a reservoir of pathogens?

Is there a link to HAIs?

Can UVGI help?
BIOFILMS: A complex microbial matrix growing on coils, drain pans & final filters
It’s not just dirt…it’s biological

- >50 hospitals
- 21 states
- >100 HVAC Systems
- Intensive Care Units & Operating Suites
- >4,500 cultures
- Culture $10^4 - 10^6$ Colony Forming Units/Sq. In.
# Bacteria Cultured From HVAC Systems

<table>
<thead>
<tr>
<th>Microorganisms</th>
<th>HVAC System Cooling Coils &amp; Final Filters</th>
<th>Supply and Return Air Diffusers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GRAM-NEGATIVE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Pseudomonas sp</em> †</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><em>Pseudomonas aeruginosa</em></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><em>Stenotrophomonas sp.</em></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><em>Acinetobacter sp.</em></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><em>Klebsiella sp.</em></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><em>Serratia sp.</em></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><em>Enterobacter sp.</em></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><em>Enterobacter cloace</em></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><em>Escherichia coli</em></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><em>Corynebacterium sp.</em></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><em>Comamonas sp.</em></td>
<td>●</td>
<td></td>
</tr>
<tr>
<td><strong>GRAM-POSITIVE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Enterococcus sp.</em></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><strong>CONS</strong></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><em>Micrococcus sp.</em></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><em>Streptococcus sp.</em></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><em>Bacillus sp.</em></td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>
Focus on Gram Negative Bacteria

30%
HAI attributed to Gram Negative Bacteria
Becoming increasingly multi-drug resistant:
• *Pseudomonas aeruginosa*
• *Acinetobacter baumannii*
• CRE

70%
Ventilator Associated Pneumonia (VAP)

50%
mortality
# Mold Cultured From HVAC Systems

<table>
<thead>
<tr>
<th>MOLD</th>
<th>HVAC System Cooling Coils &amp; Final Filters</th>
<th>Supply and Return Air Diffusers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Candida sp.</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Aspergillus sp</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Aspergillus niger</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Aspergillus fumigatus</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Penicillium sp.</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Fusarium sp.</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Cladosporium sp.</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Alternaria sp.</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Epicococcum sp.</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Epicococcum nigrum</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Cryptococcus sp.</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Aureobasidium sp.</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Aureobasidium pullulans</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Basidiomycetes sp.</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Acremonium sp.</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Rhodotorula sp.</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Chaetomium sp.</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Stachybotrys sp.</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Stachybotrys chartarum</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Rhizopus sp.</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Verticillium sp.</td>
<td>•</td>
<td></td>
</tr>
</tbody>
</table>
“A Pittsburgh hospital has temporarily stopped organ transplants after three transplant patients contracted a fungal infection and died...The air quality has also been checked for mold. "We have not received any concerning results...Still, it has replaced all of its germ-catching air filters...And it has sent in a disinfecting robot to its ICUs to zap any germs with ultraviolet light.”

CNN
Controlling Environmental Pathogens

Is Filtration Alone a Complete Solution?
Typical Filtration 100 particles
Pre-Filter 35%  65
Secondary Filter 65%  22
22% ineffective

Mechanical Filtration

Outdoor Air
Pre-Filter 35%
Secondary Filter 65%
Cooling Coil
Fan

Return Air
MERV 8
MERV 11
Why Does Continue to be a Problem?

Because Microorganisms Reproduce Quickly

- **Bacteria**: Double every 20 minutes
- **Fungi**: Reproduce Every 2-6 hours Species specific
How effective is a HEPA Filter?

Filter load (24” x 24”) 2,000 CFM
Avg. particulate concentrate (CF air) 100,000
Particles/min confronting filter 200 million
Filter efficiency rate 99.99%
Particles eluding filter 20,000/min

> 28 Million particles every
HEPA Filter Penetration – Why Does it Occur?

- HEPA filters can serve as a source for patient infections
- HEPA filters in HVAC & Ceiling Terminal HEPA in Patient Rooms
- *Chaetomium* contamination (fungal colonization)

*HEPA filters used to create “protective environment” for immunocompromised patients can occur and can serve as a source for patient infections*

### NY State Hospital – Ongoing Study
- Filters in Service < 12 Months
- Bacteria & Fungi / Sq. Inch – Air Entering Media Surface: **112,000 CFU/Sq./Inch**
- Bacteria & Fungi / Sq. Inch – Air Exiting Media Surface: **259,000 CFU/Sq./Inch**

### SC Hospital – Ongoing Study
- Filters in Service < 12 Months
- Bacteria & Fungi / Sq. Inch – Air Entering Media Surface: **3,950 CFU/Sq./Inch**
- Bacteria & Fungi / Sq. Inch – Air Exiting Media Surface: **39,750 CFU/Sq./Inch**
Hospital Infection Preventionists

- View infection prevention systemically
- Bundling of practices make for better HAI reducing outcomes
- We view HVAC hygiene similarly
- Combining and integration of technology
UV radiation can be effective in reducing the virulence of microorganisms and, therefore, in attempting to reduce infection rates . . .
How UVC Works
Germicidal UVC is destructive to organisms.

UV radiation alters the ability of DNA to create the chemical bonds needed for replication.
Timothy Leach and Robert Scheir, Ph.D
Ultraviolet Germicidal Irradiation (UVGI) in Hospital HVAC Decreases Ventilator Associated Pneumonia (NY-14-C023)
Study
6 Tertiary Care Hospitals
Surface Sample Culture Points

- HVAC systems surfaces
- Air supply
- Return diffusers
- Microorganism samples were collected pre-UVGI and 90 day post-UVGI installation
Most Effective UVC Location
Downstream Side Cooling Coil
– Source Control/Prevention
Environmental Microbial Results 90 Days Post

A 5 LOG REDUCTION

<table>
<thead>
<tr>
<th>Area</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVAC cooling coils, condensate drain pans &amp; final filters</td>
<td>1,736,396</td>
<td>33.3</td>
</tr>
<tr>
<td>Patient care area supply and return diffusers</td>
<td>1,092,779</td>
<td>28.5</td>
</tr>
</tbody>
</table>
A technology that improves operational efficiency and provides energy savings.

- 5 Log microbial load reduction per cm² HVAC coil in 6 days!
- 5 Log reduction environmental pathogen & reduced tracheal microbial loads
- Reduced antibiotic use
- Reduced antibiotic resistance
- 50% VAP reduction

$25,000 investment

$800,000 savings

Results of Women and Children’s Hospital of Buffalo

2 ½ year study

Published in *Journal of Perinatology* – Spring 2011
Full-strength coil cleaner applied to the surface of cooling coils then flushed with high-pressure hot water will result in a coil that appears to be clean, but may actually be a hotbed for microbial growth. Increased pressure drop and reduced air volume through such coils is a red flag that says it’s time for a replacement.
UVC Coil Cleaning Results

Coils Before UVC

Coils After UVC

Elimination of pathogen amplifier, reservoir, and transport mode
Sacramento Hospital – Coil Δ P Readings

Pre Power Wash

Post Power Wash

30 Days Post UVGI
Coil Contamination – Biofilm Fungal Spores & Hyphae
Toledo, Ohio Hospital (2) 25,000 CFM Systems – NICU & Labor & Delivery

- Labor & Delivery – Non UVGI Treated
- NICU – UVGI Treated – compartment shared by downstream side cooling coil / upstream side of final filter
UVGI Improves Filter Performance
Ohio Hospital

Non UVGI Treated Filters
- Initial $\Delta P$ - .35”
- Twelve month $\Delta P$ - .95”
- CFU/Sq.Inch $>$ 3,000,000

UVGI Treated Filters
- Initial $\Delta P$ - .30”
- Twelve month $\Delta P$ - .35”
- CFU/Sq.Inch None Detected
Suggested UVGI Performance Specification & System Veri
UVGI System Design – UVC Energy Field

UVGI System is base upon the amount of UVC Energy calculated across the entire irradiated surface.

UVC placement, distribution and spacing dictated by dimensions of irradiated surface.
UVGI Energy is reduced by approximately one log per one inch of coil depth
Measurements Across Irradiated Surface
Soft Glass vs. Quartz Lamps

Output vs Temperature

UVC @ 1m per Inch of Glass ($\mu$W/cm²)

Steril-Aire

Industry

Temperature (°F)
How quickly do microorganisms replicate?

- **Bacteria**
  - Doubles every 20 minutes

- **Fungi**
  - Every 2-6 hours
  - Species specific
## Energy Required for Microorganism Inactivation Efficiencies

\( \mu J = \text{Intensity (} \mu w/cm^2 \text{)} \times \text{Time} \)

<table>
<thead>
<tr>
<th>MICROORGANISM</th>
<th>( D_{90} ) (( \mu J/cm^2 ))</th>
<th>( D_{99} ) (( \mu J/cm^2 ))</th>
<th>( D_{99.9} ) (( \mu J/cm^2 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspergillus niger Spores</td>
<td>135,446</td>
<td>270,892</td>
<td>406,338</td>
</tr>
<tr>
<td>Pseudomonas aeruginosa</td>
<td>5,495</td>
<td>10,984</td>
<td>16,486</td>
</tr>
<tr>
<td>Staphylococcus aureus</td>
<td>2,599</td>
<td>5,198</td>
<td>7,797</td>
</tr>
<tr>
<td>Mycobacterium tuberculosis</td>
<td>3,332</td>
<td>6,664</td>
<td>9,997</td>
</tr>
</tbody>
</table>
UVGI System Energy Field Across Irradiated Surfaces

- Intention is to be a minimum of 99.9% microorganism inactivation at end of lamp life - 12 months of continuous operation
- In exponentially < time than microorganism replication
  - Bacteria double every 20-30 minutes
  - Destroy bacteria < 30 seconds
  - Mold reproduces every 2-6 hours
  - Destroy mold < 10 minutes
Inactivation Rate Calculations

\[ \mu J = \text{Intensity} \ (\mu \text{w/cm}^2) \times \text{Time} \]

- Minimum intensity across entire irradiated surface:
  - 1,225 \( \mu \text{W/cm}^2 \) - Initial
  - 735 \( \mu \text{W/cm}^2 \) after 12 months of continuous operation

- \textit{Pseudomonas aeruginosa}
  - \( 16,486 \mu J/cm^2 \) (Required UVC dose for 99.9% inactivation) \( \div 735 \mu \text{W/cm}^2 = 22.4 \) Seconds

- \textit{Aspergillus niger}
  - \( 406,338 \mu J/cm^2 \) (Required UVC dose for 99.9% inactivation) \( \div 735 \mu \text{W/cm}^2 = 553 \) Seconds
Suggested System Verification Standard

- UVC Intensity readings performed
  - At HVAC operating conditions
  - Factory or field performed
- UVC Intensity readings taken
  - 4 extreme corners of irradiated surfaces
  - Profile across irradiated surfaces
UVGI System Verification
Device

UVC Intensity Readings

- Pre-determined number of UVC measurements
- International Light radiometer/photometer accurate to + 3% radiometric and photometric for NIST transfer standards
- Monochromatic irradiance at 254nm or similar
Portable Radiometer
Coil UV Intensity Profile
Conclusions

- Hospital HVAC systems are reservoirs and disseminators of pathogens commonly attributed to HAIs
- UVGI improves HVAC performance
- UVGI is an effective infection prevention tool
- Energy Field is critical for proper UVGI design
- Improved HVAC & patient environmental hygiene
- Reduces HAIs
- Improves the bottom line
  - Reduced Clinical costs
  - Improves revenue generation – *Reimbursement $$*
Questions?

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Reservoirs of Gram Negative Bacteria

Are community environmental surfaces near hospitals reservoirs for Gram-negative nosocomial pathogens?

Michael Rose MD, David Landman MD, John Quale MD*

American Journal for Infection Control

May 2014
Impacts on Hospital Acquired Infections: Filters & UVGI

- There is no literature to support reduced HAI rates with increased filter efficiencies.
- There is a growing body of literature supporting UVGI integrated with filtration improves IAQ & **REDUCES** HAI rates.
ASHRAE Section 12.4

... It is viewed as a best-practice measure to assist the project team and facility owner in dealing with common complexities and features of a health care facility.
## Airborne Bacteria – Columbus, OH Hospital OR’s

<table>
<thead>
<tr>
<th>Sample</th>
<th>Pre-UVGI</th>
<th>Post-UVGI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>CFU/CFM</td>
</tr>
<tr>
<td>OR 9L</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>OR 10L</td>
<td>2</td>
<td>159</td>
</tr>
<tr>
<td>OR 22</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>OR 23</td>
<td>2</td>
<td>211</td>
</tr>
<tr>
<td>OR 28</td>
<td>2</td>
<td>175</td>
</tr>
<tr>
<td>OR 30</td>
<td>2</td>
<td>21</td>
</tr>
<tr>
<td>AHU 4</td>
<td>2</td>
<td>262</td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
<td>843</td>
</tr>
</tbody>
</table>
A technology that improves operational efficiency and provides energy savings.

Pre-sampling at HVAC & NICU air grilles.

Acinetobacter, Pseudomonas, Staphylococcus

UVGI System installed & monitored for 18 months.

>5 Log HVAC & air grille microbial contamination reduction.

WASHINGTON DC HOSPITAL STUDY
RESULTS - NICU

ZERO VAP
385 days
ZERO BSI
330 days

Results currently Unpublished