UV Surface Treatment Technology
A New Comprehensive Approach to Environmental Hygiene

CAEM (Canadian Association of Environmental Management)
Reaching for the Top at Blue Conference and Trade Show

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UV Surface Treatment Technology  
A New Comprehensive Approach to Environmental Hygiene

Outline:

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II. Types of Whole Room Treatment  
III. UV Treatment History  
IV. How does UV Treatment Work?  
V. Using UV Devices  
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I. Why Whole Room Treatment?

Whole Room Treatment Technologies may provide an effective intervention to meet Environmental Disinfection Concerns:

- **Environment plays a Role** in Healthcare Associated Infections (HAIs) such as MRSA, VRE, *C. difficile*, *P. aeruginosa*, *Acinetobacter*, and Norovirus.

- **Pathogens survive for Days to Months:**
  - Gram (+) and Gram (-) bacteria can survive for months on dry surfaces;
  - Viruses can survive for days to weeks.

- **In hospitals, previous occupancy increases risk:**
  - Patients are at higher risk of acquiring an HAI when their room was previously occupied by an infected patient.

- **Cost of HAIs is High:**
  - An HAI can cost a facility up to $45,000 dollars (CLABSI).
I. Why Whole Room Treatment?

Current HAI reduction interventions aren’t enough.

- **Product & Protocol Breakdown**
  - Only 50% of high risk surfaces in the healthcare setting are properly cleaned\(^1\). Even after thorough physical environmental cleaning and disinfecting pathogens still remain.

- **No one surface disinfectant meets all needs**
  - **Requirements**: Fast, broad spectrum, safe for humans and the environment, compatible with materials & medical devices, odorless, non-staining.
  - **2 different products** with varying protocols are often needed in a facility.

**A comprehensive approach – the use of standard cleaning and disinfection along with whole room treatment – not only aligns with industry best practices, but addresses these current concerns.**

II. Types of Whole Room Treatment

Whole room technologies are being considered to augment manual cleaning & disinfection.

UV Room Treatment & Hydrogen Peroxide Vapor (HPV) both:

- **Clinical**
  - Kill vegetative bacteria and multidrug-resistant organisms (MDROs) on surfaces.
  - Reduce *C. difficile* spores.

- **Operational**
  - Supplement, but do not replace, standard cleaning and disinfection.
  - Used only when the patient is out of the room.
  - Require staff time to move and to monitor system.
  - Are safe if used as directed.
  - Residue free.

- **Financial**
  - Requires significant incremental investment
II. Types of Whole Room Treatment

Advantages of UV Technology

UV does not require dedicated, trained staff members -- housekeepers can easily operate UV systems.

UV does not require rooms to be isolated, HVAC shut off, or vents sealed

UV does not require extensive room “down time”
  • Minimal Room Preparation
  • Short Cycle times vs. HPV of up to 2.5 hours
  • No Vapor needs to dissipate prior to re-entry

UV Capital equipment costs can be lower than HPV systems.
III. UV Treatment History: General

1892 – UV light is found to be germicidal

1916 – US UV Water disinfection

1937/1942 – Air systems: upper room, ventilation, control respiratory infections in schools/barracks

1950’s – Surfaces, especially in duct work, cooling coils, air conditioning
III. UV Treatment History: Healthcare

- **1927-29** — Bactericidal, Virucidal, Fungicidal Doses Established
- **1936** — First overhead UV system in hospitals
- **1957** — UV control spread of TB in hospital wards
- **1994** — CDC acknowledges UV effectiveness against TB
- **2003** — CDC supports UV germicidal irradiation, UV Air & Surface Treatment Committee
- **2007** — Overhead UV system proven to reduce SSIs in ORs
III. UV Treatment History

➔ The use of UV to kill organisms is not new – UV has been successfully used for years for the treatment of Water, Air, and Surfaces.

➔ What IS “new”?

• The ability to easily take effective UV treatment devices from room to room … opening the door for improved surface disinfection protocols that involve both manual cleaning/disinfection & UV Surface Treatment.
III. UV Treatment History
This has led to many UV devices entering the North American market to address Whole Room treatment.
IV. How does UV Treatment Work?

What is UV or Ultraviolet light?

Ultraviolet light is typically referred to as UV-A, UV-B, or UV-C depending on the wavelength of light, in nanometers.

<table>
<thead>
<tr>
<th>Name</th>
<th>Abbreviation</th>
<th>Wavelength Range (nm)</th>
<th>Common Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultraviolet A</td>
<td>UV-A</td>
<td>400 nm - 315 nm</td>
<td>Tanning salons, black lights</td>
</tr>
<tr>
<td>Ultraviolet B</td>
<td>UV-B</td>
<td>315 nm - 280 nm</td>
<td>Medical treatment, curing</td>
</tr>
<tr>
<td>Ultraviolet C</td>
<td>UV-C</td>
<td>280 nm - 200 nm</td>
<td>Microorganism inactivation</td>
</tr>
</tbody>
</table>

UV-A is essentially non-germicidal.

The UV-B and especially the UV-C components are germicidal.

Short wavelength, High Energy UV-C does not pass thru ozone layer or glass.

250-280 nm provides the most germicidal effect, within UV-C range.

Short wavelength, higher energy UV-C does not pass through ozone layer or glass.
IV. How does UV Treatment Work?

UV light kills microorganisms by damaging their DNA.

• When DNA absorbs UV-C energy, pyrimidine molecules such as thymine in the DNA can react to form a dimer, disrupting the DNA sequence.

• With appropriate UV exposure, this dimer formation is widespread.
  – Cells can not grow or reproduce.
  – Cells that cannot replicate are no longer infectious.
  – Cell death occurs.
IV. How does UV Treatment Work?

A closer look at dimerization …

When DNA absorbs UV-C energy, a pyrimidine dimerization reaction can occur.

- Healthy DNA
- Dimerization post UV exposure
  ✓ Cell can’t reproduce
  ✓ Is no longer infectious
IV. How does UV Treatment Work?

Are there other mechanisms?

Yes … Several mechanisms for cell degradation may occur, but …

“Pyrimidine dimers are the most common form of nucleic acid damage, being 1000 times more likely to occur …”  EPA 815-R-06-007, Nov.2006

Healthy DNA

Dimerization post UV exposure
✓ Cell can’t reproduce
✓ Is no longer infectious
IV. How does UV Treatment Work?

Key Factors that Impact the Effectiveness of UV-C Treatment

• How much UV-C light reaches the target surface?
  – UV-C is a line of sight technology
  – Reflectivity of room walls and surfaces
  – Exposure Time & Distance; Lamp Placement

• What is the Total Intensity Output of UV-C device?
  – Lamp Configuration, Number & Output
  – Height of lamps/device (distance off floor too)
  – Other design aspects such as Mast reflective components
IV. How does UV Treatment Work?

Additional Factors that impact the effectiveness of UV-C devices:

• UV-C Intensity varies as a function of distance:
  – As distance from light source increases, intensity decreases

• Type of Microorganism
  – *C. difficile* requires a higher dose vs. easier to kill pathogens like MRSA
IV. How does UV Treatment Work?

UVC Efficacy

- UVC Dose to achieve a specific log reduction varies from one micro-organism to another

UVC Dose Values for 99% Disinfection (2 Log Reduction)

- MRSA: $7,106 \mu W$-sec/cm$^2$
- Clostridium difficile: $38,500 \mu W$-sec/cm$^2$
- Acinetobacter Baumannii: $6,600 \mu W$-sec/cm$^2$
- VRE: $12,600 \mu W$-sec/cm$^2$
- Influenza A: $4,558 \mu W$-sec/cm$^2$
- Aspergillus Niger: $330,000 \mu W$-sec/cm$^2$
IV. How does UV Treatment Work?

**UV-C is typically generated using Low Pressure Germicidal Mercury Lamps**

- All low pressure mercury lamps emit a strong narrow-band in the UV-C spectrum at 253.7 nm.

- This falls in the **highest bactericidal efficacy range, 250-280 nm.**

- UV-C is effective, typically 2-4 log microbial reductions are achieved for pathogens, including *C. difficile.*
IV. How does UV Treatment Work?

→ Advantages of UV-C Surface Treatment

• Good efficacy against a wide range of health care-associated pathogens
• Automated method – no manual labour is required
• Relatively short exposure time required (15 minutes to 50 minutes)
• No residue left following disinfection
• Room does not need to be sealed prior to use
• Low operating costs

Source: Best Practices for Environmental Cleaning for Prevention and Control of Infections In All Health Care Settings - 2nd edition   Provincial Infectious Diseases Advisory Committee (PIDAC)  First Published: December 2009 Revised: May 2012
III. How does UV Treatment Work?

→ Disadvantage of UV-C Surface Treatment

• Destructive effect over time on plastics, vinyls and fading of paints and fabrics
• Low penetrating effect
• Less effective in the presence of organic materials
• Disinfection does not occur in shadowed areas where the ultraviolet light cannot penetrate; equipment and furniture must be moved from the walls
• Expensive for initial outlay of equipment
• Rooms must be vacant of patients and staff during UVI treatment and a warning sign must be posted
• Staff should avoid entry during UVI treatment

Source: Best Practices for Environmental Cleaning for Prevention and Control of Infections In All Health Care Settings - 2nd edition Provincial Infectious Diseases Advisory Committee (PIDAC) First Published: December 2009 Revised: May 2012
IV. How does UV Treatment Work?

Alternate UV-C technology: Xenon (Xe) lamps emit light across the UV (UV-A, UV-B and UV-C), visible, and infrared ranges.

**Pulsed Xe Lamp Absorption spectrum**
- High intensity UV pulses lasting a few milliseconds.
- The light produced is "momentarily up to 20,000 times as intense in the visible light spectrum".
- Xe lamps emit light over a wide range of frequencies → "Broad Spectrum".

**Mercury Lamp Absorption spectrum**

VS.

Pulsed Lamp Technology Features
IV. How does UV Treatment Work?

Disadvantages of pulsed Xe lamps

- Pulsed xenon is broad spectrum – but only 7-10% of the power output/wavelength is germicidal UV-C

- Cycles produce bright, irritating light flashes (~2 flashes per second) similar to fire alarm strobe flashes and may be very loud

- Lamps may require several minutes to warm up

- Short lamp life -- require cooling and very stable power supplies

- Small lamp -- moves up and down to provide wider light source

- Maintenance costs relatively high, may include a mandatory service plan.
  - Devices have many moving parts
  - Ozone filters must be used to prevent ozone transmission.
IV. How does UV Treatment Work?

Wide variation of devices available, for example:

**Optimum-UV™**
- Maximum Output Hg Lamps
- 4 Low pressure Lamps
- Treatment Time ~ 5-10 min
- No ozone filter required

**Tru-D® SmartUVC™**
- Standard Output Hg Lamps
- 28 Low pressure Lamps
- Treatment Time > 45 minutes
- No ozone filter required

**Xenex ® UV**
- 1 Pulsed Xe Lamp
- High Intensity, Millisecond Pulses
- Treatment Time ~ 5-10 min
- Ozone Filter Required
V. Selecting & Using UV Devices

SELECTION:

→ Consider the following when evaluating UV devices:

• Efficacy/Performance

• Quality Design

• Affordability

• Customer support
V. Selecting & Using UV Devices

USE:

- UV technology should be used as a supplement – not as a replacement – to standard terminal cleaning protocols
- Facilities should follow their room cleaning/disinfection protocols before using a UV device
- Consult PDIAC, CDC, or APIC guidelines for additional steps to take as part of a bundled cleaning and disinfection approach
V. Selecting & Using UV Devices

USE: General Guidelines

- UV Light is line of sight. Make sure all common touch surfaces are exposed to UV (ex: call button, TV remote)
- Bed rails up, pre-linen
- Place UV System per approved protocol
- Program cycle time per approved treatment time for the room
- Place Warning Sign on doors when UV System is in operation
- UV treatment is performed in unoccupied rooms
V. Selecting & Using UV Devices

USE: Why is manual cleaning required before whole room treatment? (Nerandzic, et al.; 2012)

- Organic matter reduces the efficacy of UV radiation
- UV-C radiation only penetrates a few millimeters

Studies to specifically evaluate the effect of pre-cleaning surfaces before UV-C treatment are in progress.

“Because contamination of environmental surfaces is common even after surface disinfection and because contamination of healthcare worker hands can transfer these pathogens to patients, resulting in insubstantial numbers of infections, this technology (and other effective room decontamination technology) should be considered for use in selected patient rooms and care areas to augment current surface disinfection practices.”

Dr. William A Rutala, 2010
V. Selecting & Using UV Devices

USE: Recommended departments

UV Systems provide additional pathogen reduction in units with higher-risk patient populations

ICU and CCU

Operating Room

Oncology Unit

Bone Marrow Transplant

“Soil Treatment” Room

Burn Unit
V. Selecting & Using UV Devices

USE: Patient Rooms

Use in Discharge Cleaning & Disinfecting of Isolation Rooms following manual cleaning & disinfecting protocols
V. Selecting & Using UV Devices

USE: Operating Rooms/ Specialty Areas

Use in ORs at the end of the day following manual cleaning & disinfecting protocols
VI. What do the Studies Show?

UV Devices are coming to CANADA ...

2012 – Niagara Health System (NHS) trialed UV System (Steriliz)

“Our team is committed to going above and beyond our industry’s infection prevention and control standards, and this is an additional measure to ensure we are doing everything possible to fight superbugs in the hospital,”

“UV light is a proven disinfectant in other applications, and we expect this technology will greatly reduce the presence of bacteria on surfaces in patient rooms. This in turn would reduce the potential of transmission of infection.” VP Kim Stephens-Woods.

Feb. 2013 Vancouver General Hospital began trialing Tru-D

"We've been very impressed with the almost complete eradication of organisms, even when we take it to high concentrations," "We hope it will decrease the rates of hospital-acquired organisms like superbugs." Dr. Elizabeth Bryce, Medical Director
VI. What do the Studies Show?

UV Devices are effective!

• **Microbial Reduction of Long Term Care-relevant Pathogens** (MS2, Norovirus, *C. diff* & MRSA) Gerba, APIC 2014.

• **When UV was in use there was a 20% decrease** in over all Hospital-acquired MDROs (MRSA, VRE, or other antibiotic resistant gram-negative bacteria) and *C. difficile*. The VRE infection rates during UV use were the lowest for the past 10 years & were sustained for 22 months. *Haas, Montecalvo et al., AJIC 2014*


• **57% decrease in HA-MRSA rate** attributed to a bundled approach including screening, hand hygiene, and UV. *Simmons, et al., JIP, 2013.*

• **Significantly reduce time for UV-C Treatment** by use of a UV-C reflective wall coating (Lumacept) i.e., *S. aureus* from 25 min to 5 min. *C. difficile* from 44 min to 9 min. *Rutala, et al. ICHE 2013, ICHE 2014.*

• **3-4 log reductions** were obtained for MRSA, *Acinetobacter* and VRE with use of UV in OR, intensive therapy units and isolation rooms. *Mahida, et al., JHI, 2013,*
VI. What do the Studies Show?

Clinical Studies show UV Devices are Different

In this study, the Total & Direct Line of Site $\log_{10}$ Reductions of MRSA and *C. difficile* were comparable, but …

- The UV-1 required 3- and 5-fold less time for MRSA and *C. difficile*
- UV-1 provided a 67% reduction in exposure time for MRSA and an 80% reduction in exposure time for *C. difficile* spores vs. UV-2

Indirect Log Reduction is improved for the UV-2 device due to the long cycle times required for operation of this device.

<table>
<thead>
<tr>
<th>Device</th>
<th>Organism (Decontamination Time)</th>
<th>Time (min)</th>
<th>Initial Inoculum</th>
<th>Total Decontamination $\log_{10}$ Reduction</th>
<th>Direct Decontamination $\log_{10}$ Reduction</th>
<th>Indirect Decontamination $\log_{10}$ Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>UV-1 (Formica)</td>
<td>MRSA</td>
<td>5</td>
<td>4.80</td>
<td>3.56</td>
<td>4.10</td>
<td>2.74</td>
</tr>
<tr>
<td></td>
<td><em>C. difficile</em> spores</td>
<td>10</td>
<td>3.69</td>
<td>2.78</td>
<td>3.35</td>
<td>1.80</td>
</tr>
<tr>
<td>UV-2 (Formica)</td>
<td>MRSA</td>
<td>15</td>
<td>4.88</td>
<td>3.94</td>
<td>4.31</td>
<td>3.85</td>
</tr>
<tr>
<td></td>
<td><em>C. difficile</em> spores</td>
<td>50</td>
<td>4.12</td>
<td>2.79</td>
<td>3.90</td>
<td>3.25</td>
</tr>
</tbody>
</table>
VI. What do the Studies Show?

Lab & Clinical Data Vary

<table>
<thead>
<tr>
<th>Microorganism</th>
<th>Distance (ft)</th>
<th>Time (min)</th>
<th>Log Reduction Compared to Control</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>C. difficile</em> (Endospores)</td>
<td>3</td>
<td>4</td>
<td>&gt;4.32</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>5</td>
<td>4.09</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>8</td>
<td>&gt;4.32</td>
</tr>
</tbody>
</table>

Third-party lab micro-efficacy testing

<table>
<thead>
<tr>
<th>Microorganism</th>
<th>Time (min)</th>
<th>Direct Log_{10} Reduction</th>
<th>Indirect Log_{10} Reduction</th>
<th>Total Log_{10} Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>C. difficile</em> (Endospores)</td>
<td>10</td>
<td>3.35</td>
<td>1.8</td>
<td>2.78</td>
</tr>
</tbody>
</table>

Two experimental studies published by Rutala (APIC June 2013, ICHE October 2010)

Other factors that impact total log reduction:
- Type of organism
- Reflectivity of the surface
- Sample preparation

Lab data has fewer variables and is therefore more consistent!
VII. Frequently Asked Questions

1. Do we need to be concerned using a Mercury Bulb for UV-C generation?

- No! If used appropriately, mercury UV lamps are *not* a safety hazard

- Low pressure mercury lamps have about the same amount of mercury as common 4-foot fluorescent bulbs
  - Each contain about 3-20 mg of mercury per lamp
VII. Frequently Asked Questions

2. Is Mercury elsewhere in Hospitals?

- Yes!

- There are many other sources of mercury in hospitals today
  - Blood Pressure Monitors can contain **70-90 g Hg, or 46.5%** of hospital Hg
  - All the fluorescent lamps in a hospital make up only **0.07%** of the Hg in a typical facility

CA Dept. of Health Services, 2000
VII. Frequently Asked Questions

3. Are UV Treatment Devices Safe to Use?

Well-designed UV devices, appropriate safety controls and proper procedures minimize potential hazards from UV-C exposure.

- UV-C treatment is performed in unoccupied rooms – Use a Warning Sign!

- UV-C does not penetrate significantly or cause the damage associated with UV-A and UV-B radiation

- UV-C light is absorbed by ordinary glass, so viewers behind a window are protected.

- Misuse of UV-C devices could make skin red and eyes feel gritty. This usually recedes in 24 to 48 hours.
VII. Frequently Asked Questions

4. Is there a Scent associated with UV Treatment?

• Boyce et al. noted that there was an odor in treated hospital rooms immediately after completing a UV Light Decontamination (UVLD) cycle,
  – But the odor dissipated rapidly and
  – It was shown that it was not due to ozone generation.
  – The scent observed can vary depending on the organic components present in the room air.

• Manufacturers should be able to provide air analyses that demonstrate no harmful gasses are generated by their device.
VII. Frequently Asked Questions

5. What guidance is available for UV in Canada?

**PIDAC → UVI Disinfection of Surfaces**

- Used successfully for final disinfection of isolation units
- Pre-cleaning of visibly soiled surfaces is necessary before UVI disinfection, as UV is absorbed by organic materials and its ability to penetrate is low.
- Recent studies using UV-C light (254-265 nm), have shown significant reductions in vegetative bacteria (e.g., MRSA, VRE, *A. baumannii*) and *C. difficile* spores (a longer exposure time is required to eradicate *C. difficile*).
- UVI treatment of surfaces should not be used alone for disinfection, but may be a good addition to chemical disinfection to lower the bioburden of microorganisms in isolation units and during outbreaks.

*(Health Canada, 2011, 2012c)*
VII. Frequently Asked Questions

5. What guidance is available for UV in Canada continued?

Health Canada → Water Treatment

“Ultraviolet (UV) light disinfection is highly effective for inactivating many types of pathogens.”

(Health Canada, 2011, 2012c).” Technical Document E. coli, Section 7.1.3.2 UV Light Disinfection

Additional Regulatory Guidance under development.

The Therapeutic Products Classification Committee (TPCC) is assessing the issue of generating devices to decide:

• Who should regulate these devices
• How these types of devices should be regulated.

The Canadian EPA plans to develop a policy

Health Canada does allow emerging pathogen claims for disinfectants with approved broad spectrum virucidal claims.
VIII. Summary

Take Home Message:  Daily manual disinfection is necessary, but is often not enough due to:

- HAI's & Current Environmental Cleaning/Disinfection Concerns
- Product & Protocol Breakdown, and the fact that
- No one surface disinfectant meets all needs

→ UV Treatment Technologies offers a successful means to augment manual cleaning & disinfection to better fight persistent microorganisms and reduce the occurrence of healthcare-associated infections.

→ Why adopt UV Room Treatment Technology?

Dr. Robert A. Weinstein of the University of Chicago-Rush Medical Center, sums it up …

“Given the choice of changing human behavior or designing a better device, the device will always be more successful.”

Part IX. Q&A