Are Towelettes Effective for Surface Decontamination in Healthcare Settings?
Prof. Jean-Yves Maillard, Cardiff University, Wales
A Webber Training Teleclass

BEWARE OF DRY-BIOFILMS

Jean-Yves Maillard
Cardiff School of Pharmacy and Pharmaceutical Sciences
Cardiff University

Hosted by Prof. Syed Sattar
Centre for Research on Environmental Microbiology
(and founder of Teleclass Education)

www.webbertraining.com
October 2, 2019

OVERVIEW

- Context
- Environmental surfaces in healthcare settings
- Dry surface biofilms (DSB) in healthcare settings
- Testing solutions against DSB
- Conclusions

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Cost of HAIs:

- 1 billion £ in the UK
- 16 billions $ in the US

Factors Influencing Infection Rates:

- Environmental disinfection
- Identification of infected or colonised patients
- Hand hygiene
  - Contact precautions
- Antimicrobial stewardship

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CONTEXT – RISE OF AMR

NEW ANTIMICROBIALS

DETECTION

INFECTION CONTROL

ENVIRONMENTAL SURFACES IN HEALTHCARE SETTINGS

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**SURFACES & TRANSMISSION**

- **1970s - 1990s: THE DARK AGES: AN ALMOST COMPLETE DENIAL!**

**EVIDENCE**

- Microorganisms survival on surfaces proximal to patients (high-touch surfaces)
- Pathogens survival on surfaces at concentrations sufficient for transmission and transference to the hands of healthcare workers (inc. MRSA, C. difficile, norovirus, VRE...)
- Low infectious dose for some pathogens
  - Lewis et al. AEM 2010;70:6859-66.
- Ample evidence of the genotypic link between bacteria isolated from patients and surfaces proximal to patients

---

**SURFACES & TRANSMISSION**

Environmental contamination with endemic and epidemic MRSA

<table>
<thead>
<tr>
<th></th>
<th>Outbreak</th>
<th>Endemic</th>
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</thead>
<tbody>
<tr>
<td>Floor</td>
<td>9%</td>
<td>50-55%</td>
</tr>
<tr>
<td>Bed linen</td>
<td>…</td>
<td>38-54%</td>
</tr>
<tr>
<td>Patient gown</td>
<td>…</td>
<td>40-53%</td>
</tr>
<tr>
<td>Overbed table</td>
<td>…</td>
<td>18-42%</td>
</tr>
<tr>
<td>Blood pressure cuff</td>
<td>…</td>
<td>75-33%</td>
</tr>
<tr>
<td>Bed or siderails</td>
<td>5%</td>
<td>1-30%</td>
</tr>
<tr>
<td>Bathroom door handle</td>
<td>…</td>
<td>8-24%</td>
</tr>
<tr>
<td>Infusion pump button</td>
<td>13%</td>
<td>7-18%</td>
</tr>
<tr>
<td>Room door handle</td>
<td>11%</td>
<td>4-8%</td>
</tr>
<tr>
<td>Furniture</td>
<td>11%</td>
<td>…</td>
</tr>
<tr>
<td>Flat surfaces</td>
<td>7%</td>
<td>32-36%</td>
</tr>
<tr>
<td>Sink taps or basin fitting</td>
<td>…</td>
<td>…</td>
</tr>
<tr>
<td>Average quoted**</td>
<td>11%</td>
<td>27%</td>
</tr>
</tbody>
</table>


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### SURFACES & TRANSMISSION

#### Survival of pathogens on hospital surfaces

<table>
<thead>
<tr>
<th>PATHOGEN</th>
<th>SURVIVAL TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>S. aureus</em> (incl. MRSA)</td>
<td>7 days to &gt;12 months</td>
</tr>
<tr>
<td><em>Enterococcus</em> spp. (incl VRE)</td>
<td>5 days to &gt;46 months</td>
</tr>
<tr>
<td><em>Acutetobacter</em> spp.</td>
<td>3 days to 11 months</td>
</tr>
<tr>
<td><em>C. difficile</em> (spores)</td>
<td>&gt; 5 months</td>
</tr>
<tr>
<td>Norovirus (&amp; feline calicivirus)</td>
<td>8 h to &gt; 2 weeks</td>
</tr>
<tr>
<td><em>Ps. aeruginosa</em></td>
<td>6 h to 16 months</td>
</tr>
<tr>
<td><em>Klebsiella</em> spp.</td>
<td>2h to 30 months</td>
</tr>
</tbody>
</table>

Kramer et al. BMC Infect Dis 2009;9:130

### SURFACES & TRANSMISSION

#### What is clean – visibly clean?

A number of authors proposed that aerobic colony counts on hand-touch sites should be set.

- A value of < 2.5 CFU/cm² has been proposed based on risk based considerations

- A value of <5 CFU/cm² based on ATP levels attainable values

- A zero tolerance approach for pathogens; 0 CFU/cm²?

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**BREAKING THE CHAIN OF TRANSMISSION**

- **PATIENT** <-> **PATIENT**
- **HEALTHCARE WORKERS**
- **CONTAMINATED SURFACES**
- **ANTIMICROBIAL SURFACES?**

**SURFACE DISINFECTION**
- liquid disinfectants
- antimicrobial pre-wetted wipes
- UV irradiation
- gas

**SURFACES & TRANSMISSION**

- **HCAIs cost the NHS: £1 billion annually (£3,154 per patient)**
  
  HPA 2012
  IFIC 2011

- **20-30% of HCAIs could be avoided with better application of existing knowledge and realistic infection control practices**
  
  National Audit Office 2009

- **Enhanced cleaning practices are reported to save hospitals between £30,000--£70,000**
  
SURFACES & TRANSMISSION

Antimicrobial Surfaces

**Silver**
- Electrical switches
- Flooring
- Keyboards
- Showers
- Waste bins
- Water machines
- Laptop screens
- Mobile phone screens
- Contact lenses
- Paper pens

**Copper**
- Arms of chair
- Bed rails
- Door handles
- Door locks
- Door push plates
- Dressing trolleys
- Electrical switches
- Floor drains
- Handrails
- IV drip poles
- Keyboards
- Nurses' call devices
- Over bed tables
- Table tops
- Taps
- Toilet flush plates
- Toilet seats
- Towel rails

**Triclosan**
- Cutting boards
- Plastic lunchboxes
- Refrigerators

SURFACES & TRANSMISSION

Biocidal products for domestic market

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**DRY SURFACE BIOFILMS**

Biofilms

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Environmental biofilms in hospitals

Dry biofilms on hospital surfaces (DSB)

Semi-dry biofilms on medical devices

Wet/hydrated biofilms in drain systems

What is dry surface biofilm (DSB)?

- Dry surface biofilms are complex microbial communities formed and grown in dry habitats.

- DSB colonize various materials from textile (chair), hard surfaces including plastic (PVC, PP), lacquered wood, wood, metal (stainless steel) to many others

- Dry biofilms have been isolated from diverse environmental conditions: low moisture, varying temperature and nutrients levels.

- Much less attention has been paid to dry biofilms compared to most commonly researched wet/hydrated biofilms

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**Dry surface biofilms in healthcare settings**

Venetian blind cord MRSA +ve

Curtain – MRSA +ve

Desiccation resistance

[Images of biofilms]

Courtesy of K. Vickery, Macquarie University, Sydney, Australia

**HOSPITAL SURFACE SAMPLES**

Samples

Sample processing

- Sterility control
- Microbial recovery in enrichment broth
- Partial identification of pathogens on selective agar

Surface disinfection & recovery

- Exposure to chlorine (1,000 ppm) & peracetic acid (30 g/L) for 1 min
- Neutralisation in D/E neutralising broth & recovery at 37°C

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Dry surface biofilms in healthcare settings

<table>
<thead>
<tr>
<th>Samples</th>
<th>Colorex MRSA Agar</th>
<th>Colorex VRE agar</th>
<th>Colorex Acinetobacter agar</th>
<th>Vogel Johnson Agar</th>
<th>MacConkey Agar</th>
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</thead>
<tbody>
<tr>
<td>Rubber tilt</td>
<td>× (0/3)</td>
<td>× (0/3)</td>
<td>× (0/3)</td>
<td>× (0/3)</td>
<td>✓ (2/3)</td>
</tr>
<tr>
<td>Bed frame</td>
<td>× (0/3)</td>
<td>× (0/3)</td>
<td>× (0/3)</td>
<td>✓ (1/3)</td>
<td>✓ (3/3)</td>
</tr>
<tr>
<td>Side wheel</td>
<td>✓ (1/3)</td>
<td>× (0/3)</td>
<td>× (0/3)</td>
<td>✓ (1/3)</td>
<td>× (0/3)</td>
</tr>
<tr>
<td>Folder-1</td>
<td>✓ (1/3)</td>
<td>× (0/3)</td>
<td>× (0/3)</td>
<td>× (0/3)</td>
<td>× (0/3)</td>
</tr>
<tr>
<td>Folder-2</td>
<td>✓ (2/3)</td>
<td>× (0/3)</td>
<td>× (0/3)</td>
<td>✓ (2/3)</td>
<td>✓ (2/3)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rubber tilt</th>
<th>Cable</th>
<th>Bed wheel</th>
<th>Folder-1</th>
<th>Folder-2</th>
</tr>
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<tbody>
<tr>
<td>Control</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Chlorine (1,000 ppm)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Peracetic acid (30g/L)</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>✓</td>
</tr>
</tbody>
</table>

Dry surface biofilms in healthcare settings

Hospital samples

Commode

Patients' folder

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Dry surface biofilms in healthcare settings

Presence of biofilm containing viable multiresistant organisms despite terminal cleaning on clinical surfaces in an intensive care unit

Intensive care unit environmental surfaces are contaminated by multidrug-resistant bacteria in biofilms: combined results of conventional culture, pyrosequencing, scanning electron microscopy, and confocal laser microscopy

Multi-centre study on dry biofilms from several frequently touch surfaces

- 3 hospitals (Wales, England, Scotland)
- 61 samples

Trauma and orthopaedics, adult intensive care, joint assessment unit, acute admission unit, kidney and transplant, nephrology, cardiology, gastroenterology, intensive therapy unit, and haematology

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Dry surface biofilms in healthcare settings

- keyboards
- patient folders
- clipboards
- sanitising bottles
- DSB abundance
- DSB diversity (NGS)
- DSB appearance (SEM)


Dry surface biofilms in healthcare settings

DSB abundance - swabbing

0%


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Dry surface biofilms in healthcare settings

DSB abundance – recovery in broth

95%


Dry surface biofilms in healthcare settings

DSB abundance – recovery in broth

Next generation sequencing (NGS) analysis of hospital samples


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Dry surface biofilms in healthcare settings

DSB abundance – recovery in broth

<table>
<thead>
<tr>
<th>Species</th>
<th>%</th>
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</thead>
<tbody>
<tr>
<td>S. aureus</td>
<td>34.6</td>
</tr>
<tr>
<td>S. epidermidis</td>
<td>24.6</td>
</tr>
<tr>
<td>B. licheniformis</td>
<td>20.4</td>
</tr>
<tr>
<td>S. lugdunensis</td>
<td>5.9</td>
</tr>
<tr>
<td>B. subtilis</td>
<td>3.8</td>
</tr>
<tr>
<td>B. cereus</td>
<td>3.0</td>
</tr>
<tr>
<td>B. thuringiensis</td>
<td>2.3</td>
</tr>
<tr>
<td>B. amyloliquefaciens</td>
<td>1.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Species</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>S. epidermidis</td>
<td>24.2</td>
</tr>
<tr>
<td>S. aureus</td>
<td>23.8</td>
</tr>
<tr>
<td>B. cereus</td>
<td>9.7</td>
</tr>
<tr>
<td>B. licheniformis</td>
<td>9.5</td>
</tr>
<tr>
<td>B. thuringiensis</td>
<td>9.1</td>
</tr>
<tr>
<td>A. flavithermus</td>
<td>6.3</td>
</tr>
<tr>
<td>B. anthracis</td>
<td>3.5</td>
</tr>
<tr>
<td>B. subtilis</td>
<td>3.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Species</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>S. saprophyticus</td>
<td>20.6</td>
</tr>
<tr>
<td>B. subtilis</td>
<td>19.1</td>
</tr>
<tr>
<td>B. amyloliquefaciens</td>
<td>17.9</td>
</tr>
<tr>
<td>B. pumilus</td>
<td>17.6</td>
</tr>
<tr>
<td>S. epidermidis</td>
<td>5.7</td>
</tr>
<tr>
<td>B. cereus</td>
<td>5.2</td>
</tr>
<tr>
<td>S. aureus</td>
<td>4.5</td>
</tr>
<tr>
<td>B. thuringiensis</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Dry surface biofilms in healthcare settings

DSB appearance: SEM

Image source: https://www.medicalxpress.com/
Dry surface biofilms in healthcare settings

- Multi-species dry biofilms were recovered from 95% of samples.
- All biofilms harbored **gram-positive bacteria** including pathogens associated with HCAIs.
- Dry biofilms had complex composition. Community of 11-27 different microbial species
- DNA of gram negative bacteria was also identified in some of the samples: *Pseudomonas* spp., *Pseudomonas aeruginosa* and *Acinetobacter baumannii*.

Dry biofilms could not be detected by swabbing
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Why DSB can be a problem?

“(…) hand-touch sites are habitually contaminated by hospital pathogens, which are then delivered to patients on hands”

“(…) contamination of the inanimate environment around patients constitutes an important reservoir of MRO with the risk of HAI (…)”

“…” In 2002, the estimated number of HAs in U.S. hospitals, (…) was approximately 1.7 million (…). The estimated deaths (…) were 98,987.”

“(…) evaluating the clinical effectiveness of cleaning and disinfecting methods is challenging”

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Why DSB can be a problem?

Dry surfaces are a major contributor of pathogens persistence on surfaces

Hospital gowns retain superbugs even after being treated with disinfectant.

Many treatments fail to eradicate dry surface biofilms highlighting their high resistance and transferability.

We hypothesize that dry surface biofilms play a significant role in Healthcare associated infections.

TESTING SOLUTIONS AGAINST DSB

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Solutions?

- Improved hand hygiene
- Improved cleaning
- Disinfectants targeting DSS
- Improved monitoring of contamination level

Dry surface biofilm model

- **Day 0**
  - Incubation
  - Wet phase (15%)
  - Rotary shaker at room temperature
- **Day 2**
  - Dry phase (media drained out)
  - Incubation at 37°C/25°C in incubator
- **Day 4**
  - Wet phase (15%)
  - Rotary shaker at room temperature
- **Day 6**
  - Dry phase (media drained out)
  - Incubation at 37°C/25°C in incubator
- **Day 8**
  - Wet phase (15%)
  - Rotary shaker at room temperature
- **Day 10**
  - Dry phase (media drained out)
  - Incubation at 37°C/25°C in incubator
- **Day 12**
  - Dry bioburden ready for testing

**NOW**
- *Staphylococcus aureus*
- *Candida auris*
- *Bacillus subtilis*
- *Bacillus linchenformis*
- *Klebsiella pneumoniae*

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Dry surface biofilm model

Dry artificial biofilm

Environmental biofilm

Dry surface biofilm model – S. aureus

Without organic load

X2,500  x5,000

With organic load

X2,500  x5,000

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Dry surface biofilm model – *S. aureus*

Without organic load

<table>
<thead>
<tr>
<th>Day</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td><img src="image1.png" alt="Image" /></td>
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<tr>
<td>8</td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>12</td>
<td><img src="image3.png" alt="Image" /></td>
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</table>

With organic load

<table>
<thead>
<tr>
<th>Day</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
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<tr>
<td>8</td>
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</tr>
<tr>
<td>12</td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
</tbody>
</table>

Testing against dry surface biofilm

- ASTM International E2967-15


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Testing against dry surface biofilm

Effect of chlorine on dry biofilm
- 1000 and 5000ppm – recovered 1 day
- 10,000ppm – Recovered after 8 days
- 20,000ppm – Recovered after 12 days

Transmission following touching a dry biofilm

Testing against dry surface biofilm

- AISI 430 stainless steel sterile discs
- $10^6$ CFU/ml S. aureus NCTC 10788
- $10^6$ CFU/ml C. auris DSM 21092
- 1ml of inoculum per disc
- TSB/MEB + 3 g/L BSA
- 48h wet/dry cycles for of 12 days
- High uniformity ensuring testing repeatability
- More resistant to disinfection treatment than dried bacterial suspension

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### Treatment efficacy against *S. aureus* DSB

**Log$_{10}$ reduction**: number of bacteria killed / removed after treatment

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Log$_{10}$ reduction</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No OL</td>
<td>OL</td>
</tr>
<tr>
<td>Commercial wipe A</td>
<td>3.54</td>
<td>2.68</td>
</tr>
<tr>
<td>Commercial wipe B</td>
<td>6.73</td>
<td>3.55</td>
</tr>
<tr>
<td>Commercial wipe C</td>
<td>0.25</td>
<td>4.97</td>
</tr>
<tr>
<td>Commercial wipe D</td>
<td>6.87</td>
<td>&gt;8.45</td>
</tr>
<tr>
<td>Commercial wipe E</td>
<td>4.65</td>
<td>1.08</td>
</tr>
<tr>
<td>NaOCl 1,000ppm</td>
<td>5.76</td>
<td>5.05</td>
</tr>
<tr>
<td>NaDCC 1,000ppm</td>
<td>0.51-1.58</td>
<td>4.07</td>
</tr>
<tr>
<td>ClO$_2$ 200ppm</td>
<td>0</td>
<td>1.69</td>
</tr>
<tr>
<td>VH$_2$O$_2$</td>
<td>3.08</td>
<td>0.71</td>
</tr>
<tr>
<td>Cold gas plasma</td>
<td>6.27</td>
<td>0.84</td>
</tr>
</tbody>
</table>

OL: organic load

### Treatment efficacy against *S. aureus* DSB

**Transferability**: determines how well bacteria in a dry biofilm can transfer between surfaces post treatment

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Log$_{10}$ reduction</th>
<th>Transferability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No OL</td>
<td>OL</td>
</tr>
<tr>
<td>Commercial wipe A</td>
<td>3.54</td>
<td>2.68</td>
</tr>
<tr>
<td>Commercial wipe B</td>
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<td>3.55</td>
</tr>
<tr>
<td>Commercial wipe C</td>
<td>0.25</td>
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<td>&gt;8.45</td>
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</tr>
<tr>
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<td>5.05</td>
</tr>
<tr>
<td>NaDCC 1,000ppm</td>
<td>0.51-1.58</td>
<td>4.07</td>
</tr>
<tr>
<td>ClO$_2$ 200ppm</td>
<td>0</td>
<td>1.69</td>
</tr>
<tr>
<td>VH$_2$O$_2$</td>
<td>3.08</td>
<td>0.71</td>
</tr>
<tr>
<td>Cold gas plasma</td>
<td>6.27</td>
<td>0.84</td>
</tr>
</tbody>
</table>

OL: organic load

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### Treatment efficacy against *S. aureus* DSB

**Regrowth: time needed for a dry biofilm to recover after treatment**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Log₁₀ reduction No OL</th>
<th>Log₁₀ reduction OL</th>
<th>Transferability No OL</th>
<th>Transferability OL</th>
<th>Regrowth (days) No OL</th>
<th>Regrowth (days) OL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial wipe A</td>
<td>3.54</td>
<td>2.68</td>
<td>75%</td>
<td>78%</td>
<td>3.9</td>
<td>2</td>
</tr>
<tr>
<td>Commercial wipe B</td>
<td>6.73</td>
<td>3.55</td>
<td>31%</td>
<td>33%</td>
<td>6.2</td>
<td>5</td>
</tr>
<tr>
<td>Commercial wipe C</td>
<td>0.25</td>
<td>4.97</td>
<td>100%</td>
<td>85%</td>
<td>1.3</td>
<td>2</td>
</tr>
<tr>
<td>Commercial wipe D</td>
<td><strong>6.87</strong></td>
<td>&gt;8.45</td>
<td>8%</td>
<td>1%</td>
<td><strong>2</strong></td>
<td>4.3</td>
</tr>
<tr>
<td>Commercial wipe E</td>
<td>4.65</td>
<td>1.08</td>
<td>39%</td>
<td>50%</td>
<td>&gt;1.5</td>
<td>1.3</td>
</tr>
<tr>
<td>NaOCl 1,000ppm</td>
<td>5.76</td>
<td>5.05</td>
<td><strong>44%</strong></td>
<td>100%</td>
<td>4.8</td>
<td>3.9</td>
</tr>
<tr>
<td>NaDCC 1,000ppm</td>
<td>0.51-</td>
<td>1.58-</td>
<td>100%</td>
<td>69%</td>
<td>1.3-1.7</td>
<td>1-2</td>
</tr>
<tr>
<td>ClO₂ 200ppm</td>
<td>4.07</td>
<td>5.91</td>
<td>100%</td>
<td>100%</td>
<td>1.3</td>
<td>1.1</td>
</tr>
<tr>
<td>VHG₂O₃</td>
<td>0</td>
<td>1.69</td>
<td>100%</td>
<td>100%</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Cold gas plasma</td>
<td>6.27</td>
<td>0.84</td>
<td>19%</td>
<td>100%</td>
<td>2.5</td>
<td>1</td>
</tr>
</tbody>
</table>

OL: organic load

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### Development of a dry biofilm model – *C. auris*


**Candida auris** Dry Surface Biofilm (DSB) for Disinfectant Efficacy Testing

Katerina Lekahosis and Jean-Yves Maillard. School of Pharmacy and Pharmaceutical Sciences, Cardiff University, Cardiff CF10 3TB, UK.

* Correspondence should be addressed to Jean-Yves Maillard.

Received: 30 November 2018 / Revised: 12 December 2018 / Accepted: 14 December 2018 / Published: 21 December 2018

Abstract

*Candida auris* is an emerging pathogen that needs to be controlled effectively due to its association with a high mortality rate. The presence of biofilms on dry surfaces has been shown to be widespread in healthcare settings. The produced *C. auris* dry surface biofilm (DSB) on stainless steel surfaces. In the present study, the effect of DSB on the number of colony-forming units (CFU) of *C. auris* DSB on stainless steel surfaces was assessed. The determination of the number of colony-forming units (CFU) per square centimeter (CFU/cm²) was used to calculate the bacterial load of the biofilm. The results showed that the biofilm formed on stainless steel surfaces was highest for *C. auris* DSB. Although no reduction in viability was observed at 24 hours, a significant reduction in viability was observed at 48 hours. The results suggest that *C. auris* DSB is a high-risk biofilm that needs to be controlled effectively.

Keywords: Candida auris; dry surface biofilm; disinfection; antibiotic; CFU/cm²; bacterial load; biofilm; disinfection efficacy; resistance.©

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**Figure**

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Development of a dry biofilm model – C. auris

With organic load

X2,500

x5,000

Treatment efficacy against C. auris DSB

Log$_{10}$ reduction / removal

Transferability

Regrowth

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DSB KNOWLEDGE

BEWARE OF DRY BIOFILMS

- Widespread on environmental (dry) surfaces
- Cannot be detected by swabbing (of dry surfaces)
- Less susceptible to biocidal products if no mechanical removal
- Can easily be transferred post-treatment (when wet)
- Product formulation matters

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**BEWARE OF DRY BIOFILMS**

- Contribute to HCAI?
- Difficult to eradicate
- Patients and staff directly exposed
- Harbor pathogens
- Require improved control measures

**THANK YOU**

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- M MAGOGA
- R WEISER
- K KERR
- D ROPOSTE
- D D MUIR

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Macquarie University, Australia
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