ANTIMICROBIAL ENVIRONMENTAL SURFACES IN HEALTHCARE SETTINGS
CAN THEY REALLY BE BENEFICIAL?

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

Hosted by Bruce Gamage
Provincial Infection Control Network of British Columbia

www.webbertraining.com October 27, 2016

OVERVIEW

- Antimicrobial & surfaces
- Principle for activity
- Test for antimicrobial surfaces
- Dry biofilms
- Considerations
ANTIMICROBIAL & SURFACES

Some facts

- HCAIs cost the NHS: £1 billion annually (£3,154 per patient)
  26-33$ billion annually 99000 death
  
  HPA 2012
  National Audit Office. The management and control of hospital acquired infection in acute NHS trusts in
  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 additional cleaner calculation based
  on MRSA – 27% reduction
  
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ANTIMICROBIAL & SURFACES
Some facts

- Microorganisms survival on surfaces proximal to patients (high-touch surfaces)
- Low infectious dose for some pathogens
- Pathogens survival on surfaces at concentration sufficient for transmission
- Genotypic link between bacteria isolated from patients and surfaces

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

ANTIMICROBIAL & SURFACES
Some facts

<table>
<thead>
<tr>
<th>Organism</th>
<th>Persistence</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Acinetobacter</em> spp.</td>
<td>3 days to 5 months</td>
</tr>
<tr>
<td><em>Clostridium difficile</em> (spores)</td>
<td>5 months</td>
</tr>
<tr>
<td><em>Enterococcus</em> spp. including vancomycin-resistant enterococci</td>
<td>5 days to 4 months</td>
</tr>
<tr>
<td><em>Escherichia coli</em></td>
<td>1.5 h to 16 months</td>
</tr>
<tr>
<td><em>Klebsiella</em> spp.</td>
<td>2 h to 30 months</td>
</tr>
<tr>
<td><em>Mycobacterium tuberculosis</em></td>
<td>1 day to 4 months</td>
</tr>
<tr>
<td><em>Pseudomonas aeruginosa</em></td>
<td>6 h to 16 months</td>
</tr>
<tr>
<td><em>Salmonella typhimurium</em></td>
<td>10 days to 4.2 years</td>
</tr>
<tr>
<td><em>Shigella</em> spp.</td>
<td>2 days to 5 months</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em>, including MRSA</td>
<td>7 days to 7 months</td>
</tr>
<tr>
<td><em>Haemophilus influenzae</em></td>
<td>12 days</td>
</tr>
</tbody>
</table>

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ANTIMICROBIAL & SURFACES
Some facts

CONTAMINATED SURFACES

PATIENT

PATIENT

HEALTHCARE WORKERS

ANTIMICROBIAL SURFACES?

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

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ANTIMICROBIAL & SURFACES

Some facts

Possible scenarios for decontaminating high-touch environmental surfaces by wiping

- Soak dry towelette in disinfectant & wipe
- Spray disinfectant & wipe with dry towelette
- Environmental surfaces & objects
- Fog, mist or fumigate & wipe with a towelette
- Wipe with a prewetted towelette

Barker & Maillard AJIC 2012;41:597-610.

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ANTIMICROBIAL & SURFACES
Some facts

Increasing body of knowledge which highlights improved infection control practices can help break the chain of transmission

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ANTIMICROBIAL & SURFACES
Antimicrobial surfaces

Environmental surfaces – not medical devices such as implants etc.

Aim

✓ To reduce microbial surface bioburden in conjunction with current surface cleaning protocols
✓ To minimise interventions but NOT to replace it

NHS Rapid Review Panel concerned with the reality of antimicrobial surface manufacturer’s performance claims
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ANTIMICROBIAL & SURFACES
Antimicrobial surfaces – global usage

We touch our nose, mouth or eyes about 16 times in one hour.

- 27% of us admit not washing our hands after visiting the toilet.
- 9.8% of us use our mobile phone in the bathroom.
- 70% of us eat lunch at our desks.
- Bacteria feed on food crumbs.
- A computer mouse harbours 3x more germs than a toilet handle.

10 million bacteria live on the average office desk.

7,500 bacteria lurk in the average office keyboard.

ANTIMICROBIAL & SURFACES
Antimicrobial surfaces

<table>
<thead>
<tr>
<th>Silver</th>
<th>Copper</th>
<th>Triclosan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical switches</td>
<td>Arms of chair</td>
<td>Cutting boards</td>
</tr>
<tr>
<td>Flooring</td>
<td>Bed rails</td>
<td>Plastic lunchboxes</td>
</tr>
<tr>
<td>Keyboards</td>
<td>Door handles</td>
<td>Refrigerators</td>
</tr>
<tr>
<td>Showers</td>
<td>Door locks</td>
<td></td>
</tr>
<tr>
<td>Waste bins</td>
<td>Door push plates</td>
<td></td>
</tr>
<tr>
<td>Water machines</td>
<td>Dressing trolleys</td>
<td></td>
</tr>
<tr>
<td>Laptop screens</td>
<td>Electrical switches</td>
<td></td>
</tr>
<tr>
<td>Mobile phone screens</td>
<td>Floor drains</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Handrails</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IV drip poles</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Keyboards</td>
<td></td>
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<tr>
<td></td>
<td>Nurses’ call devices</td>
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<td></td>
<td>Over bed tables</td>
<td></td>
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<td></td>
<td>Table tops</td>
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<tr>
<td></td>
<td>Taps</td>
<td></td>
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<tr>
<td></td>
<td>Toilet flush plates</td>
<td></td>
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<tr>
<td></td>
<td>Toilet seats</td>
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</tr>
<tr>
<td></td>
<td>Towel rails</td>
<td></td>
</tr>
</tbody>
</table>

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ANTIMICROBIAL & SURFACES
Antimicrobial surfaces – healthcare settings

- Many healthcare facilities around the world have installed copper/copper alloy fittings

- Clinical trial in an acute medical ward in UK – copper alloys presented a 90% microbial reduction vs. standard fittings
  

- One study claimed copper surfaces can reduce HCAIs by >50%
  
  Salgado et al. Infect Control Hospital Epidemiol 2013; 34:479-486

Copper fittings in an ICU £105,000 vs. standard fittings £74,400

ANTIMICROBIAL & SURFACES
Antimicrobial surfaces – healthcare settings

- Metallic
  Copper alloys, silver – not a coating – no issues with duration

- Coating
  Metallic and other biocides
  Duration, scratches, robustness?

- Spray to deposit some coating
  Uniformity?
  Biocides?
  Duration?
  Robustness?

- Embedded in materials
  Bio-availability? – type of biocides
  Preservative effect i.e. protect the material from degradation?
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ANTIMICROBIAL & SURFACES
Antimicrobial surfaces – healthcare settings

- **Role**
  - Decrease microbial bioburden on surfaces
  - Decrease the transfer of pathogens form surface to healthcare staff, patients and visitors
  - Decrease the transfer of pathogens between objects

- **Challenges**
  - Contact time – how fast do they work?
  - Duration
  - Compatibility with cleaning products
  - Aesthetic
  - Costs

- **Claims**
  - Decrease HAIs - kill all pathogens on surface
  - Stop all microbial transfer
  - Kill all pathogens in seconds
  - No need for additional cleaning

PRINCIPLES FOR ACTIVITY
PRINCIPLES FOR ACTIVITY
General considerations

- Contact
- Penetration
- Accumulation

PRINCIPLES FOR ACTIVITY
Factors affecting antimicrobial efficacy

Factors inherent to the product
✓ concentration
✓ formulation
✓ water activity
✓ pH*

Factors inherent to the application
✓ surface
✓ organic load (soiling)
✓ temperature
✓ contact time
✓ humidity

Factors inherent to the micro-organism
✓ type
✓ number
✓ phenotype
✓ pH*
24
PRINCIPLES FOR ACTIVITY
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- number
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- pH*

JIS-Z-2801 standard efficacy test
- Temperature: 35°C
- Humidity: 100% humidity
- Contact time: 24 hours

Surface Temperature and Relative Humidity, UHW

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TESTS FOR ANTIMICROBIAL SURFACES

Parameters to consider

Physical conditions in healthcare settings
- Temperature
- Relative humidity
- Duration – high touch surfaces
What is the contact time between individuals touching a high touch surface?

Microorganisms
How are micro-organisms deposited on surface?
- Contamination from hands – some RH
- Contamination from the atmosphere – dry, on fomites
- Contamination from objects – low RH
TESTS FOR ANTIMICROBIAL SURFACES
Parameters to consider

- Over a one year period high-touch surfaces were sampled for temperature and humidity to help set parameters in vitro.
- Gastroenterology, ICU and Theatre at University Hospital Wales

![Surface temperature chart]

![Surface relative humidity chart]

TESTS FOR ANTIMICROBIAL SURFACES
Current standard tests

ISO22196 / JIS Z 2801
Plastics. Measurement of antibacterial activity on plastics surfaces

ASTM E2180-01
Standard Test Method for Determining the Activity of Incorporated Antimicrobial Agent(s) In Polymeric or Hydrophobic Materials

ASTM E2149-01
Standard Test Method for Determining the Antimicrobial Activity of Immobilized Antimicrobial Agents Under Dynamic Contact Conditions

XP G 39-010
Propriétés des étoffes bioétoffes à propriétés antibactérienne par contact
TESTS FOR ANTIMICROBIAL SURFACES

Current standard tests - ISO22196 / JIS Z 2801

• Test surfaces inoculated with bacterial suspension, covered with a film, incubated at 35°C, 100% RH for 24 h, viable bacteria determined

Problems?
• 37°C and 100 % RH – too high, not realistic
• 24 h contact – too long
• Liquid interface

---

TESTS FOR ANTIMICROBIAL SURFACES

Current standard tests - ASTM E2180-01 / ASTM E2149-01

• Test for fabrics not hard surface – high volume to sample ratio hydrophobic textiles, plastics

• Material in contact with an nutrient broth for 1-24 h (ASTM E2180-01) or 0.3% agar slurry in saline for 24H (ASTM E2149-01) at 37°C.

Problems?
• Temperature and RH not controlled
• 1-24 h contact – too long
• Bacteria seeded in the broth or agar – wet inoculum
• Agar/broth – facilitate the diffusion of antimicrobial – e.g. ionic silver

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TESTS FOR ANTIMICROBIAL SURFACES
Current standard tests - XP G 39-010

- Test for fabrics not hard surface – cell suspension intimate contact test
- Material in contact with an agar plate inoculated with test bacteria (S. aureus and K. pneumoniae) microorganisms for 1 min with 200 g weight
- Use of a neutralizer to quench the activity of the biocide

Problems?
- Not for hard surface
- Temperature and RH not controlled
- Bacteria seeded in the agar – wet inoculum
- Agar – facilitate the diffusion of antimicrobial – e.g. ionic silver

TESTS FOR ANTIMICROBIAL SURFACES
Current standard tests

- A surface may pass ISO22196 or ASTM E2149-0. However a lower incubation conditions (i.e. in situ) may not present the same antimicrobial activity – false positive claims by manufacturers?
- No current ‘dry inoculum’ standard test exists
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TESTS FOR ANTIMICROBIAL SURFACES
Do antimicrobial surface work? – from the literature

In vitro testing
Researchers have utilised a low-volume, ‘dry’ inoculum that dries within 5 s

• Use of 1 µL (‘dry’) or 20 µL (‘wet inoculum’) on Cu surfaces

• Staphylococci were inactivated by both moist (40 µL) and dry (1 µL) Cu surfaces

Field trials
• Cu resulted in diminishing bacterial surface-loads up to 90% as compared to controls

• Decrease rate of HAI and/or MRSA or VRE colonization in ICU rooms
  (0.071 vs. 0.123; P=0.020)
• Decrease rate of HAI from 0.081 to 0.034 (P=0.013)

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TESTS FOR ANTIMICROBIAL SURFACES
Do antimicrobial surface work? – Novel test

Dry inoculum test set-up – to mimic dry touch contamination

Deposition of dry/wet inoculum on surfaces

Incubate surfaces for 30 min, 60 min and 24 h at:
- 37°C-100% RH
- 20°C-50% RH
- 20°C-40% RH

Enumerate viable bacteria

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Tests for Antimicrobial Surfaces

Do antimicrobial surface work? – Novel test

Wet inoculum (S. aureus) testing results - aerosol deposition

At 37°C-100% RH copper alloys displayed a >4 log_{10} reduction of viable S. aureus after 30 min

At in-use conditions antimicrobial activity was slower; 60 min required for >4 log_{10} reduction

20°C-40% RH; A. baumannii

>4 log_{10} reduction of viable A. baumannii after 30 min at in-use conditions

Copper not sporicidal – <1 log_{10} reduction after 24 h and no significant differences between stainless steel and copper (P>0.05)
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TESTS FOR ANTIMICROBIAL SURFACES
Do antimicrobial surface work? – Novel test

Dry inoculum testing results- dry aerosol deposition

20°C-40% RH; S. aureus

- Some copper alloys presented a >1 log₁₀ reduction after 60 min
- After 24 h all copper alloys presented a >1 log₁₀ but <2 log₁₀ reduction in viable S. aureus and A. baumannii

TESTS FOR ANTIMICROBIAL SURFACES
Do antimicrobial surface work? – Novel test

Transfer of S. aureus from a dry inoculum - dry aerosol deposition

- Transfer from latex glove from Cu surface incubated at 20°C-40% RH
- Transfer from latex glove to Cu surface and then incubation at 20°C-40% RH

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**DRY BIOFILMS?**

**MICROBIAL BIOFILMS**

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Biofilm resistance mechanisms

<table>
<thead>
<tr>
<th>Observation</th>
<th>Biofilm resistance mechanisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diffusion gradient</td>
<td>Establishing a reduced local biocide concentration</td>
</tr>
<tr>
<td>Non-specific neutralising interaction with cell constituents</td>
<td>Enhanced bacterial insusceptibility</td>
</tr>
<tr>
<td>Lysed bacterial community offering mechanistic inactivation as a result of increased organic load</td>
<td>Degradation of antimicrobial</td>
</tr>
<tr>
<td>Efflux (more effective against lower concentrations)</td>
<td>Slow growth/metabolism</td>
</tr>
<tr>
<td>Early stress-response</td>
<td>A local chemical gradient (reduced nutrients / O₂) can retard growth rate, mitigating against biocide injury</td>
</tr>
<tr>
<td>Formation of pockets of surviving bacteria</td>
<td>Selection for increased resistance</td>
</tr>
<tr>
<td>Dormant cells (which re-grow rapidly in the presence of exudates released from lysed community)</td>
<td>Increased genetic exchange</td>
</tr>
<tr>
<td>Nature of micro-organisms (i.e. some being more resistant than others)</td>
<td>Acquisition of new resistance determinants</td>
</tr>
</tbody>
</table>

Venetian blind cord MRSA +ve

Curtain – MRSA +ve

Desiccation resistance

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


1. Department of Microbiology, School of Medicine and Pharmacology, University of Western Australia, Perth, WA, Australia
2. University College London, London, UK
3. University of Manchester, Manchester, UK
4. Instituto de Investigación Sanitaria Ramón y Cajal, Madrid, Spain
5. University College London, London, UK

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ABSTRACT

Background: Biofilms are crucial to the survival of multiresistant bacteria in clinical settings. Multiresistant bacteria are often found in biofilms, and the increases in antibiotic resistance observed across healthcare settings are thought to be partly due to the biofilm-protective effect on susceptible organisms. Biofilm resistance has been studied for decades, but currently little is known about the role of desiccation in biofilm resistance.

Aim: To examine the role of desiccation in biofilm resistance.

Methods: In vitro biofilm resistance experiments were performed with Staphylococcus aureus strains (ATCC 43300 and MRSA) to determine their sensitivity to desiccation. Biofilms were grown on clinical surfaces for 72 h at 37°C. Biofilms were then transferred to a desiccation chamber and subjected to a temperature cycling regime of 1°C - 46°C over a period of 24 h. After desiccation, biofilms were transferred back to the growth media and incubated for 24 h to determine the viability of biofilms and the formation of new biofilms.

Results: The results showed that desiccation significantly reduced the viability of biofilms and the formation of new biofilms. The percentage of biofilms surviving desiccation was significantly lower than that of control groups. The survival rate of biofilms subjected to desiccation was significantly lower than that of control groups. The results also showed that the survival rate of biofilms subjected to desiccation was significantly lower than that of control groups.

Conclusions: The results of this study indicate that desiccation can significantly reduce biofilm resistance. This finding suggests that desiccation may be an effective strategy for controlling biofilm resistance in clinical settings.

Desiccation resistance

Venetian blind cord MRSA +ve

Curtain – MRSA +ve

Courtesy of K. Vickery, Macquarie University Sydney, Australia

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MICROBIAL BIOFILMS
“Dry” biofilm - a new challenge

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

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MICROBIAL BIOFILMS
“Dry” biofilm - a new challenge

<table>
<thead>
<tr>
<th>CT</th>
<th>Log_{10} reduction</th>
<th>Growth-R</th>
</tr>
</thead>
<tbody>
<tr>
<td>GTA 2% w/v</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1.33 ± 0.35</td>
<td>24 h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>48 h</td>
</tr>
<tr>
<td>60</td>
<td>4.19 ± 0.00</td>
<td>24 h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>48 h</td>
</tr>
<tr>
<td>PMA 3% w/v</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0.93 ± 0.34</td>
<td>24 h</td>
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<td></td>
<td></td>
<td>48 h</td>
</tr>
<tr>
<td>60</td>
<td>0.13 ± 0.30</td>
<td>24 h</td>
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<td>48 h</td>
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<tr>
<td>Chlorine 1000 ppm</td>
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<td></td>
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<tr>
<td>5</td>
<td>0.80 ± 0.71</td>
<td>24 h</td>
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<tr>
<td></td>
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<td>48 h</td>
</tr>
<tr>
<td>60</td>
<td>2.19 ± 0.02</td>
<td>24 h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>48 h</td>
</tr>
</tbody>
</table>

- Dry biofilms are present on dry surfaces of the ICU
- Multi-species and contain organisms from the skin, gut and environment
- Can be associated with organic matter, soiling, food...
- Can contain and protect pathogens including MDR
- Dry biofilms have increased resistance to disinfectants.
- This may be one of the mechanisms by which MDR persist within the hospital environment and contribute to HAI

- What about antimicrobial surfaces?
CONSIDERATIONS

Antimicrobial surfaces yes or no?

✓ Studies in ICU shows a decrease in microbial bioburden (90%)  

• Claimed decrease in HAI needs further evidence – too few studies

• Efficacy in vitro (product claim and product development) – Urgently need a standard to avoid inappropriate claims

✓ Costs – is it worth it?

• Beneficial for high touch surfaces?

✓ Other usages: light fitting, high surfaces, air conditioning

DOES NOT REPLACE APPROPRIATE HYGIENE & CLEANING
THANK YOU

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November 10
NOROVIRUS AND HEALTHCARE FACILITIES: HOW TO KEEP THE VIRUS OUT AND WHAT TO DO WHEN IT GETS IN
Dr. Ben Lopman, CDC, Atlanta
Prof. Miren Iturriza-Gomara, University of Liverpool

November 23
AIR TRAVEL AND INFECTION TRANSMISSION
Dr. Paul Edelson, CDC JFK Airport Quarantine Station, New York
Sponsored by GOJO (www.gojo.com)

December 1
2017 TELECLASS SCHEDULE RELEASED

December 8
VIABILITY OF BACTERIA ON FABRICS
Prof. Jerry H. Kavouras, University of Illinois at Chicago

December 15
INFECTION CONTROL IN ELDERLY CARE INSTITUTIONS – WHERE SHOULD WE GO?
Prof. Andreas Voss, Radboud University Medical Centre, The Netherlands

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