Antimicrobial-Impregnated Surfaces in Preventing Healthcare-Associated Infections. Differentiating the Hype from the Hope

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Hosted by Paul Webber
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Declaration-1

The views expressed are in a personal but professional capacity & do not necessarily reflect those of the RCSI or Beaumont Hospital.

I have recent research collaborations with Pfizer. I have also recently received lecture & other fees from, Novartis, AstraZenca, Astellas & Pall Medical.

Declaration-2

I am not an engineer

I am not a biochemist

I am not a molecular scientist

Learning Outcomes

By the end of this session you should …

1. Understand the challenge of HCAI-causing microbes persisting in the environment
2. Appreciate the options for impregnating surfaces with antimicrobial activity
3. Have an overview of the *in vitro* results with different products
4. Be aware of the conclusions from the relatively few clinical studies
5. Know the requirements in to the future

The Problem & Challenges - 1

The patient

High CFU (50/cm^2) on skin of VRE patients

The pathogen

Clostridium difficile, VRE, MRSA & *Acinetobacter* spp. may survive on dry surfaces for 4-5 months

Practice

8-60% patients acquire VRE in a room previously occupied by a VRE +ve patient

Infect Control Hosp Epidemiol 2011;32: 689-699

Eur J Clin Microbiol Infect Dis
DOI 10.1007/s10096-014-2205-9

Organism	Persistence (range)
Acinetobacter spp.	3 days to 5 months
Clostridium difficile (spores)	5 months
Enterococcus spp. including vancomycin-resistant enterococci	5 days to 4 months
Escherichia coli	1.5 h to 16 months
Klebsiella spp.	2 h to>30 months
Mycobacterium tuberculosis	1 day to 4 months
Pseudomonas aeruginosa	6 h to 16 months
Salmonella typhimurium	10 days to 4.2 years
Shigella spp.	2 days to 5 months
Staphylococcus aureus, including MRSA	7 days to 7 months
Haemophilus influenzae	12 days
Adenovirus	7 days to 3 months
Influenza virus	1–2 days
Norovirus and feline calicivirus (FCV)	8 h to 7 days

The Problem & Challenges - 2

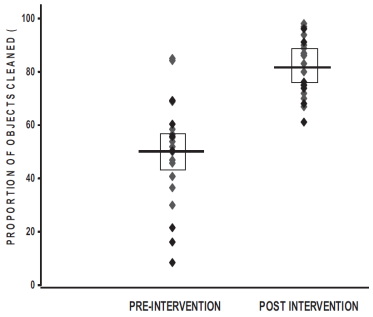
- 92/939 (10%) patients +ve for MRSA in extensive screening study
- 65/1,252 (5%) environmental sites positive adjacent to MRSA patients
  - MRSA isolated from environment of MRSA -ve patients
- Sites +ve included
  - mattresses, 14%
  - air, 8%

Eur J Clin Microbiol Infect Dis 2012, 3151-3161

The Problem & Challenges - 3

Decontamination, cleaning inadequate even in ICUs

Improved cleaning enhances aesthetics & reduces bioburden, but some pathogens may persist



Crit Care Med 2010; 38: 1054-1059

The Problem & Challenges - 4

A wide variety of chemicals as disinfectants are used

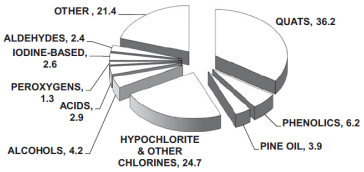


Fig 1. Chemicals used as disinfectants in institutional and industrial settings in the United States (modified from Fu et al[15]).

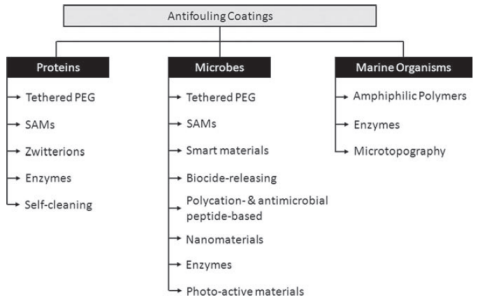
Concern over efficacy, resistance & the environment

Am J Infect Control 2010; 38: S34-40

What to do?

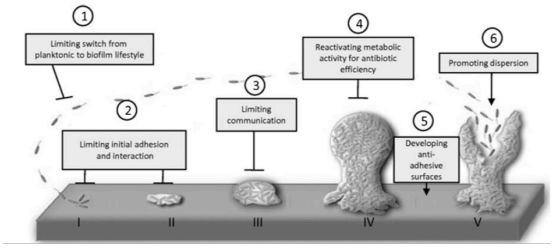
- Alter the surface components
- Coat with or incorporate into the surface/fabric an antimicrobial compound
- Use a different material that has inherent anti-biofilm/microbial activity

Antifouling Coatings against Proteins, Bacteria & Marine Organisms



Adv Mater 2011; 23: 690-718

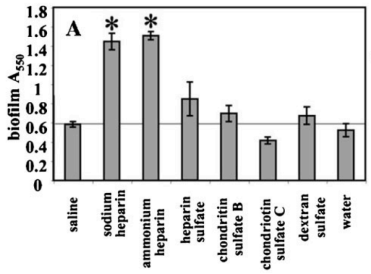
The Biofilm



Appl Microbiol Biotechnol (2012) 95:299–311
DOI 10.1007/s00253-012-4144-7

Biofilm & Surface

Surfaces with pits enhance attachment of bacteria
Extracellular polymeric substances interact with surfaces



Appl Microbiol Biotechnol 2012; 95: 299-311

Coatings on Materials

Polyethylene glycol, a polymer imparts protein resistance to a surface but can auto-oxidise & lose its activity

Phosphorylcholine-based zwitteronic surfaces bind water, creating a hydration layer that does not allow proteins to adhere

Protease-based films in oil-based paints

Adv Mater 2011; 23: 690-718

Microbicidal Coatings

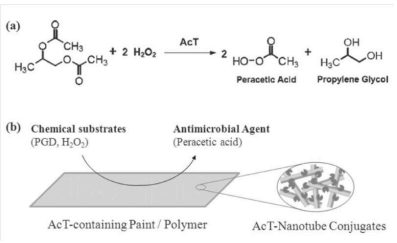
1. **Silver ions/ nanoparticles embedded in polyamides, fibreglass, etc.**
2. **Octenidine dihydrochloride surfaces inhibit *S. aureus* & *P. aeruginosa***
3. **Nanoparticle-impregnated textiles used in bandages, etc, with antimicrobial properties**
4. **Conjugates of perhydrolase generate peracetic acid**

Adv Mater 2011; 23: 690-718

Enzyme-based Coatings

Starch **Glucoamylase** **Hexose oxidase**

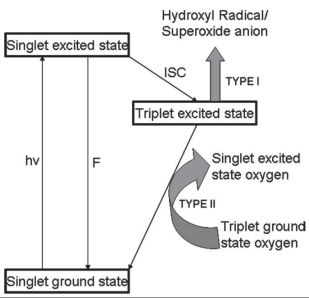
Hydrogen peroxide biofilm



Adv Mater 2011; 23: 690-718

Photo-Activated Self-Cleaning Films

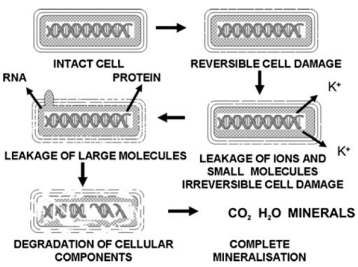
Lotus Leaf – water droplets roll down surfaces & pick up dirt, bacteria, etc
Photoactive films – UV leads to reactive oxygen species (ROS)
T_i0_2 - most commonly used photoactive material



Adv Mater 2011; 23: 690-718

Photocatalysis & Titanium Dioxide

- **Activity related to H_2O_2 & other hydroxyl radicals**
- **Indoor use limited by need for UVA**
- **Membrane & cell wall damage; Gram + ve more resistant to killing**



Appl Microbiol Biotechnol 2011; 90: 1847-1868

Light-Activated Antimicrobial Coating

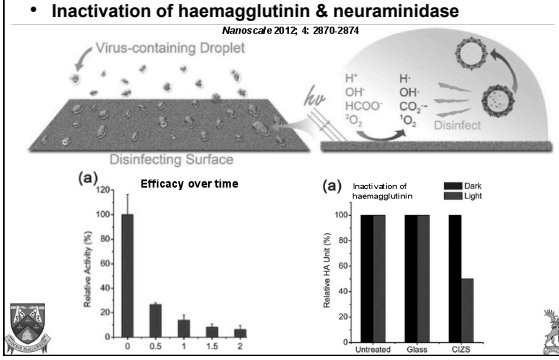
Type of bacteria	Viable bacterial count, median (range), 10^2 colony-forming units/m^2/h: Agar plates	Control coatings	25-μmol/L TBO and RB–containing coatings	Percentage of organisms killed, median (range)
Aerobes	9.2 (3.7–19.9)	15.5 (3.6–114.2)	7.2 (0.6–38.9)	63.8 (0–95.8)
Anaerobes	5.7 (1.9–8.9)	6.6 (0–93.2)	1.8 (0–14.9)	81.8 (0–100)

- Toluidine blue O & rose bengal coated surfaces under suspended lamp in clinic
- Settle plates & culture of coating
- 64-82% reductions (p<0.005)
- Surviving organisms were skin, e.g. *Micrococcus luteus*

***Infect Control Hosp Epidemiol* 2008, 1181-1184**

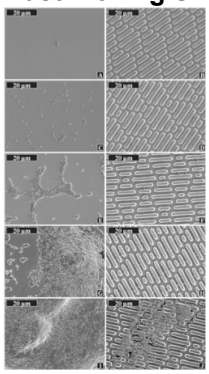
Visible Light & Influenza

- 71% of virus activity eradicated in 15 min
- Inactivation of haemagglutinin & neuraminidase



Sharket AF™ – Skin of Fast-Moving Shark

- Microbial retention depends on cell surface pits
- Diamond-like array
- *S. aureus* biofilm assay
- Delays biofilm formation on surface

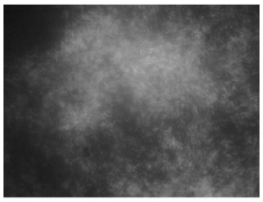


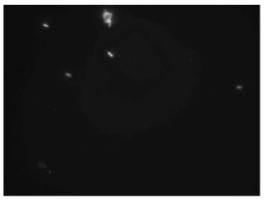
***Bionterphases* 2007; 2: 89-94**

Poly (ethylene glycol),PEG on Surfaces

Long chain PEG more effective for *P. aeruginosa*

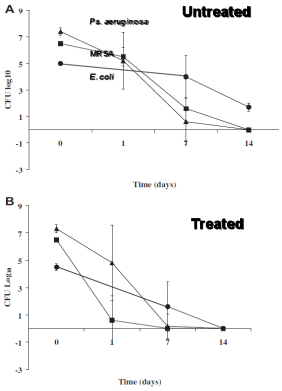
Reduced adherence & biofilm for *S. epidermidis* & *P. aeruginosa*


Glass


pSBMA

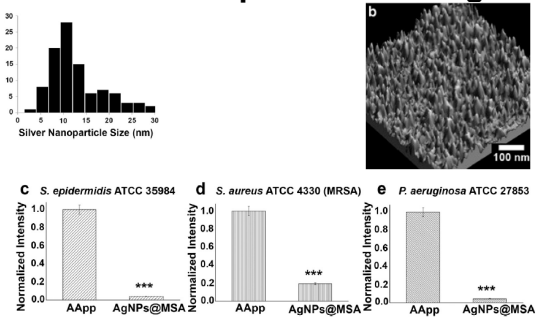
***Biomaterials* 2007; 28: 4192-4199**

Quaternary Ammonium Salt



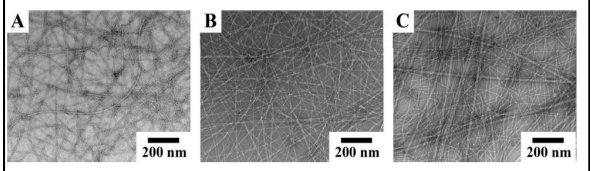
***Am J Infect Control* 2011; 39: 483-7**

Silver Nanoparticle Coatings



Biomaterials 2014; 35: 4601-4609

Ultrashort Cationic Naphthalene derived Self-assembled Peptides as Antimicrobial Nanomaterials
Garry Laverty, Alice P McCloskey, Brendan Francis Gilmore, David S Jones, Jie Zhou, and Bing Xu
Biomacromolecules, **Just Accepted Manuscript** • DOI: 10.1021/bm500981y • Publication Date (Web): 28 Jul 2014
Downloaded from http://pubs.acs.org on August 5, 2014



- **~ 85% reduction in biofilm (*E. coli* & *S. epidermidis*)**
- **Greater selectivity against bacterial cells**
- **Lysine-containing cationic peptides show promise**

Copper & HCAI

1. **Clarity on copper content required for efficacy & other factors, e.g. durability**
2. **Trials of surface microbes & HAI rates**
3. **Impact on aesthetics, cleaning & durability**

***J Hosp Infect* 2012; 81: 217-223**

Copper & *Clostridium difficile*

Stainless steel had no activity against *C. difficile*

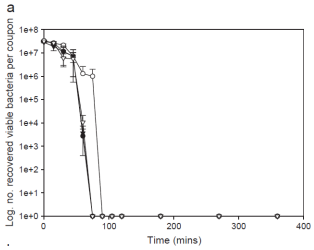
2-3 log reduction in spores at 3 h with no impact from soil load

Surface/exposure time	Mean *C. difficile* cfu/mL remaining (range)	
	NCTC 11204	027
Stainless steel		
0 min	7.6×10^6 (6.8–8.3)	5.6×10^6 (5.5–5.6)
30 min	7.3×10^6 (6.8–7.8)	3.2×10^6 (2.4–4.0)
Copper		
0 min	1.2×10^6 (1.0–1.4)	4.6×10^6 (3.6–5.6)
30 min	0*	0*

***J Antimicrob Chemother* 2008; 62: 522-525**

Copper & *E. coli* 0157

- **Brasses (78-95%), bronze (74-97%), copper nickel (70-96%) & copper-nickel-zinc alloys (55-72%) reduced numbers**

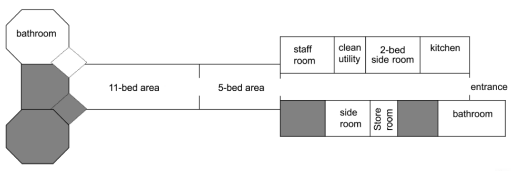


- ***E. coli* 0157 could survive in a desiccated state for 28 days & some alloys less effective at 4º C**

Int J Food Microbiol 2005; 105:445-454

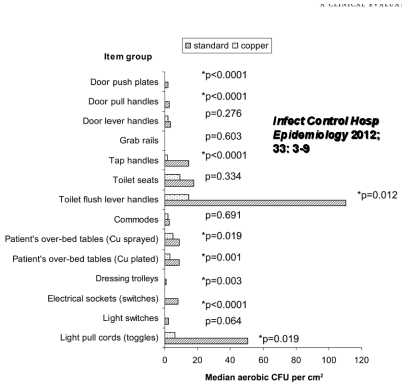
Copper Alloy Furnishing – Cross Over Study

- **Open-plan, with no partition between beds**
- **Domestic staff, 7.30 – 12.30 h & 17.00- 20.00 h**
- **Detergent & Na dichlorasocyanurate for high touch surfaces**
- **Door handles, rails, toilet seats, light switches, etc.**
- **Sampled 14-17.00 h & cfu/cm²**



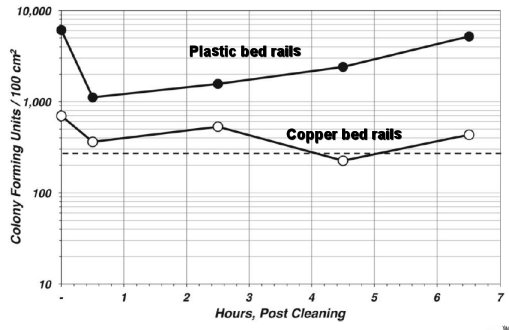
Infect Control Hosp Epidemiol 2012; 33: 3-9

Copper Furnishing – Crossover Study



***Infect Control Hosp Epidemiology* 2012; 33: 3-9**

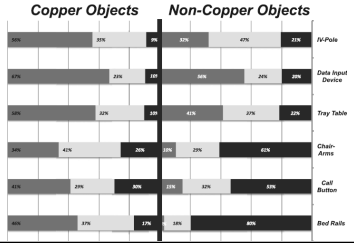
Copper, Bed Rails & ICU



Infect Control Hosp Epidemiol 2013; 34: 530-533

Copper Objects in 16 Rooms x 43 Months

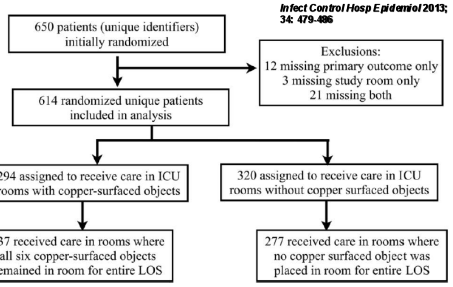
J Clin Microbiol 2012; 50: 2217-2223



Copper Surface & HAI Rates

- Three medical centres, ICUs, coffee-alloy surfaces, weekly sampling of objects

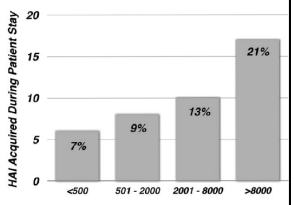
Infect Control Hosp Epidemiol 2013; 34: 479-486



Copper Surfaces & HAI Rates

	Copper	Control	p
No HAI/colonisation	93%	87%	
HAI/colonisation	7%	13%	0.02
HAI only	3.4%	8.1%	0.13
Colonisation only	1.7%	3.8%	0.063
ICU LOS > 7 days	21.9%	21.9%	0.96
RIP in ICU	14%	16%	0.64

Infect Control Hosp Epidemiol 2013; 34: 479-486



J. Hyg., Camb. (1964), **62**, 519
Printed in Great Britain

Tests on self-disinfecting surfaces

By D. KINGSTON and W. C. NOBLE*

Cross-Infection Reference Laboratory, Central Public Health Laboratory, Colindale Avenue, London, N.W. 9

(*Received* 26 *June* 1964)

Blankets, wood & painted surfaces have some self-disinfecting processes

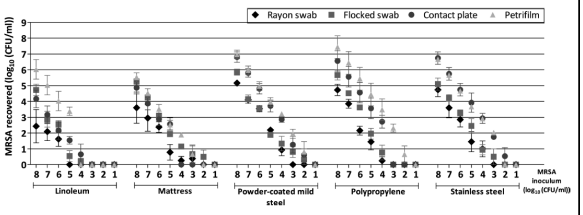
Used fine cotton dust impregnated with organisms in broth suspension

How to Evaluate?

- **Surfaces**
  - **Semi-quantitative culture**
  - **Target organisms**
  - **Mixed flora**
  - **Biofilm**
- **Fabrics – American Association of Textile Chemists & Colorists protocol**

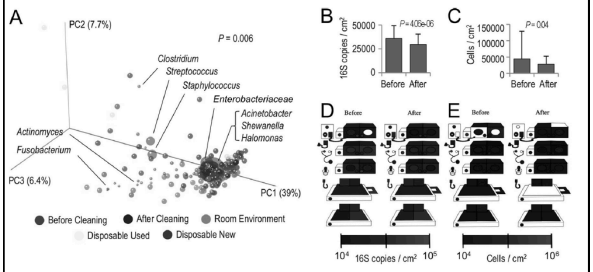
Which Method on What Surfaces?

Infect Control Hosp Epidemiol 2014;35(7):869-871



High Throughput Sequencing & Hygiene

***J Clin Micro* 2013; 51: 2617-2624**



- **147 samples before & after cleaning**
- **Less bacteria & fungi after cleaning**

Conclusions

1. **Impregnated surfaces reduce bacterial counts but do not eradicate**
2. **Methodologies of assessment vary**
3. **Impact on use of item over period of time not evaluated**
4. **Longevity of anti-microbial effect**
5. **Commercially-driven innovative approaches with potential but remain to be proven**

The Future

A. **More trials that include optimal cleaning**

B. **Some standardisation of methods for impregnated surfaces**

C. **Patient & staff response to antimicrobial & or disinfection – impregnated surfaces, fabrics**

D. **Intervention studies, multi-site involvement & stepwise models**

11 September **ECONOMIC ANALYSIS OF VRE: ASSESSING ATTRIBUTABLE COST AND LENGTH OF STAY**
Dr. Marc Romney, Providence Health Care, Vancouver

16 September *(FREE.WHO Teleclass - Europe)*
KEY MEASURES FOR THE PREVENTION AND CONTROL OF EBOLA VIRUS DISEASE
Dr. Sergey Romualdovich Eremin, World Health Organization
Sponsored by the World Health Organization

16 September *(FREE.Teleclass)*
INFECTION PREVENTION AND CONTROL – THE ARGENTINA EXPERIENCE
Carolina Giuffré, Buenos Aires British Hospital, Argentina

18 September **HEALTH ECONOMIC EVALUATION OF AN INFECTION PREVENTION AND CONTROL PROGRAM**
Dr. Elizabeth Bryce, Vancouver Hospital

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