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Antibacterial Textiles

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Why would you want to Control Micro-organisms in Textiles?

- Prevent
 - Degradation
 - Odor
- Provide health benefits
 - Reduce infection
 - Promote healing
- Homeland defense
 - Reduce risk from biological attack

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▪ Hospital Wards

- 1930s
 - Pneumonia, meningitis, typhoid fever, syphilis, tuberculosis, rheumatic fever
- 1980s
 - Cancer, heart disease, complications from diabetes or hypertension
- Change => antimicrobial agents



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▪ **But Micro-organisms Fought Back! – 1992**

- 95% *Staphylococcus aureus* strains resistant to
 - penicillin,
 - ampicillin
 - antipseudomonas penicillins
- Methicillin-resistant *S. aureus* appeared in 1980' s
- Pathogens associated with
 - prosthetic orthopedic devices,
 - heart valves,
 - dialysis catheters

MICROORGANISMS



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<https://theifaiexpo.com/2017/10/17/how-antibiotics-impact-microorganisms-and-why-we-should-care/>

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▪ ***Enterococcus faecalis* and *E. faecium***

- Responsible worldwide for 95% of
 - endocarditis and urinary tract infections,
 - Wound infections,
 - intra-abdominal infections,
 - pelvic infections
- They also have developed resistance to antibiotics.



Enterococcus faecalis



E. faecium

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https://www.ncbi.nlm.nih.gov/pub/Enterococcus_faecalis

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▪ **Nosocomial Infections**

- “Hospital acquired infections(HAI)”
- USA
 - 8 Million excess hospital stays/yr
 - 88,000 deaths/yr
 - \$ 4.5 billion/yr
- 67% due to Gram +ve bacteria
- 27% due to Gram –ve bacteria
- 8% due to fungi & growing!!!!



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<https://medgadget.com/blog/nosocomial-infections-hai/>


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- **Staphylococcus aureus**
 - *Staphylococcus aureus* part of our natural flora (grows on our skin)
 - Very prolific micro-organism
 - One of first infections to infect external wounds in skin
 - Resistant to many antimicrobial agents
 - If you catch a resistant micro-organism – it is very difficult to control!!

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Now for the bad news!

The REALLY bad news!

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- **Viabile life span for micro-organisms – (Days)**

Micro-organism	Cotton Apparel	Cotton Towels	Scrubs cotton/PET	Privacy Curtains PET	Splash Guards PE/PP
<i>S. aureus</i>	4-21	2-24	1-21	1-56	11->90
<i>E. faecium</i>	22 - >90	33 - >90	29 - >90	43 - >90	68 - >90
<i>E. faecalis</i>	11-33	20-29	18-29	73 - >90	>80

Neely & Maley – 2000


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▪ **My \$\$ v. Your \$\$**

- Add the antimicrobial agent where you make the most money
 - Fiber manufacturers – in or on the fiber
 - Fabric manufacturers – on the fabric
 - Laundry supply manufacturers – in the detergent
 - Hospital – on the patient’s gown, bed linens, etc.
 - ...
- Often not effective for hospital use



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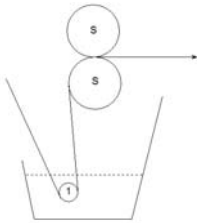
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▪ **Padding on fabric**

- Fabric immersed in bath containing antimicrobial agent
 - Examples:
 - Triclosan®
 - Quaternary ammonium compounds (QAC)
- Dry and cure in oven
 - Antimicrobial agent diffuses into surface, similar to dyestuffs.



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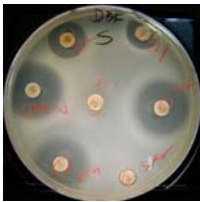
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▪ **Effectiveness**

- Usually measured by “Zone of inhibition”
- Requires antimicrobial agent to diffuse from fabric so as to kill micro-organism.



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▪ **Example**

- Topical
 - Vantocil™ (Arch Chemical) *poly(hexamethylene biguanide)*
 - Lost effectiveness after 25 home launderings



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▪ **Example**

- Bide et al “dyed” polyester, polyurethane, silk, wool, nylon and polyacrylonitrile (acrylic) fibers with Ciprofloxacin and Ofloxacin.
- Broad-spectrum antibiotics in fluoroquinolone class. Active against some Gram-positive and many Gram-negative bacteria.
- However, treated fibers lose effectiveness.
 - Silk – 4 hours
 - Nylon – 24 hours.
 - Polyester –14 days.

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▪ **Example**

- Yang et al dyed polyester and cotton with Triclosan®
- Provided 50% reduction in *S. aureus* after 50 home launderings
- But 0% reduction in *E. coli* after only one laundering

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▪ **Antimicrobial Strategies for 21st Century**

- Make textile materials that
 - Kill wide range of micro-organisms
 - Quickly
 - Slowly
 - Are durable enough (How many washings?)
 - Does not harm people
 - Is cost effective



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<https://textiles.ncsu.edu/antibacterial-textiles-1532/>


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▪ **Observation**

- Micro-organisms exist everywhere in a hospital
 - Bed cloths
 - Privacy curtains
 - Lab coats
 - Doctor's ties
 - Visitor's chairs
 - ...



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▪ **Need multiple approaches**

- Lab coats
 - Rapid kill
 - Broad spectrum
 - About 1 week between launderings
- Privacy curtains
 - Broad spectrum
 - Effective for several months
 - Slow kill (hours) probably OK

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▪ **Antimicrobial Strategies for 21st Century**

- AEGIS Microbe Shield (quaternary ammonium silane)
 - Pad and cure surface treatment against microbes such as stain and odor causing bacteria, mold and mildew.
 - Silane reacts with fiber surface
 - Bacteria are attracted to the coating's positive charge
 - Benzethonium chloride also kills roaches, fleas, ants, beetles, bedbugs, and their larvae
 - <https://www.microban.com/antimicrobial-solutions/technologies/aegis-microbe-shield>


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▪ **New Innovative Approaches**

- Add antimicrobial agent to resorbing coating
- Attach antimicrobial releasing material to surface
 - Recharge
- Attach antimicrobial synthesizing materials to fiber surface


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▪ **Releasing Antimicrobial Agent**

- King & Jones coated braided polyester sutures with resorbable polymer containing antibiotics
 - As the coating resorbed, antibiotic is released, killing *S. aureus*
 - Releases most of antibiotic in first few days
 - Excellent for implantable materials

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▪ Polyester Braided Sutures

Coating (Poly-ε-caprolactone-co-glycolide)
 $-(O(CH_2)_6CO(CH_2)_4CO)_n-$

Uncoated polyester suture + Clindamycin → Clindamycin coated braided suture
 • 0.85% (10X MIC)
 • 8.5% (100X MIC)

+ Moxifloxacin → Moxifloxacin coated braided suture
 • 0.1% (10X MIC)
 • 1.0% (100X MIC)

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▪ Zone Diameters of Clindamycin

Coated Sutures after 1 Day in Buffer

0.85% Clindamycin 8.5% Clindamycin

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▪ Suture Zone Diameter Results

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▪ **Rechargeable Antimicrobial Agent**

- Sun & Xu attached halamines to cotton & cotton/polyester blend fabrics
 - When challenged, treated fabrics release chlorine (Cl₂)
 - Maintain their activity for 15 launderings
 - Recharged by laundering in dilute bleach
 - Restores log 6 reduction in *S. aureus* and *E. coli* CFUs
 - Potential to be cheap – dilute household bleach

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$$\begin{array}{c} X \\ | \\ R_1 - N - R_2 \end{array}$$


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▪ **Rechargeable Antimicrobial Agent**

- Passive-Aggressive
- Micro-organisms have not developed resistance
- Probably most suitable for
 - Bedding
 - Towels and wash cloths
 - Undergarments
 - Lab coats
- Also useful for bandages (recharging not needed)



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▪ Synthesizing Antimicrobial Agent

- Synthesize antimicrobial agent directly on the surface
- Requires antimicrobial agent be simply created from materials that are readily available to the fiber's surface.

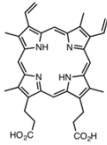
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▪ Synthesizing Antimicrobial Agent

- Sherrill, Michielsen and Stojiljkovic
 - Ingredients = oxygen in air
 - Energy source for synthesis = visible light
- Attach Protoporphyrin IX (PPIX) or Zinc protoporphyrin (ZnPPIX) to fiber's surface
 - Photo-excite PPIX & ZnPPIX with visible light
 - O₂ in air converted to singlet oxygen
 - Singlet oxygen = antimicrobial



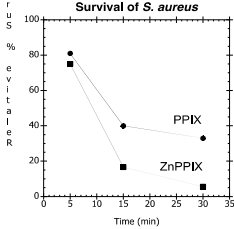
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▪ Synthesizing Antimicrobial Agent

- Kill *S. aureus*
 - Upon exposure to light
 - But not in dark.
- Treatment is
 - Durable
 - Active for long periods
 - Requires room light or sunlight



Time (min)	PPIX (%)	ZnPPIX (%)
0	100	100
5	80	80
15	40	20
30	40	20

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▪ **Synthesizing Antimicrobial Agent**

Advantages

- No need to store antimicrobial agent. Synthesize on demand
- Broad range of activity

Disadvantages

- Does not work in dark
- Needs ingredients to make anti-microbial

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▪ **Synthesizing Antimicrobial Agent**

- Probably most suitable for materials that are rarely laundered
 - Privacy curtains
 - Wall and floor coverings
 - Upholstery
 - Other surfaces

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▪ **Embedded Antimicrobial Agent**

- Unifi spins polyester fibers with antimicrobial agent inside the fiber (Similar to solution dyeing)
 - Effective to control odor
 - Non-migratory
 - Environmentally safe
 - Does not prevent infections
 - Use for sportswear, intimate apparel



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▪ **Future of Antimicrobial Agents**

- Although no single approach to anti-microbial fabrics will meet all the needs of today's modern hospitals
- But
 - Each approach has own niche
 - Many fabrics will self-sterilize
 - Expect the micro-organisms to fight back.
 - With such a wide range of approaches, we hope they will not be successful!


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▪ **Summary**

- Micro-organisms can survive on textile surfaces for months!
- New fibers/fabrics/fabric treatments can eliminate or control micro-organisms
 - Can be durable
 - Can be difficult for micro-organisms to develop resistance
- These antimicrobial textiles will become part of a regimen to reduce the threat of micro-organisms throughout health care.

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Thank You



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