**Healthcare Textiles: Factors That Affect Cleanliness**

**Dr. Lynne Sehulster, Division for Healthcare Quality Promotion, CDC**

**A Webber Training Teleclass**

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**Topics for Today**

- Healthcare laundry basics:
  - Some observations
  - Basic steps of the laundry process
  - Antimicrobial activity in the wash cycle
- Key observations from the report of the 2009 mucormycosis outbreak
- Assess the holding/transport/storage stage for contamination opportunities
- Fungi (and bacteria) as agents of textile biodegradation
- Strategies to minimize environmental contamination of hygienically clean healthcare textiles (HCTs)
- Antimicrobial treatment of textiles

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**Laundry and Infectious Diseases**

- Textiles contaminated with body substances can contain large numbers of microorganisms ($10^6 – 10^8$ cfu/100 cm² fabric)
- Few reports in the literature link laundry to disease transmission when proper procedures are followed
- Annual estimates for volume of laundry processed in U.S. health care: several billion lbs. higher than the 5 billion lbs. in the late 1980s
- Continue current infection prevention practices

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**Current Healthcare Textiles Standard in the U.S.**

- Standard for reusable textiles: Hygienically clean
- Not quantified for microorganisms, but assume textiles are generally rendered free of vegetative pathogens
- Through a combination of soil removal, pathogen removal, pathogen inactivation, contaminated laundry is rendered hygienically clean
- Carries negligible risk to healthcare workers and patients, provided that the clean textiles are not inadvertently contaminated before use
- Sensory attributes: visual, tactile, olfactory
- Reusable surgical textiles: Sterilized

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**AAMI: Hygienically Clean**

- No one has ever defined what “sufficient numbers” means
- Underlying medical conditions may increase risk of infection by opportunistic pathogens

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**Observations from a Recent Study**

- 135 personnel (45% physicians, 55% nurses) in surgical depts. (60%) and medical depts. (40%)
- Nonpathogenic skin organisms isolated from all attire tested
- Rate of contamination with pathogens higher in attire changed every 2 days compared to that for daily changes ($p < .05$)
- Isolated pathogenic bacteria:
  - Acinetobacter spp. 37% (89/238 cultures)
  - Staphylococcus aureus 13% (32/238 cultures)
  - Enterobacteriaceae 8% (18/238 cultures)
  - Pseudomonas aeruginosa 3% (8/238 cultures)
- Only skin bacteria isolated from 4 uniforms cultured immediately after receipt from the hospital laundry
- Bacterial loads significantly lower than on uniforms being worn

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### Main Steps of Healthcare Laundry Processing

- Collection of soiled textiles at point of use
- Transport to laundry
- Wash cycle:
  - Flush, main wash, bleaching, rinsing, souring
  - Dried and pressed
- Packaged, loaded into carts
- Delivery back to the hospital

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### Conventional Laundering: Log Reductions in Bioburden

- **In the wash, rinse cycles:**
  - Agitation: ~3 log unit reductions
  - Addition of bleach: ~3 log unit reductions

- **In the dry cycle:**
  - ~1 – 2 log unit reductions


- Post wash microbial burden ~10 – 100 CFU/cm²
- Predominantly Gram-positive organisms

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### Alternatives to Hot-water Laundry

- In-house laundries consume an average of 50% - 70% of the facility’s hot water (10% - 15% of the total energy used)
- Water temperature may be regulated locally
- Lower temperature (e.g., 22° – 50° C) wash cycles can be used with appropriate detergents and laundry additives
- New detergents and processes (e.g., oxidative products) are being evaluated in Europe
- Current problems associated with bleach use:
  - Not all fibers and fabrics are compatible with bleach
  - Chlorine + residual chlorhexidine gluconate (CHG) = brown stains

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### The Laundry Process: Log Reductions

<table>
<thead>
<tr>
<th>Process</th>
<th>Gram Positive LR*</th>
<th>Gram Negative LR*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-wash at 35°C</td>
<td>0.73 – 2.47</td>
<td>0.70 – 1.16</td>
</tr>
<tr>
<td>Main wash at 45°C w/o pre-wash</td>
<td>0.97 – 2.50</td>
<td>1.11 – 2.66</td>
</tr>
<tr>
<td>Main wash at 60°C w/o pre-wash</td>
<td>1.34 – 5.56</td>
<td>3.71 – 5.6</td>
</tr>
<tr>
<td>E60 + 3% pre-wash at 50°C, main wash at 60°C</td>
<td>1.91 – 7.58</td>
<td>5.6 – 7.76</td>
</tr>
<tr>
<td>Completed main wash at 70°C</td>
<td>5.56 – 7.88</td>
<td>5.6 – 7.76</td>
</tr>
<tr>
<td>Disinfecting only at 70°C</td>
<td>5.56 – 7.88</td>
<td>5.6 – 7.76</td>
</tr>
<tr>
<td>Complete 3-step cycle (with disinfecting at 80°C)</td>
<td>&gt;5.56 – &gt;7.88</td>
<td>&gt;5.6 – &gt;7.76</td>
</tr>
</tbody>
</table>

- *Detergent was mix of anionic and nonionic surfactants, phosphates
- Bleach: H₂O₂ agent; Disinfecting agent was peracetic acid, H₂O₂, acetic acid
- Starting inocula: 10⁶ – 10⁷ CFU in 1 square cm
- The disinfecting step by itself could not remove stains
- E. faecium had the greatest survival; Gram positive > Gram negative

  - LR* = log reduction

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### U.S. EPA: Laundry Sanitizers and Disinfectants

- **OCSP 810.2400:** Fabrics and Textiles – efficacy data recommendations
- Efficacy testing for antimicrobial pesticides intended to be used on fabrics and textiles, and which bear label claims as disinfectants or sanitizers
- Sanitizers used on fabrics: 3 log₁₀ reduction
- Disinfectants used in laundry facility: ≥ 59 carriers out of 60 – no growth (carriers inoculated with ≥ 10⁶ microbes)
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HACCP: An Assessment Tool for Infection Prevention

- HACCP
  - Hazard Analysis and Critical Control Points
  - Used extensively in the food service industry to help maintain product quality
  - Look critically at the laundry facility and the laundry process to identify possible points at which contamination could be introduced, diminishing textile hygienic quality
  - Helps to identify quality control strategies to prevent contamination of the product

HACCP Analysis for Possible Opportunities for Environmental Contamination

- Laundry Contractor A:
  - Facility was not climate controlled, ventilated with unfiltered outdoor air
  - Clean HCTs in uncovered bins, exposed to outdoor air before loading into trucks
  - Bins not lined with plastic that could be tied shut
- Hospital A:
  - Bins with clean HCTs held inside the loading dock receiving area for unspecified time
  - HCTs placed on shelves in Central storage area
  - Construction near the loading dock for the last 5 months of the epidemic period


Conclusions From the Outbreak Investigation

- HCTs were the most likely vehicle to have brought Rhizopus in contact with the patients
- Genetic subtyping of fungal isolates supported this epidemiologic hypothesis
- Contamination of clean HCTs with Rhizopus happened repeatedly, but might have been intermittent
- HCTs should be laundered, shipped, and stored in a manner that minimizes exposure to environmental contaminants


Chain of Infection (COI)

- Virulent pathogen:
  - Bacteria, fungi, viruses, parasites, prions
  - Sufficient number of pathogen:
  - Infectious dose
  - Mode of transmission:
    - Contact, droplet, airborne
  - Portal of entry:
    - Broken skin, mucous membrane, respiratory tract, ingestion
  - Susceptible host:
    - Age, immunity, medical conditions
  - Other possible links include reservoir, portal of exit

Questions Raised

- Customers are beginning to question the standard
  - Is hygienically clean good enough? Should we be doing something different?
  - Should we be incorporating more antimicrobials into the laundry process on a routine basis?
  - Reports of customers asking laundry operators to do ATP sampling of laundry facility surfaces, cleaned textiles
  - What does this mean?
  - Should microbial sampling of clean textiles be implemented?
  - Use of ATP monitoring of hard surfaces in a HACCP approach

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Outbreaks Attributed to Laundered Healthcare Textiles (HCTs)
- 12 outbreaks in 43 years worldwide attributed to laundered, clean HCTs
- U.S. – 3, U.K. – 5, Japan – 3, Singapore – 1
- > 353 patients affected
- Pathogens identified:
  - Aspergillus flavus
  - Bacillus cereus (712, 58% of the outbreaks)
  - MRSA
  - Staphylococcus pyogenes
  - Rhizopus delawarensis
  - Clostridium difficile
- Root causes included environmental contamination during transport, dust, improper storage conditions, washing machine malfunctions, inadequate drying, construction dust, recycled water in wash and rinse

Outbreaks Attributed to Soiled Healthcare Textiles (HCTs)
- 5 outbreaks of occupationally-acquired infections or exposure to hazardous pharmaceuticals in 43 years
- 148 – 248 workers affected
- Pathogens/chemicals identified:
  - Scabies
  - Microsporis canis
  - Salmonella hadar
  - Hepatitis A virus
  - Antineoplastic pharmaceuticals
- Breach of infection prevention practices identified
  - Improper handling created aerosols
  - Failure to use appropriate PPE
  - Exposures to fecal and other body substance contamination

Four Key Observations: Infections and HCTs
- Patient-to-patient transmission of infection has not as yet been reported in association with hygienically-clean HCTs
- Launder processes carried out in accordance with recommended industry operational specifications for water quality, cycle parameters, proper laundry chemical selection and use, and proper equipment maintenance
- Outbreaks involve environmental contamination and failure to maintain HCT cleanliness after washing and drying
  - Root causes identified and corrected
  - Problems with storage are most frequently identified
- Occupational infection or chemical exposure involve failure to use PPE and follow standard infection prevention procedures when handling soiled HCTs
- Rare events, but is underreporting at work here?

Biodegradation of Textiles
- Textiles, especially those containing natural fibers, are readily attacked by microbes
  - Some processing and finishing agents (e.g., dyes) are also vulnerable
  - Over time loss of strength, discoloration, change of appearance, odor
- Fungi are the most important microbial class associated with biodegradation
- Three things necessary for fungal growth:
  - Food source (e.g., cellulose)
  - Moisture
  - Favorable environmental conditions (e.g., temperature, humidity)

Biodegradation of Textiles
- There are two main ways to control and/or prevent biodegradation of HCTs:
  - Control of environmental and physical conditions of clean HCTs, or
  - Use antimicrobial treatments

Laundry Holding/Transport / Storage
- Controlling the environmental conditions is considered to be the best means of protecting textiles
- Clean HCTs touch clean surfaces
  - That includes clean hands and worker uniforms
- HCTs should be as dry as practical prior to bundling or packaging
- Unwrapped HCTs should be stored and transported using strategies to prevent inadvertent contamination by soil or body substances
  - Covered containment, either bins, carts, or shelves

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Laundry Transport / Storage

- Separate clean textiles from contaminated textiles when transporting in a vehicle
- Physical barriers and/or space separation
- Clean, unwrapped textiles can be stored in a clean location for short periods of time
- Unwrapped textiles should be stored so to prevent inadvertent contamination by soil or body substances
- This is the part of the overall process that is most vulnerable to outside contamination

Laundry Holding/Transport / Storage: Area Cleanliness and Dust Control

- Evaluate HCT storage area in the hospital for ways to minimize dust intrusion
- Self-closing doors help to maintain positive pressurization
- Location of HCT storage room relative to the loading dock and other services
- Amount of traffic through the room
- Establish hospital policy for regular cleaning and disinfection of the room’s storage surfaces
- Where are clean HCTs unloaded in the hospital?
- Visual inspection of outermost bundle surfaces

Climate Control via Ventilation: Key Engineering Specifications

- Why this is important:
  - Fungi grow rapidly at RH > 80%
  - Keeping the ventilation parameters consistent helps to minimize microbial growth
  - Trapped excess moisture due to packaging may create opportunities for growth when RH fluctuates
  - Proactive management is key to maintaining stability
  - Higher temperatures encourage fungal growth

Clean HCT Storage:
- Temperature: 72 - 78°F
- Relative humidity (RH): NR*
- Air changes/hour (ACH): 2
- Airflow direction: Positive

Surgical Pack Room Storage:
- Temperature: < 78°F
- Relative humidity: < 70%
- Air changes/hour (ACH): 2
- Airflow direction: Positive

Antimicrobial Chemical Treatments

- Different approaches to adding chemical treatments:
  - Impregnation of the fiber (e.g., copper)
  - Treatment of the fabric before final garment/item construction
  - Treatment of the garment/item (e.g., add/recharge an antimicrobial residual)
- Function of the antimicrobial treatment
  - Protection of the fabric/garment to maintain textile function
  - Hygienic treatment
- Antimicrobial treatments for hygiene purposes:
  - Low toxicity to humans, minimize skin irritation
  - Should not leach from the fabric (e.g., when moistened by sweat)
  - Should not interfere with proper function of the textile
  - Low cost, withstand repeated washings

A Short List of Antimicrobial Chemicals for Textiles

- Silver (Ag) nanoparticles
- Copper (Cu) nanoparticles
- Gold (Au) nanoparticles
- Siloxane sulfopropylbetaine (SSPB)
- Titanium dioxide (TiO₂)
- Ag nanocomposite with TiO₂ and citric acid as a crosslinker
- Triclosan
- Quaternary ammonium compounds plus acrylic copolymer fluid repellent
- Chitosans and chitooligosaccharides
- Quaternary ammonium compounds plus organosilane (forming a silicon-nitrogen carbon polymer)
- Hydrophobic N-alkyl plus benzophenone containing polyethylenimine
- Trichloroethylene (TCE)
- Dichloromethane (DCM)

Treatment of Fabric with Quaternary Ammonium/Organo-silane During the Wash Process


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Log Reductions on Untreated Fabric (Control) and Silver Treated Fabric

Table 1: Average inhibition of growth and reduction times of four bacterial species on untreated and silver treated fabric, depending on the contact time.

<table>
<thead>
<tr>
<th>No.</th>
<th>Species</th>
<th>Control (log)</th>
<th>Silver treated (log) 1</th>
<th>Silver treated (log) 5</th>
<th>Silver treated (log) 24</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>B. subtilis</td>
<td>3.5 ± 0.5</td>
<td>4.0 ± 0.2</td>
<td>4.5 ± 0.3</td>
<td>4.7 ± 0.4</td>
</tr>
<tr>
<td>2</td>
<td>E. coli</td>
<td>4.1 ± 0.4</td>
<td>4.3 ± 0.5</td>
<td>4.5 ± 0.6</td>
<td>4.7 ± 0.7</td>
</tr>
<tr>
<td>3</td>
<td>S. aureus</td>
<td>4.2 ± 0.3</td>
<td>4.4 ± 0.4</td>
<td>4.6 ± 0.5</td>
<td>4.8 ± 0.6</td>
</tr>
<tr>
<td>4</td>
<td>P. aeruginosa</td>
<td>4.3 ± 0.4</td>
<td>4.5 ± 0.5</td>
<td>4.7 ± 0.6</td>
<td>4.9 ± 0.7</td>
</tr>
</tbody>
</table>

Dermatophyte Susceptibility to Selected Antimicrobial Textiles

Table 2: Results of testing the defined textiles for antifungal activity.

<table>
<thead>
<tr>
<th>Textile Type</th>
<th>Growth Inhibition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0</td>
</tr>
<tr>
<td>DDAC</td>
<td>1</td>
</tr>
<tr>
<td>PHMB</td>
<td>2</td>
</tr>
<tr>
<td>AgCl</td>
<td>3</td>
</tr>
<tr>
<td>Cu</td>
<td>4</td>
</tr>
<tr>
<td>Co</td>
<td>5</td>
</tr>
</tbody>
</table>

Chitosans and Chitooligosaccharides

Antimicrobial Activity - Candida albicans

Figure 3: Effects (Average ± Standard Deviation) of Different MW Chitosans and COS Upon Candida albicans.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Initial silver content (mg/L)</th>
<th>Silver released in artificial sweat (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.5</td>
<td>0.3</td>
</tr>
<tr>
<td>B</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>C</td>
<td>1.5</td>
<td>0.8</td>
</tr>
<tr>
<td>D</td>
<td>2.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Effect of Artificial Sweat on Silver Leaching from Treated Fabrics

Table 3: Initial silver content and total silver release in standard formula of artificial sweat for 24 h.

<table>
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<th>Sample</th>
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<tr>
<td>D</td>
<td>2.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

EPA: Treated Article Exemption

- According to FIFRA, “treated articles” refer to articles or products that are treated with an antimicrobial pesticide to protect the article or product themselves.
- Treated Articles Exemption:
  - An article or substance treated with or containing a pesticide to protect the article or substance, if the pesticide is registered for such use
  - The Treated Articles Exemption is available only for the protection of the product and not for public health uses
  - Odor control, prevention of deterioration
  - Products bearing a public health claim must be registered in addition to the registration of the antimicrobial pesticide

Quality Issues for Consideration

- Conduct risk-benefit analysis
- Potential toxicologic and allergic side effects
- Does exposure alter the microbial ecology of the skin, skin integrity?
- Potential selection for resistant microorganisms with long-term use
- Potential environmental issues
- Biodegradability, toxicity to plants, marine life
- Persistence of the antimicrobial effect
- Is recharge needed, or is another treatment necessary?
- Can consistent adherence to existing infection prevention practices achieve similar results?
- Need to document an impact on healthcare-associated infection (HAI) rates while using antimicrobial treatment of textiles

http://www.epa.gov/pesticides/factsheets/treatart.htm

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Resources for More Information

- CDC:
  - Options for Evaluating Environmental Cleaning
  - Appendices to the Conceptual Program Model for Environmental Evaluation
  - CDC Environmental Checklist for Monitoring Terminal Cleaning
  - CDC Environmental Checklist
  - Environmental Cleaning Evaluation Worksheet (Excel format)
  - CDI Prevention Tool Kit

- EPA:
  - Selected EPA-Registered Disinfectants: http://www.epa.gov/oppad001/chemregindex.htm

Thank You!

"Protect patients, protect healthcare personnel, and promote safety, quality, and value in the healthcare delivery system."

For more information please contact Centers for Disease Control and Prevention
1600 Clifton Road NE, Atlanta, GA 30333
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E-mail: cdcinfo@cdc.gov  Web: www.cdc.gov

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Thank you!