Water Bugs and Infection Prevention
Andrew Streifel, University of Minnesota
A Webber Training Teleclass

Water Bug Management for Infection Prevention
Andrew Streifel
Environmental Health & Safety
University of Minnesota

Hosted by Nicole Kenny
Virox Technologies Inc, Toronto

March 29, 2012

INFECTION CONTROL ISSUES AT U OF MN SINCE 1960's
• increases in immune compromised patients
• technology advances
  - transplantation
  - cancer treatment
  - advanced surgeries

Water Systems in Healthcare

• Drinking water
• Kidney dialysis
• Laboratory
• Therapeutic
• Cooling
• Fire management

ENVIRONMENTAL MICROBIAL BIOLOAD

<table>
<thead>
<tr>
<th></th>
<th>COLONY FORMING</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAW MILK</td>
<td>10³ – 10⁵/ml</td>
</tr>
<tr>
<td>SEWERAGE</td>
<td>10⁶ – 10⁷/ml</td>
</tr>
<tr>
<td>FLOORS</td>
<td>10⁴ – 10¹⁰/cm²</td>
</tr>
<tr>
<td>FECAL MATTER</td>
<td>10⁸ – 10¹⁰/cm²</td>
</tr>
<tr>
<td>NATURAL WATER</td>
<td>&lt;1 – 10⁴/ml</td>
</tr>
<tr>
<td>AIR</td>
<td>10 – 10⁶/m³</td>
</tr>
</tbody>
</table>

EPA DRINKING WATER STANDARD AT <100CFU/100ML COLIFORM & <100KU/100ML E. COIUS

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Alert Organisms from Clinical Microbiology Rounds

Water bacteria
- Pseudomonas aeruginosa
- Burkholderia cepacia
- Serratia marcescens
- Acinetobacter calcoaceticus
- Aeromonas hydrophila
- Atypical Mycobacterium species
  - M. chelonae, M. avium, M. mucogenicum,
  - M. gordonae, M. fortuitum, etc.
- Legionella species
  - L. pneumophila, L. bozemanii, etc.,

The bacteria are there but we notice them only when they become resistant. Some of these microbes have doubling times of around 20 minutes.

Hospital Tap Water & Infection Prevention

US Hospitals Yearly: 1.7 million infections; 99,000 deaths

Pseudomonas aeruginosa alone: 1,400 deaths in US

Problem: Waterborne pathogens such as Legionella, adapted to life in a relatively nutrient-poor environment, may be hard to culture using a nutrient-rich environment for 24-48 hours at 37°C.

Solution: Use special media (e.g., R2A) for 14-28 days at 25°C.


Infection Control Risk Assessment for Water Systems

1) What at risk patients are treated in the hospital
   - oncology, transplantation, advanced surgery
2) Environmental Critical Control Points
   - water supply, hot water system, cooling towers
3) Design for Control of Water Bacteria
   - piping material, water temperature, storage
4) Operational issues
   - water flow rate, timers for backwash or flushers
5) Unusual events
   - drought, fires, water main leak
6) Water stagnation
   -During new construction, after disasters

ASHRAE STD 188 Prevention of Legionellosis Status under public review

Are the water bacteria resistant?

Drinking water standards:
- <1 cfu/100 ml coliform bacteria
- <500 cfu/ml heterotrophic plate count

Goal: prevent biofilm buildup
Issue: stagnant water

During construction water stagnates

UMMC reduced water from 56M to 25M gal/yr over 13 years

Factors in Water that Make Microorganisms Resistant to Treatment

- Cell walls containing waxy material
- Thick protective resistant stage (e.g., cyst, oocyst, spore)
- Viruses with double-stranded DNA
- Small genome
- Low iso-electric point
- Low hydrophobicity
- Small size
- Clumping factor (genetically controlled surface structures of the specific microbe)
- Ability to associate with organic particulate matter

Emerging waterborne pathogens: can we kill them all? Nena Nwachuku, Charles P. Gerba, Current Opinion in Biotechnology, 2004

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Operating Criteria / On-Going Operations

Biofilm development from planktonic to sessile colonies

Water systems can be complex differences in design are important

Bacterial Attachment to Selected Surfaces

Legionella pneumophila (highest attachment to lowest)
1. Latex
2. Ethylene-propylene
3. Chlorinated polyvinyl chloride
4. Polypropylene
5. Mild steel
6. Stainless steel
7. Unplasticized polyvinyl chloride
8. Polyethylene
9. Glass

Aeromonas hydrophila (highest attachment to lowest)
1. Polyethylene
2. Stainless steel
3. Copper

Biofilm Formation in Water Systems

- Pipe
- Operations
- Disinfection
- Monitoring
- Flow
- Temperature control

Guideline for Environmental Infection Control-2003
Centers for Disease Control & Prevention
Water

- Control spread of waterborne microbes
- Routine prevention of waterborne microbial contamination within distribution system
- Remediation strategies for distribution repair or emergencies
- Control of legionella
- Dialysis water quality
- Ice machines and ice
- Hydrotherapy tanks and pools
- Endoscope processing

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The kidney machine with artificial kidney mimics renal function

About 100,000 on chronic dialysis

MICROBIOLOGY WATER QUALITY LIMITS COLONY FORMING UNITS/ml

<table>
<thead>
<tr>
<th>ANSI HEMODIALYSIS STD 1992 2003</th>
<th>DIABYSATE</th>
<th>PRODUCT WATER</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;200</td>
<td>&lt;200 (2EU)</td>
<td></td>
</tr>
<tr>
<td>&lt;2000</td>
<td>&lt;200 (2EU)</td>
<td></td>
</tr>
</tbody>
</table>

Drinking water has from 0 to 12 EU endotoxin

About 100,000 on chronic dialysis

Change out of Water treatment systems needs coordination and quality control.

- supply water quality
- water treatment system
- piping
- disinfection
- sampling ports

Table 18. Microbiologic limits for hemodialysis fluids*

<table>
<thead>
<tr>
<th>Hemodialysis fluid</th>
<th>Maximum total heterotrophs (CFU/ml)</th>
<th>Maximum endotoxin level (EU/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product water</td>
<td>200</td>
<td>No standard</td>
</tr>
<tr>
<td>Dialysate</td>
<td>200</td>
<td>5</td>
</tr>
<tr>
<td>Disinfection</td>
<td>2,000</td>
<td>No standard</td>
</tr>
</tbody>
</table>

Change out of Water treatment systems needs coordination and quality control.

- supply water quality
- water treatment system
- piping
- disinfection
- sampling ports

CDC-Environmental Infection Control-6/3/2003

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Reservoir Water Bacteria Identification

- Hoses
- Stagnant Water
- Hydro-therapy tanks
- Ice machines
- Brushes for cleaning
- Water pumps
  - Heart surgery
  - Dialysis
- Water supply systems
  - Lab water, recirculating, etc.

Hospital Sources of Nonfermentative Gram-Negative Bacilli

<table>
<thead>
<tr>
<th>Non-Fermentative Gram-Negative Bacilli</th>
<th>Lab Water</th>
<th>Tap Water</th>
<th>Humidification Water</th>
<th>Distilled Water</th>
<th>Sterile Water or Saline</th>
<th>Water Supply Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pseudomonas aeruginosa</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Pseudomonas fluorescens</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Stenotrophomonas maltophilia</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Acinetobacter species</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Pseudomonas maltophilia</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Burkholderia cepacia</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Pseudomonas stutzeri</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sphingomonas paucimobilis</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Ralstonia pickettii</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Adapted From: Chapter 34 - Non Fermentative Gram-Negative Bacilli | J. Flaherty et al. Hospital Epidemiology & Infection Control, Lippincott Williams & Wilkins 2004

Breaking the chain of infection requires understanding mode of transmission and reservoirs of the organisms.

Cleaning for endoscope forceps

Ice machine maintenance
• charcoal filters?
• moldy storage bins

Ice maker
• sanitize surfaces
• internal parts

Cleaning device
• not designed for medical equipment
• heavily contaminated

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Formula preparation equipment caused GI Problems in “short bowel” infants

Pseudomonas infections
• new open heart program
• CABG procedure
• infectious agent in heart pump and glove basin?

Hand contamination from reservoir to three-way stopcock

Blood product thawing water bath

Contamination during blood product pooling

Blood warmer
• water contamination
• contaminate blood lines
• air warmer substitute

Water supply bio-film organisms

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Potable water used during bronchoscopy, instrument reprocessing</td>
<td>M. chelonae</td>
</tr>
<tr>
<td>Potable water, ice</td>
<td>M. fortuitum, M. gordonae, M. kansasi, M. terrae, M. xenopi</td>
</tr>
<tr>
<td>Intrinsically-contaminated laboratory solution</td>
<td>M. gordonae</td>
</tr>
</tbody>
</table>

Cluster Mycobacterium mucogenicum infections from water

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What to do about water in a clinical setting?

<table>
<thead>
<tr>
<th></th>
<th>Number of Samples</th>
<th>Mean (CFUs/ml)</th>
<th>Median (CFUs/ml)</th>
<th>Range (CFUs/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before Flush</td>
<td>16</td>
<td>49,471</td>
<td>25,050</td>
<td>110-196,000</td>
</tr>
<tr>
<td>After Flush</td>
<td>16</td>
<td>146</td>
<td>35</td>
<td>3-970</td>
</tr>
</tbody>
</table>

Shower hose with Silver impregnation
- low usage in BMT
- reduced microbial
- patient minimal usage

Construction related infection related to water

Rhode Island - Legionella during construction

Minnesota - water outage NNICU Elizabethkitek sp. and Pseudomonas aeruginosa after sink outage.

Bio-film disrupted free floating bacteria escape and contaminate water and equipment to cause transmission.

Anticipate flushing in areas affected by water outages.
- Flush till clear about 3 minutes.
- Top down riser flush
- Start at end of horizontal run

Healthcare-associated Outbreaks of Legionellosis

- Contaminated aerosols
- Exposure to aerosols produced from:
  - Cooling towers
  - Showers, aerators
  - Faucets
  - Respiratory therapy equipment
  - Room-air humidifiers
  - Decorative fountains

Colonization of Man-made Aqueous Environments

- Temperatures of 25° - 42° C (77° - 107.6° F)
- Stagnation; dead legs
- Scale and sediment
- Presence of certain free-living aquatic amobae that can support intracellular growth of Legionella

Prevention and Control

- Culture Water for Legionella
  - If found, culture patients
  - Retrospective epidemiology
  - Water system decontamination
- Follow High Risk Patient
  - If found in patient with nosocomial pneumonia
  - Initiate search for water source
  - Maintain cooling towers and use sterile water for nebulization
- Maintain Potable Water
  - 50C or <20C recirculation ideal
  - Heated water at 1-2mg/l free residual chlorine

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Drinking Water System Disinfection
- Superheat & Flush
  - 158F (70C)
- Hyperchlorination
  - Continuous 2-6ppm free chlorine residual
  - Bolus intermittent 17ppm
- Instantaneous Steam Heating
  - Flash heating 88C
  - Blend water & recirculate

- Ultraviolet Light
  - No residual
  - Maintenance essential
- Ozone
  - Effective microbicidal
  - No residual
- Metal ion
  - Silver & copper
  - Electrostatic stresses affect cell death
- Continuous chlorination
  - Chlorine dioxide

Microbial Control with Chlorination
- In 1990 - 23% of municipalities in US with >50,000 people used mono chloramine disinfection
- Advantages:
  - does not form trihalomethanes
  - heat stable
  - more effective at penetrating biofilm
Hospitals with outbreaks of Legionellosis predominately >200 beds
  - 73% of those hospitals have a transplant program
  - 31 outbreaks in hospitals with free available chlorine
  - only one outbreak with mono chloramine
- Chlorine dioxide
  - local production for legionella management (PCU area or whole hospital?)
  - long term disinfection Royal Infirmary Glasgow Scotland (10 years)
- Electro-chemical activation of water and brine to produce disinfection products

Cooling Tower Concerns
- Cooling towers provide ideal environments for Legionella spp. growth
- Locate cooling towers to minimize intake of drift aerosols into the ventilation system
- Perform maintenance cleaning and treatment as per manufacturer’s instructions and other available guidance
- Clean and treat before seasonal start-up

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Cooling Tower Considerations

- Location of air intakes
- Drift eliminators in place
- Design to facilitate cleaning & disinfection
- Corrosion and biomass treatment
- Tower materials resistant to disinfection
- Startup of tower greater risk for dispersal
- Routine maintenance
- Testing & record keeping

CONTINUOUS TREATMENT OF TOWER WATER WITH CHEMICALS
- Optimize chemical usage
- Control biofilm to control legionella
- Enhance efficiency
- Precautions when cleaning

Automatic Faucets

Component parts harbor bacteria
Instant water no adjustment first drop water

Manual faucet

All soft rubber or cellulose components harbor bacteria
Manual faucets require adjustment hence flushing fewer sources

While spigots may get contaminated the removal of the microbial load prevent colonization and/or infection.

Point of use filters are not a long term solution but a short term to allow time for correction.
Silting index of water determines plugging time till exchange.

WATER SOURCES ARE VARIED IF YOU KNOW WHERE TO LOOK

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Infection prevention depends on understanding the chain of infection.

Methods to culture bacteria in water

<table>
<thead>
<tr>
<th></th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spread Plate</td>
<td>easy, low tech</td>
<td>not sensitive to low levels</td>
</tr>
<tr>
<td>Broth</td>
<td>easy, low tech</td>
<td>grows dominant microbe</td>
</tr>
<tr>
<td>Membrane Filter</td>
<td>sensitive to low conc</td>
<td>higher tech, specialized methods</td>
</tr>
</tbody>
</table>

In a suspect infection associated with water bacteria
- determine culture site
- sputum culture may indicate water usage
- ice for mouth care
- drinking water
- carafe or bottle source of DW
- wound infection
- water sources
- ice machine showers
- blood stream sepsis access
- showers
- bathing methods
- procedures
- hand transmission potential
- water connectors
- hand wash sinks

Questions and Answers??

strei001@umn.edu

Water usage
- ice for mouth care
- drinking water
- carafe or bottle
- source of DW
- wound infection
- water sources
- ice machine showers
- blood stream sepsis access
- showers
- bathing methods
- procedures
- hand transmission potential
- water connectors
- hand wash sinks

University of Minnesota Medical Center-1986
UMMC Amplatz Children’s Hospital-2011

Advantages

Spread Plate
- easy
- low tech
- uses low volumes of water
- good screen

Broth
- easy
- low tech
- sensitive to low volumes

Membrane Filter
- sensitive to low conc.
- specialized methods

Disadvantages

Spread Plate
- not sensitive to low levels

Broth
- grows dominant microbe

Membrane Filter
- higher tech
- expensive

Coming Soon

5 April  Standardized Training for Environmental Cleaning in Healthcare
Speaker: Grace Volkening, Brenda Smith, Nora Boyd, Public Health Ontario
Sponsor: Virox Technologies Inc.

12 April  (FREE A.D. Russell Memorial Teleclass) Innate Resistance to Sporicides and Potential Failure to Decontaminate
Speaker: Prof. Jean-Yves Maillard, Cardiff University, Wales

17 April  (FREE WHO Teleclass – North America) Implementing Change: The Technical & Socio-Adaptive Aspects of Preventing Catheter-Associated Urinary Tract Infection
Speaker: Prof. Sanjay Saint, University of Michigan
Sponsor: World Health Organization First Global Patient Safety Challenge

18 April  Central Line Associated Infection in the ICU
Speaker: Prof. M. L. McLaue, University of New South Wales, Australia

www.webbertraining.com/schedulepl.php

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