Andrew Streifel  
Environmental Health & Safety  
University of Minnesota  
strei001@umn.edu

Water Quality in Health Care

U of MN  
Academic Health Center and Hospital

Andrew Streifel  
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strei001@umn.edu

The Infection Control Issues at U of MN Since 1960
- Increases in immune compromised patients
- Technology advances
- Transplantation
- Cancer treatment
- Advanced surgeries

Infection control & technology
Water Systems in Healthcare

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

WATER SOURCE PROFILE TWIN CIYTES MINNESOTA USA

Ground water or surface water sources

WATER TREATMENT DEPENDS ON SOURCE OF WATER SUPPLY

Depends on season
Intake water quality
Chemical components
Aesthetic parameters

ENVIRONMENTAL MICROBIAL BIOLOAD

<table>
<thead>
<tr>
<th>COLONY FORMING UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAW MILK 10³ – 10⁵/ml</td>
</tr>
<tr>
<td>SEWERAGE 10⁶ – 10⁷/ml</td>
</tr>
<tr>
<td>FLOORS 10⁶ – 10⁷/cm²</td>
</tr>
<tr>
<td>FECAL MATTER 10⁸ – 10⁹/gm</td>
</tr>
<tr>
<td>NATURAL WATER &lt;1 – 10⁴/ml</td>
</tr>
<tr>
<td>AIR 10 – 10⁵/m³</td>
</tr>
</tbody>
</table>

EPA DRINKING WATER STANDARD AT <1.0 CFU/100ML COLIFORM & <500CFU/HPC
The DWG for coliform is an enforceable standard while the HPC is not enforceable.
Waterborne Infections

- Many cases cited
- Causes vary
- Single case vs. outbreak
- Distinguish healthcare associated (nosocomial) from community acquired infection
  - Determine source: supply vs. healthcare facility vs. reservoir
- Many unrecognized cases
- Biofilms protect & insulate

Alert Organisms from Clinical Microbiology Rounds

- Water bacteria
  - Pseudomonas aeruginosa
  - Burkholderia cepacia
  - Serratia marcescens
  - Acinetobacter calcoaceticus var.
  - Chryseobacterium meningosepticum
  - Aeromonas hydrophillia
  - 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; 96,000 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
Hazard Analysis of Critical Control Points

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

Legionellosis

<table>
<thead>
<tr>
<th>State</th>
<th>2011 (Up to Sept. 10)</th>
<th>2012 (Up to Sept. 10)</th>
</tr>
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<tbody>
<tr>
<td>California</td>
<td>178</td>
<td>128</td>
</tr>
<tr>
<td>Colorado</td>
<td>24</td>
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</tr>
<tr>
<td>Maryland</td>
<td>60</td>
<td>72</td>
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<tr>
<td>Minnesota</td>
<td>21</td>
<td>30</td>
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<tr>
<td>Missouri</td>
<td>36</td>
<td>55</td>
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<tr>
<td>New York</td>
<td>204</td>
<td>192</td>
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<tr>
<td>Wisconsin</td>
<td>45</td>
<td>0</td>
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<tr>
<td>USA</td>
<td>2387</td>
<td>1921</td>
</tr>
</tbody>
</table>

Examples of Potable Water Flow Process Diagrams for a Building Water System

Schematic representation of how potable water is processed and used in the facility. Note that processing steps are named and numbered.
Water Bugs and Infection Prevention

MINNESOTA ASHE  APRIL 2012

Adapted from ASHE publication: HACCP Plan for Prevention of Legionellosis Associated with Building Water Systems
ASHE Advocacy February 23, 2012

<table>
<thead>
<tr>
<th>Types of Hospital Water Usage</th>
<th>Potable</th>
<th>Micro Standards</th>
<th>Exposure to potential infection</th>
<th>Legionella issue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potable Water System</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Water intake</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Heating/cooling</td>
<td></td>
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<td></td>
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<tr>
<td>3. Distribution</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>4. Filtration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Waste</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Potable Water System

1. Water intake
   - Steam/steam
   - Drinking water

2. Heating/cooling
   - Bathing-showering
   - Drinking water

3. Distribution
   - Galvanic

4. Filtration
   - Laboratory

5. Waste
   - Sanitary sewer

Utility Water System

1. Water intake
   - Municipal water

2. Conditioning
   - Condensate
   - Return water

3. Heating
   - Steam, hot water

4. Distribution
   - Heat transfer
   - Drinking water

5. Recirculating

Adapted from ASHE publication: HACCP Plan for Prevention of Legionellosis Associated with Building Water Systems
ASHE Advocacy February 23, 2012

ANDREW STREIFEL
Hospital Environment Specialist
Water Bugs and Infection Prevention

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ANDREW STREIFEL
Hospital Environment Specialist

6

Waterborne (Legionella) Transmission Steps

1. Survival in Reservoir
2. Amplification
3. Dissemination
4. Transmission
5. Multiply in Human
6. Risk Minimization (Prevention)
7. Diagnosis

Adapted from Barbarie ASHRAE 1995

Control-Waterborne

- Design – potable water; cooling towers
- Maintenance
- Temperature >140° F?
- Treatment of water
  - Municipal source
  - In-hospital treatment
- Source recognition
  - Water reservoirs
  - Dead-legs & dormant
- Flushing pre-occupancy

Control-Design

- Potability
- Monitoring
- Sizing system for design

Drinking water standards:
- <1 cfu/100ml 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

Are the water bacteria resistant?

- Drinking water standards:
- <1 cfu/100ml 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

Operating Criteria / On-Going Operations

Water systems can be complex differences in design are important

Biofilm development from planktonic to sessile colonies

1 2 3 4 5
Bacterial Attachment to Selected Surfaces

L. 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

A. hydrophila (highest attachment to lowest)
1. Polybutylene
2. Stainless steel
3. Copper

Bacteria biofilms within the clinical setting: what healthcare professionals should know, D. Lindsay, A van Noiley, Journal of Hospital Infection, 2006.

Biofilm Formation in Water Systems
- Pipe
- Operations
- Disinfection
- Monitoring
- Flow
- Temperature control

Biocontamination of Drinking Water
- Macroscale
- Mesoscale
- Microscale

ANDREW STREIFEL
Hospital Environment Specialist
Municipal Water Quality

- Debris & color
- Bacteria (DWS <1cfu/100ml coliform)
- Minimal fungi & virus (<500cfu/ml - HPC)
- Residual disinfectant
- Water usage source for:
  - Drinking
  - Dialysis
  - Laboratory
  - Process

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
The kidney machine with artificial kidney mimics renal function.

About 100,000 on chronic dialysis.
Change out of Water treatment systems needs coordination and quality control.

- Supply water quality
- Water treatment system
- Pre-treatment
- Piping
- Water disinfection
- Sampling ports

### Table 18. Microbiologic limits for hemodialysis fluids*

<table>
<thead>
<tr>
<th>Hemodialysis fluid</th>
<th>Maximum total heterotrophic (CFU/mL)</th>
<th>Maximum endotoxin level (EU/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-filter water</td>
<td>200</td>
<td>No standard</td>
</tr>
<tr>
<td>Dialysate</td>
<td>200</td>
<td>0.5</td>
</tr>
</tbody>
</table>

**Proposed standard**

| Product water    | 200                              | 2                               |
| Dialysate        | 200                              | 2                               |

* The material in this table was compiled from references 391, 793, and 791 (ANSI/AAMI standards RD 5-1992 and ANSI/AAMI RD 47-1993).

† Sustained for seven days at room temperature.

§ Endotoxin units per milliliter.

¶ Product water generally includes water used to prepare dialyzer and water used to prepare dialyzer fluid.

**Dialysate for hemodialysis, RD 52, under development, American National Standards Institute, Association for the Advancement of Medical Instrumentation (AAMI).**

CDC-Environmental Infection Control-6/6/2003

### 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>Organism</th>
<th>Tap Water</th>
<th>Humidification Water</th>
<th>Distilled Water</th>
<th>Sterile Water or Saline</th>
<th>Nonsterile Water</th>
<th>Faucet Aerator</th>
<th>Sink or Wash Basin</th>
<th>Ice Machine</th>
<th>Water Fountain</th>
<th>Dialysis Machine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pseudomonas aeruginosa</td>
<td>√</td>
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<tr>
<td>Pseudomonas fluorescens</td>
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<td>Stenotrophomonas maltophilia</td>
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<td></td>
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<tr>
<td>Acinetobacter species</td>
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<tr>
<td>Sphingomonas paucimobilis</td>
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<tr>
<td>Burkholderia cepacia</td>
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<td></td>
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<tr>
<td>Ralstonia pickettii</td>
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<tr>
<td>Pseudomonas stutzeri</td>
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</tbody>
</table>

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

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

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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

Solution = malt mixer

Formula preparation equipment caused GI problems in "short bowel" infants
Water Bugs and Infection Prevention

Blood product thawing water bath

Contamination during blood product pooling

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 warmer
- Water contamination
- Contaminate blood lines
- Air warmer substitute
### Water supply bio-film organisms

<table>
<thead>
<tr>
<th></th>
<th></th>
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</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. kansas, 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

- Clinicalsetting

### What to do about water in a clinical setting?

<table>
<thead>
<tr>
<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>110-196,000</td>
</tr>
<tr>
<td>After Flush</td>
<td>16</td>
<td>146</td>
<td>35</td>
</tr>
</tbody>
</table>
Water Bugs and Infection Prevention

MINNESOTA ASHE  APRIL 2012

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

Wild Type

<table>
<thead>
<tr>
<th>Hours</th>
<th>0</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
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</tr>
</tbody>
</table>

Construction related infection related to water

Rhode Island - Legionella during construction
Minnesota - water outage NNICU Elizabethkii 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
  — 50°C or <2°C recirculation ideal
  — Heated water at 1-2mg/l free residual chlorine
Drinking Water System Disinfection

- Superheat & Flush
  - 158°F (70°C)
- Hyperchlorination
  - Continuous 2-6ppm free chlorine residual
  - Bolus intermittent 17ppm
- Instantaneous Steam Heating
  - Flash heating BCC
  - Blend water & recirculate
- Ultraviolet Light
  - No residual
  - Maintenance essential
- Ozone
  - Effective microbiocide
  - No residual
- Metal ion
  - Silver & copper
  - Electrostatic stresses affect cell death
- Continuous chlorination
  - Chlorine dioxide

Electrochemical Activation of Water

Metal ion Silver & Copper electrodes

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 bio film
Hospitals with outbreaks of Legionellosis predominately >200 beds
- 78% 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
Chlorine dioxide is a stable water disinfectant that can be added to an existing water distribution system. The methods of adding chemical to the water supply makes the hospital a secondary water treatment facility needing added sampling for residual and by product.

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

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

Was the intention of AF to be:
- hands free
- water usage

Component parts harbor bacteria
Instant water no adjustment first drop water

Manual faucets

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

Water usage is dropping due to change out of water to air cooled devices, chemical to digital processors for radiology, low flow toilets and aerators as well as waterless hand cleansing systems.

UMMC Water Usage 1999-2011
[Random Samples]
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??

Methods to culture bacteria in water

<table>
<thead>
<tr>
<th>Spread plate</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy</td>
<td>Low tech</td>
<td>Not sensitive to low levels</td>
</tr>
<tr>
<td>Low volumes</td>
<td>Good screen</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Broth</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy</td>
<td>Low tech</td>
<td>Sensitive to low volumes</td>
</tr>
<tr>
<td>Low volumes</td>
<td>Grows dominant microbe</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Membrane filter</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitive to low conc</td>
<td>Specialized methods</td>
<td></td>
</tr>
<tr>
<td>Higher tech</td>
<td>Expensive</td>
<td></td>
</tr>
</tbody>
</table>

Advantages
- Spread plate
- Broth
- Membrane filter

Disadvantages
- Not sensitive to low levels
- Sensitive to low volumes
- Expensive

Methods to culture bacteria in water

- Spread plate
- Broth
- Membrane filter

Advantages
- Easy
- Low tech
- Sensitive to low conc

Disadvantages
- Not sensitive to low levels
- Sensitive to low volumes
- Expensive
Questions and Answers??

streif001@umn.edu