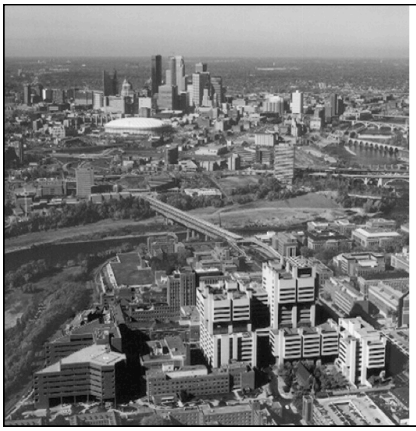
Water Bugs and Infection Prevention
Andrew Streifel, University of Minnesota
A Webber Training Teleclass

Water Bug Management for Infection Prevention

Andrew Streifel
Environmental Health & Safety
University of Minnesota

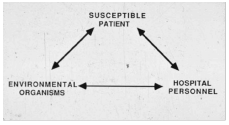
Hosted by Nicole Kenny
Virox Technologies Inc, Toronto

www.webbertraining.com **March 29, 2012**



U of MN Academic Health Center and Hospital

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

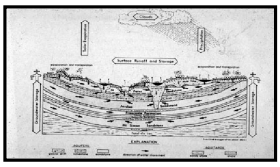


Infection control & technology

Water Systems in Healthcare

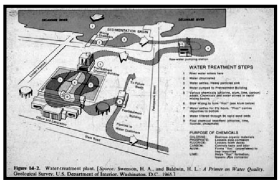
- Drinking water
- Kidney dialysis
- Laboratory
- Therapeutic
- Cooling
- Fire management

WATER SOURCE PROFILE TWIN CITIES MINNESOTA USA



Ground water or surface water sources

WATER TREATMENT DEPENDS ON SOURCE OF WATER SUPPLY



Depends on season
Intake water quality
Chemical components
Esthetic parameters

ENVIRONMENTAL MICROBIAL BIOLOAD

	COLONY FORMING UNITS
RAW MILK	$10^3 - 10^5$/ml
SEWERAGE	$10^6 - 10^7$/ml
FLOORS	$10 - 10^3$/cm^2
FECAL MATTER	$10^8 - 10^{10}$/gm
NATURAL WATER	$<1 - 10^4$/ml
AIR	$10 - 10^5$/m^3

EPA DRINKING WATER STANDARD AT <1.0CFU/100ML COLIFORM & <500cfu/HPC

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Alert Organisms from Clinical Microbiology Rounds

- **Water bacteria**
  - **Pseudomonas aeurginosa**
  - **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; 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.

Cervia, et al, A Reservoir of Risk for Health Care-Associated Infection, *Infect Dis Clin Pract* 2008;16:349-353

Infection Control Risk Assessment for Water Systems

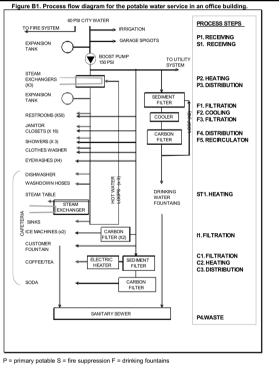
Hazard Analysis of Critical Control Points

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

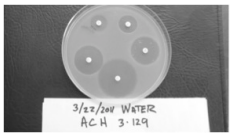
Examples - Potable Water Process Flow Diagram for a Building Water System

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



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 Nwachcuku, Charles P. Gerba, *Current Opinion in Biotechnology*, 2004

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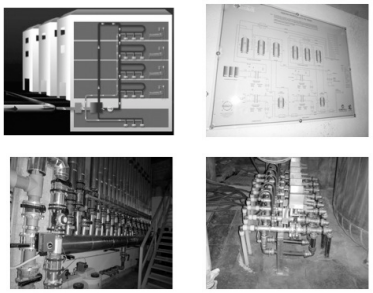
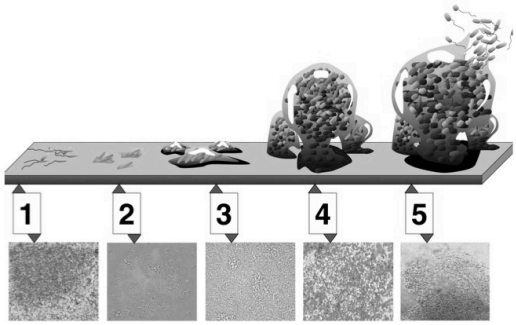
Operating Criteria / On-Going Operations



Water systems can be complex differences in design are important

Biofilm development from planktonic to sessile colonies



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

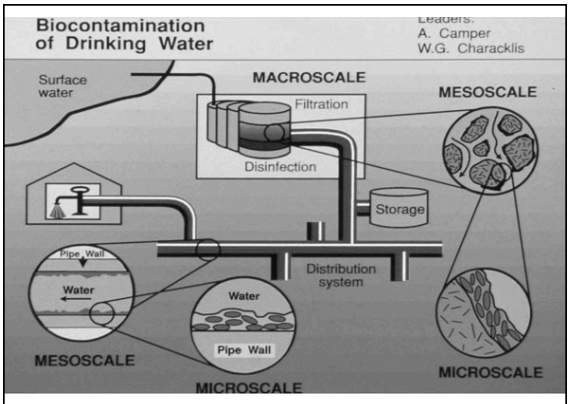
- ***Aeromonas hydrophila*** (highest attachment to lowest)

1. Polybutylene
2. Stainless steel
3. Copper

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

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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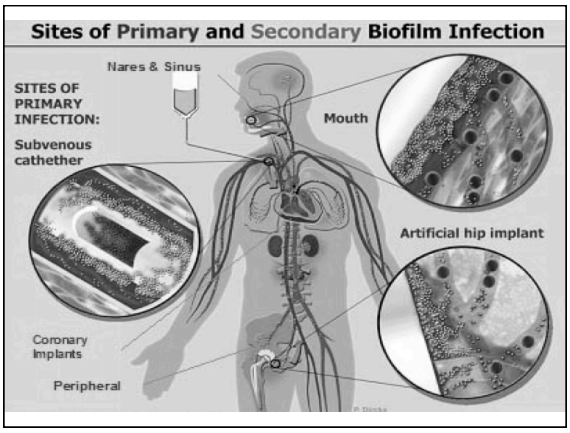
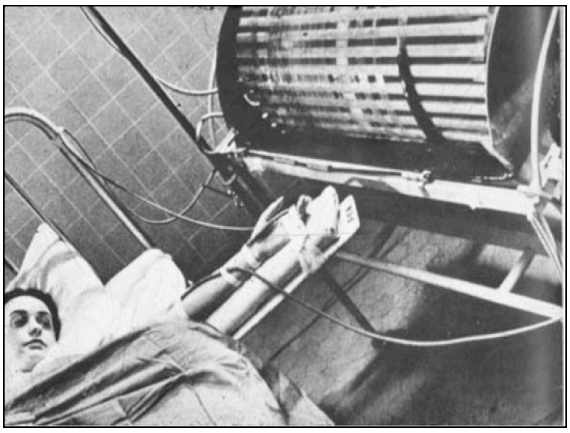
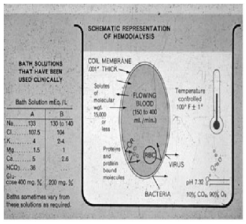




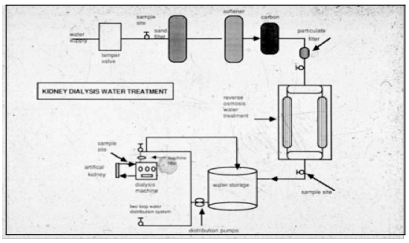
The kidney machine with artificial kidney mimics renal function



About 100,000 on chronic dialysis

MICROBIOLOGY WATER QUALITY LIMITSCOLONY FORMING UNITS/ml

	ANSI HEMODIALYSIS STD 1992	2003	DWS	
Dialysate Product water	<200	<200 (2EU')		*-coliforms
Dialysate	<2000	<200 (2EU')	<1*/100	'-endotoxin unit/ml



Drinking water has from 0 to 12 EU endotoxin

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

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

ANSI-AAMI Standard for Dialysis Water 1992-3

Table 18. Microbiologic limits for hemodialysis fluids*

Hemodialysis fluid	Maximum total heterotrophs (CFU/mL)+	Maximum endotoxin level (EU/mL)§
Present standard		
Product water¶		
Used to prepare dialysate	200	No standard
Used to reprocess dialyzers	200	5
Dialysate	2,000	No standard
*Proposed standard***		
Product water	200	2
Dialysate	200	2

* The material in this table was compiled from references 789 and 791 (ANSI/AAMI standards RD 5-1992 and ANSI/AAMI RD 47-1993).
+ Colony forming units per milliliter.
§ Endotoxin units per milliliter.
¶ Product water presently includes water used to prepare dialysate and water used to reprocess dialyzers.
** 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

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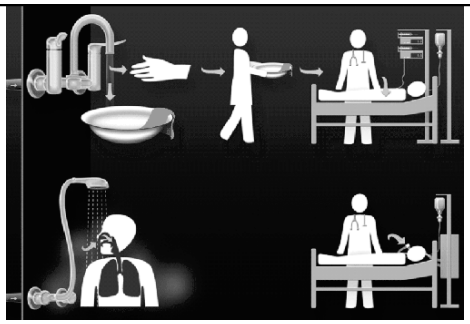
Reservoir Water Bacteria Identification

- **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

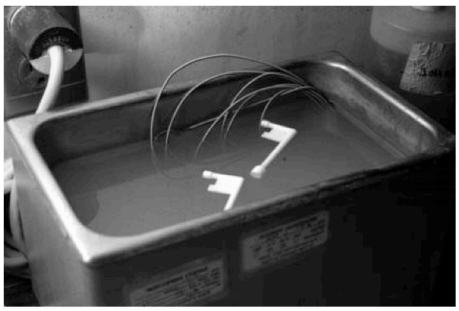
	Tap Water	Humidification Water	Distilled Water	Sterile water or Saline	Nonsterile Water	Faucet aerator	Sink or wash basin	Ice machine Water fountain	Dialysis machine
Pseudomonas aeruginosa	√	√	√	√	√	√	√	√	√
Pseudomonas fluorescens	√	√	√						
Stenotrophomonas maltophilia	√						√		√
Acinetobacter species		√	√	√	√		√		√
Sphingomonas paucimobilis		√		√					
Burkholderia cepacia			√	√	√				√
Ralstonia pickettii			√	√					
Pseudomonas stutzeri									√

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



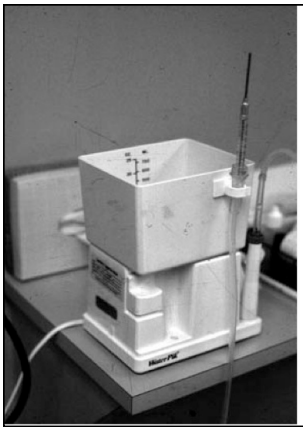
Breaking the chain of infection requires understand mode of transmission and reservoirs of the organisms.

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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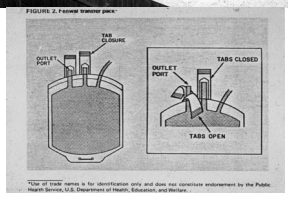
Solution = malt mixer

Formula preparation equipment caused GI Problems in "short bowel" infants

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?

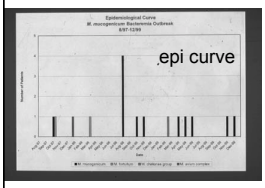
Hand contamination from reservoir to three-way stopcock

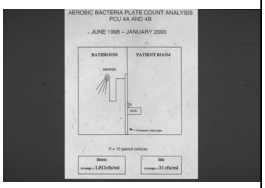
Blood warmer
- water contamination
- contaminate blood lines
- air warmer substitute

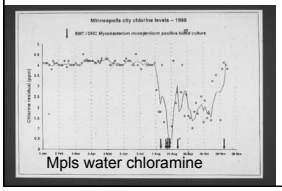
Water supply bio-film organisms

Implicated Environmental Vehicle	*Mycobacterium* Spp.
Potable water used during bronchoscopy, instrument reprocessing	*M. chelonae*
Potable water, ice	*M. fortuitum, M. gordonae, M. kansasii, M. terrae, M. xenopi*
Intrinsically-contaminated laboratory solution	*M. gordonae*

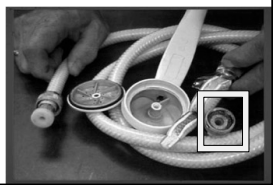
Cluster Mycobacterium mucogenicum infections from water







Mpls water chloramine



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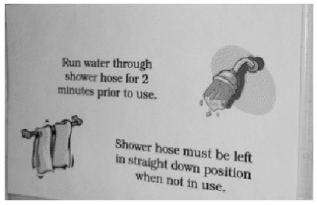
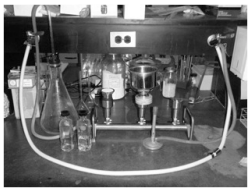
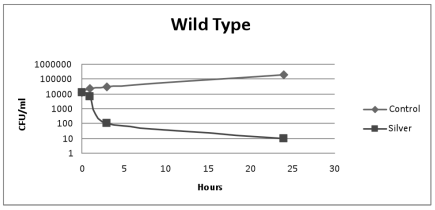
What to do about water in a clinical setting?



	Number of Samples	Mean (CFUs/ml)	Median (CFUs/ml)	Range (CFUs/ml)
Before Flush	16	49,471	25,050	110-196,000
After Flush	16	146	35	3-970

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 Elizabethtikei 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 25º - 42º C (77º - 107.6º 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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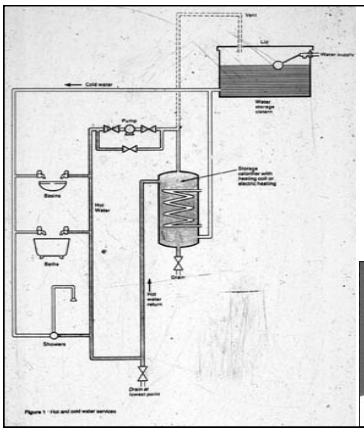

WATER DISTIBUTION SYSTEM BUILDING ISSUES RELATED TO DEAD END CONNECTIONS FROM DISCONTINUED LINES.

Biofilm buildup from stagnant water and additives.

Biofilm + corrosion

Drinking Water System Disinfection

- Superheat & Flush
  - 158F (70C)
- Hyperchlorination
  - Continuous 2-6ppm free chlorine residual
  - Bolus intermittant 17ppm
- Instantaneous Steam Heating
  - Flash heating 88C
  - 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

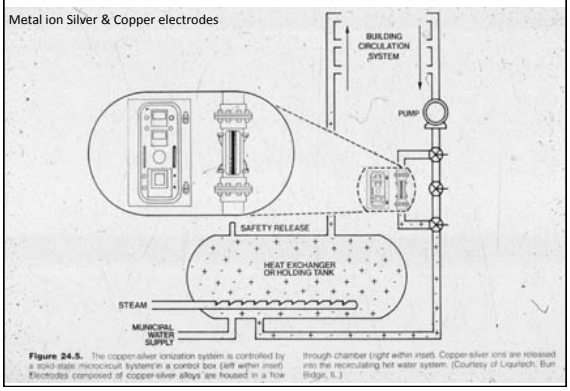

Figure 24.5. The copper-silver ionization system is controlled by a solid-state microcircuit system in a control box (left within inset). Electrodes composed of copper-silver alloys are housed in a flow through chamber (right within inset). Copper-silver ions are released into the recirculating hot water system. (Courtesy of Liquitech, Burr Ridge, IL.)

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
  - 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

Electrochemical Activation of Water

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

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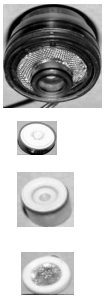
Cooling Tower Considerations

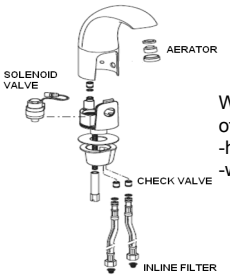
- Location of air intakes
- Drift eliminators in place
- Design to facilitate cleaning & disinfection
- Corrosion and biomass treatment
- Tower materials resistant to disinfection
- Startup of tower greater risk for dispersal
- Routine maintenance
- Testing & record keeping

CONTINUOUS TREATMENT OF TOWER WATER WITH CHEMICALS

-optimize chemical usage
-control biofilm to control legionella
-enhance efficiency
-precautions when cleaning

Automatic Faucets

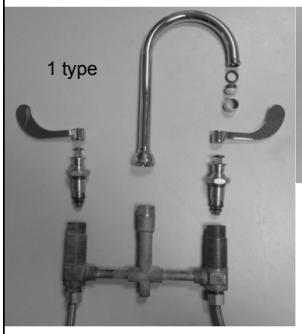


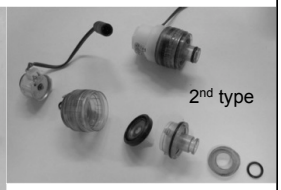


Was the intention of AF to be:
-hands free
-water usage

Component parts harbor bacteria
Instant water no adjustment first drop water

Manual faucet

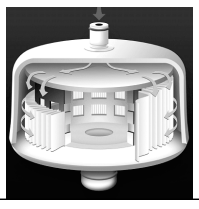




All soft rubber or cellulose components harbor bacteria

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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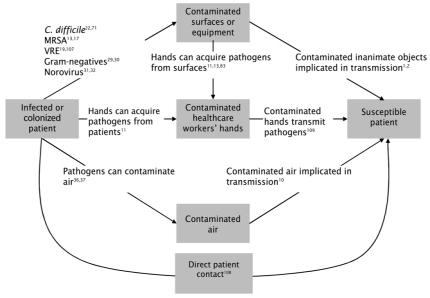
www.webbertraining.com

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

Infection prevention depends on understanding the chain of infection.



The Role played by Contaminated Surfaces in the Transmission of Nosocmial Pathogens, J. Otter et. al., ICHE July 2011

In a suspect inflection 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

	Advantages	Disadvantages
Spread Plate	easy low tech uses low volumes of water good screen	not sensitive to low levels
Broth	easy low tech sensitive to low volumes	grows dominant microbe
Membrane Filter	sensitve to low conc specialized methods	higher tech expensive

University of Minnesota Medical Center-1986

UMMC Amplatz Children's Hospital-2011

Questions and Answers??

strei001@umn.edu

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. McLaws, University of New South Wales, Australia

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