Water and Infection Control for Facility Management

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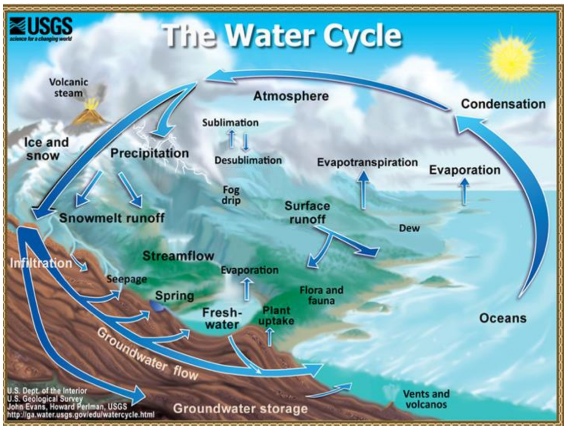
Water Systems in Healthcare

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

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
The DWS for coliform is an enforceable standard while the HPC is not enforceable.

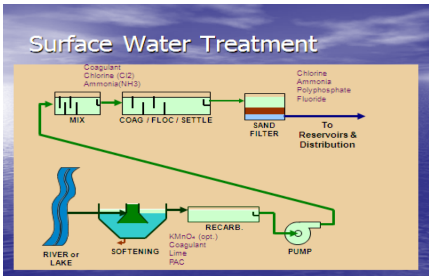


Water Quality Parameters

	Well Water	Surface Water	
		Reservoir	*River*
Mineral Content	High	Variable	Seasonal
Organic Content	Low	High Depth Dependent	Variable Seasonal
Chlorination	Free Available	Free/Combined	Combined
Bacteria	Low	Variable	Seasonal
PH	Stable	Stable	Variable
Ability to be treated	Stable	Seasonal	Variable

Contaminant (units)	MCLG	MCL	Level Found Range(2012)	Level Found Average Result	Typical Source of Contaminant	Meets Standard
Fluoride (ppm)	4	4	.94-1.1	1.05	State of Minnesota requires all municipal water systems to add fluoride to the drinking water to promote strong teeth; Erosion of natural deposits; Discharge from fertilizer and aluminum factories.	✓
Haloacetic Acids (HAA5) (ppb)	0	60	1.3-90.8	51.15	By-product of drinking water disinfection.	✓
Nitrate (as Nitrogen) (ppm)	10.4	10.4	N/A	.2	Runoff from fertilizer use; Leaching from septic tanks, sewage; Erosion of natural deposits.	✓
TTHM (Total Trihalomethanes) (ppb)	0	80	8.8-105.9	54.85	By-product of drinking water disinfection	✓
Total Coliform Bacteria	0 present	>5% present	N/A	1%*	Naturally present in the environment.	✓
Turbidity (NTU)	N/A	TT	100% for the lowest % of compliance	0.27 NTU Highest Measurement	Soil runoff.	✓
Chlorine (ppm)	4 MRDLG	4 MRDL	2.3-4 Highest and Lowest Monthly Avg.	3.28 Highest Quarterly Avg.	Water additive used to control microbes.	✓
Total Organic Carbon	25%-30% Removal Required		Quarters below removal rate= 0	46%-59.1% Removal Achieved	Naturally present in the environment.	✓
Copper (ppm)	1.3	1.3 AL	90% Level .07	0 out of 50 sites over AL	Corrosion of household plumbing systems; Erosion of natural deposits.	✓
Lead (ppb)	0	15 AL	90% Level 3.2	1 out of 50 sites over AL	Corrosion of household plumbing systems; Erosion of natural deposits.	✓
Sodium (ppm)	-	-	N/A	12.6	Erosion of natural deposits.	✓
Sulfate (ppm)	-	-	N/A	28.4	Erosion of natural deposits.	✓

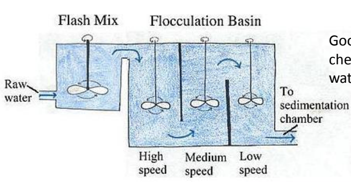
Minneapolis MN



Primary
- -KMNO[3]
- -Coagulation
- -Lime

Secondary
- -Coagulation
- -Chlorine/Ammonia

Tertiary
- -Chlorine/Ammonia
- -Polyphosphate
- -Fluoride



Good mixing is necessary for chemical reaction with incoming water.

Sand filtration prone to channeling
Removes particles including bacteria
Protozoa.

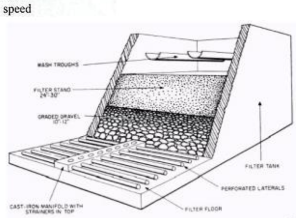


Figure 9-16.-Typical sand filter showing relationship of filter media.

Minneapolis Water Treatment Ultrafiltration

Ultrafiltration Plant will remove microns as small as 0.03 micometers (µm

Relative sizes:

red blood cells	4 to 10 µm	Viruses	0.02 to 0.09 µm
Harmful bacterial	0.2 to 2 µm	Dissolved salts	0.0003 to 0.002 µm
Microsproridium	1 to 3 µm	Dissolve minerals (Calcium, etc)	0.0002 to 0.0003 µm

Municipal Water Quality

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

Microorganisms

Contaminant	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Long-Term Exposure Above the MCL (unless specified as short-term)	Sources of Contaminant in Drinking Water
Cryptosporidium	zero	TT[3]	Gastrointestinal illness (such as diarrhea, vomiting, and cramps)	Human and animal fecal waste
Giardia lamblia	zero	TT[3]	Gastrointestinal illness (such as diarrhea, vomiting, and cramps)	Human and animal fecal waste
Heterotrophic plate count (HPC)	n/a	TT[3]	HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is.	HPC measures a range of bacteria that are naturally present in the environment
Legionella	zero	TT[3]	Legionnaire's Disease, a type of pneumonia	Found naturally in water; multiplies in heating systems
Total Coliforms (including fecal coliform and *E. Coli*)	zero	5.0%[4]	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present[5]	Coliforms are naturally present in the environment; as well as feces; fecal coliforms and *E. coli* only come from human and animal fecal waste.
Turbidity	n/a	TT[3]	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (such as whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.	Soil runoff
Viruses (enteric)	zero	TT[3]	Gastrointestinal illness (such as diarrhea, vomiting, and cramps)	Human and animal fecal waste

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

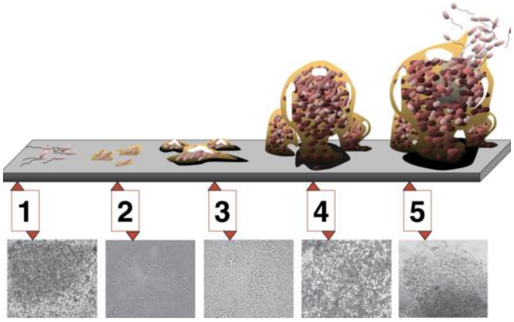
Vol. 15, No. 2

REVIEWS

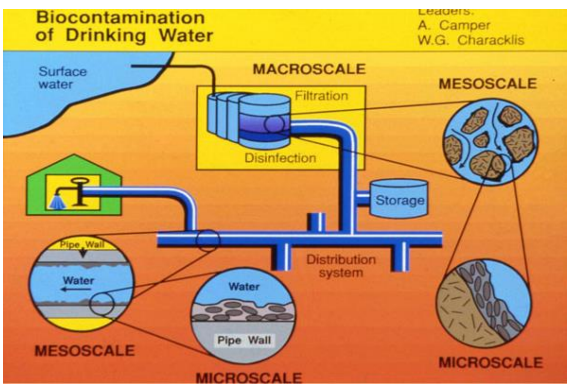
Biofilms: Survival Mechanisms of Clinically Relevant Microorganisms

INTRODUCTION
BIOFILMS DEFINED
HOW MICROORGANISMS FORM BIOFILMS
BIOFILM EXAMINATION AND MEASUREMENT
BIOFILM ULTRASTRUCTURE
RESISTANCE TO ANTIMICROBIAL AGENTS

Biofilm development from planktonic to sessile colonies



Biofilm thrives in stagnant water



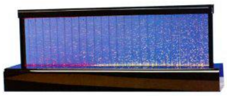
WATER FEATURES CAN BE THE SOURCE OF EXPOSURE

Biofilm development is enhanced when:
-temperature is >68F
-submerged lighting is present
-nutrients
-water feature materials support growth
-water flow slow or stagnant
-aerosol generation

Water treatment
-size of fountain
-ozone
-halogens
-chlorine dioxide
-UV

Water feature risk analysis

Low aerosol production



Aerosol producers

Spray

Enclosed

cascade

Water wall

Mist

An Outbreak of Legionnaires Disease Associated with a Decorative Water Wall Fountain in a Hospital Haupt, TE. et al, Infect Control Hôpital Epidemiology 2012;33(2):185-191

Healthcare Acquired Legionellosis from Fountains

NIH-2008
2 BMT pts

- 30 month old fountain
  - -stagnation of water during 4 month outage before usage
- contamination despite ozone and filtration
- routine maintenance being conducted
- false negative sample results
  - -sampling error
  - -inadequate culture techniques from commercial lab

Wisconsin-2010

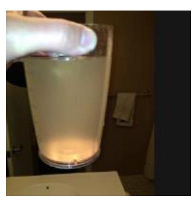
- 8 outpatients affected
- 9 of 44 environmental samples positive 20%
- support foam most contaminated
- 8 positive cultures from fountain
- glass wall, ionization disinfection
- maintenance, testing and more measures still there was contamination
- supplemental disinfection with ionization did not help
  - Issues: foam and heat from lights

Waterless Fountain
University of Minnesota Medical Center

FGI Guidelines for Design and Construction of Hospitals ……. 2014
"Installation of indoor, unsealed open water fountains shall not be permitted"

Will we be know what to when it happens?

Water Main Break Minneapolis 2013



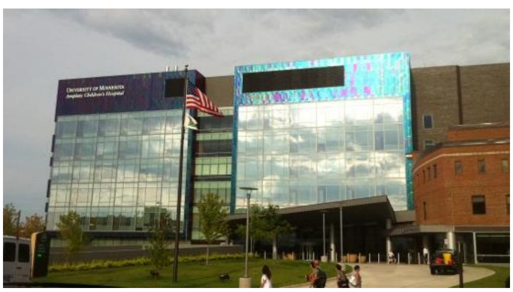
Water Main Break Area Affected

January 2013

What Constitutes a Water Emergency

- No water
- Reduced water flow from drought/rationing
- Contaminated water
- Insufficient water pressure

Design Segment



Amplatz Children's Hospital University of Minnesota Medical Center 2011

Design Considerations

- Source water
  - Well or surface
- Hot water plan
  - Instantaneous
  - Mixing valves
  - Expansion tanks
- Pipe material
- Construction
  - Pipe storage
  - Avoid stagnation

Plumbing Component Considerations

- Hot water heaters (instantaneous)
- Pipe material (galvanized, copper, plastic)
- Expansion tanks (bladders)
- Holding tanks
- Water hammer arrestors (pistons)
- Water softeners (brine tanks)
- Valves, backflow preventers, etc.
- Lubricants & other

Design Practice

- Redundancy
- Dead-leg Piping
- Balancing return hot water
- Zoning for Maintenance
- Sizing Equipment to Handle Peak Loads
- Lack of actual data on hot water usage

Plumbing components
water hammer arrestors
surge tanks
under sink filters

Bacterial Attachment to Selected Surfaces

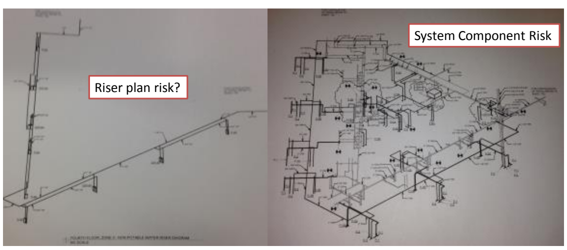
Legionella pneumophila (highest attachment to lowest)

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.



When looking at design what do we need to be concerned about in the system?

Expansion tanks
Water hammer arrestors
Dead end connections
Amplification devices
Flow restrictors

Other locations of concern:
- Dialysis
- Lab water
- Cooling towers
- Ice machines

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..**

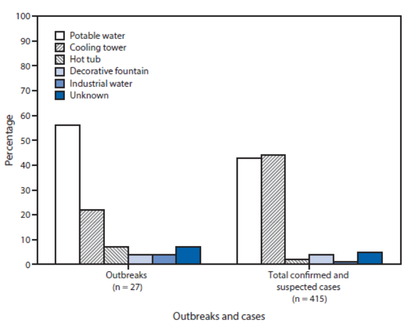
The bacteria are there but we notice them only when they become resistant.

Some of these microbes have doubling times of around 20 minutes

Control-Waterborne

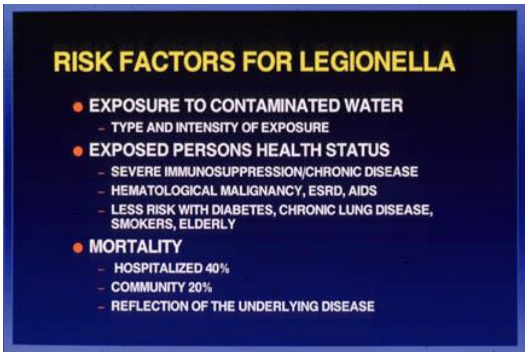
- Design – potable water; cooling towers
- Maintenance
- Temperature >140° F?
- Treatment of water
  - Municipal source
  - In-hospital treatment
- Source recognition
  - Water reservoirs
  - Dead-legs & dormant
- Flushing pre-occupancy

Percentage of outbreaks an cases Legionellosis by environmental source
North America 2000-2014



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



Legionella Facts

•Gram-negative bacteria that includes L. pneumophila

•Legionella is common in many environments (soil & aquatic) with 50 sp & 70 sero groups

•Detection requires special culturing methods

•In the natural environment, *Legionella* lives within amoebae such as *Acanthamoeba* spp., *Naegleria* spp., *Tetrahymena pyriformis*, and *Vermamoeba vermiformis*

•The disease is generally not a threat to most healthy individuals, and tends to lead to harmful symptoms only in those with a compromised immune system and the elderly.

•According to *Infection Control and Hospital Epidemiology*, hospital-acquired *Legionella* pneumonia has a fatality rate of 28%, and the source is the water distribution system.

•In the United States, the disease affects between 8,000 and 18,000 individuals a year.

•Person-to-person transmission of *Legionella* has not been demonstrated

Temperature affects the survival of Legionella as follows:

-Above 70 °C (158 °F) - Legionella dies almost instantly

-At 60 °C (140 °F) - 90% die in 2 minutes(Decimal reduction time (D= 2)

-At 50 °C (122 °F) - 90% die in 80–124 minutes, depending on strain (Decimal reduction time (D = 80-124)

-48 to 50 °C (118 to 122 °F) - can survive but do not multiply

-32 to 42 °C (90 to 108 °F) - ideal growth range

-25 to 45 °C (77 to 113 °F) - growth range

-Below 20 °C (68 °F) - can survive but are dormant, even below freezing

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 Final adoption July 2015

Types of Hospital Water Usage

Type	Potable	Micro Standards	Exposure to potential infection	*Legionella* issue
Drinking	YES	YES	Aerosol ingestion	YES
Laboratory	NO	YES	False positive	NO
Dialysis	NO	YES	Endotoxin reaction/infection	NO
Process/heating-cooling	NO	YES	Heat transfer	YES
Fire suppression	NO	NO	Inefficiency	NO

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

Best Practices in Plumbing System Design Operations and Maintenance

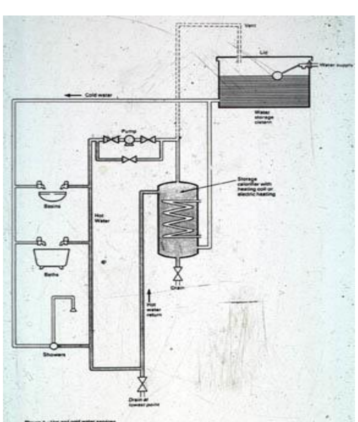
- Extend recirculation lines to the point farthest from the supply.
- Run all lines at a slight fall to make draining the system easier and to reduce air locks.
- Run hot piping above cold piping to prevent warming of cold water.
- Ream all pipe ends to remove burrs. Burrs can trap sediments and cause corrosion and/or biofilm
- Apply pipe compound only to male threads to keep it from being pushed into the fitting when the join is made.

Best Practices in Plumbing System Design Operations and Maintenance

–Avoid Washers, O-rings or Gaskets that are Made of Natural Rubber. Natural rubber in plumbing fixtures, flanges and equipment provide a porous surface for the growth of pathogens. Porous surfaces can protect pathogens from disinfectants. Use gaskets made of neoprene or other synthetics instead.

–Just like ductwork and medical gas piping, pipe, valves and other plumbing fittings should be protected on site to prevent contamination.

– Replace Heavily-Scaled Faucets and Shower Heads
  - Scale build-up in shower heads is a sign of hard water or minerals in the water supply. The scale provides a nutrient source for legionella or other pathogens to grow on.
– Use Showerheads that have Large Water Droplets
  - Showerheads that have a fine spray mist allow small droplets of water to be inhaled into the lungs. This provides a transmission path for Legionella or other pathogens to get into the lungs

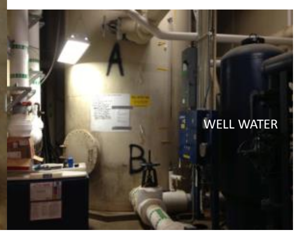
WATER DISTIBUTION SYSTEM
BUILDING ISSUES RELATED TO DEAD END CONNECTIONS FROM DISCONTINUED LINES.

Microbial buildup from stagnant water and additives is biofilm.

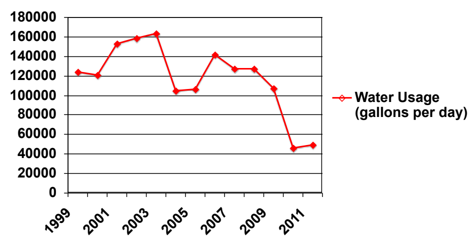
Biofilm = corrosion, scale & fouling

Know the sources of water for hospitals

UMMC uses about 80,000 gallons a day
Of city water
UMMC uses about 2000 gallons a day
for dialysis, cart washing and lab water.



UMMC Water Usage 1999-2011
[Random Samples]



Why did the water usage go down?

- Switch to digital from chemical x-ray processors for Radiology
- Switch to air cooled from water cooled medical air compressors
- Lower gallons per flush
- Flow restrictors for faucets
- Automatic faucets for hand washing
- Waterless antisepsis for surgical and patient care hand cleansing

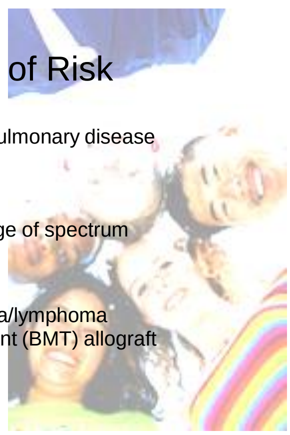
Cardioplegia machine

Dialysis water treatment

Water hammer arrestor

Ultrasonic cleaner

Levels of Risk



Healthy person

- Chronic obstructive pulmonary disease
- Diabetes
- Steroids
- Cancer - solid tumor
- HIV infection-end stage of spectrum
- Organ transplant
  - Kidney/heart
  - Lung/liver
- Malignancy - leukemia/lymphoma
- Bone marrow transplant (BMT) allograft

Immunocompromised Sub-Populations in U.S.

- AIDS patients = 274,000
- Cancer patients on immuno-suppressive therapy = 4.3 million (est.)
- People with organ transplants = 195,561
- Diabetics = 8 million
- Hospitalized burn patients = 75,000/year
- Cystic fibrosis = 30,000
- 300,000 people on dialysis in USA

Hospital Tap Water & Infection Prevention

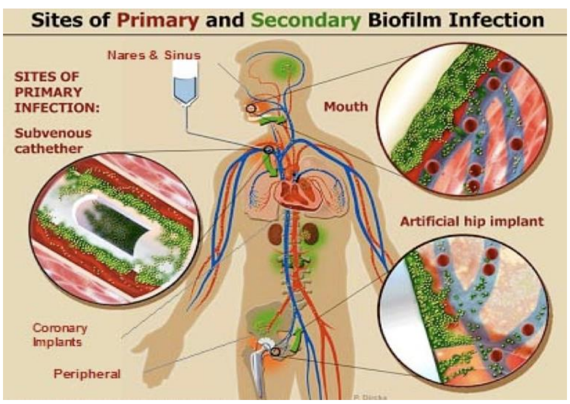
US Hospitals Yearly: 1.7 million infections; 99,000 deaths

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

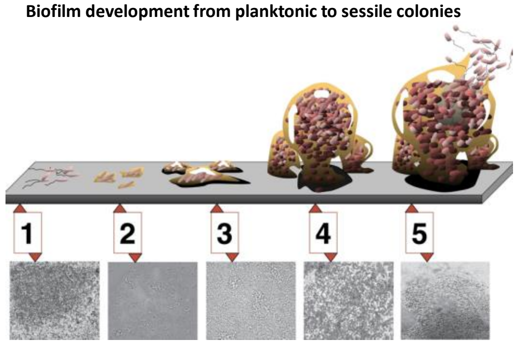


WATER SOURCES ARE VARIED IF YOU KNOW WHERE TO LOOK





Biofilm development from planktonic to sessile colonies

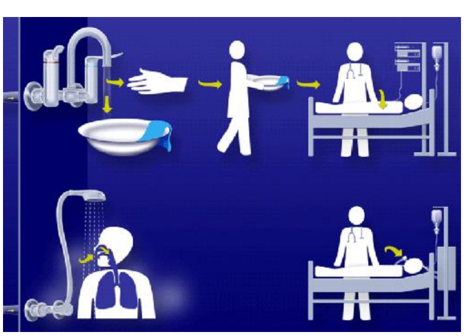


Biofilm thrives in stagnant water

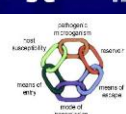
Hospital Sources of Nonfermentative Gram-Negative Bacilli

	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.



Ice machine maintenance
•charcoal filters?
•moldy storage bins

Ice maker
•sanitize surfaces
•internal parts

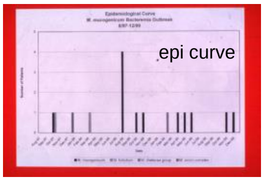
Ultrasonic or mixing in sterile water to get quantity or qualitative isolates

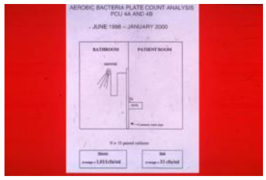
Swab method to culture ice machine components

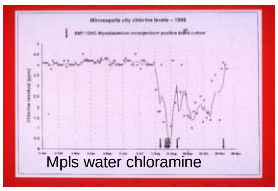
Water supply bio-film organisms

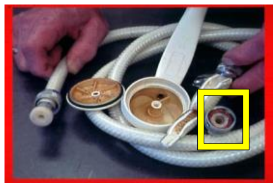
Implicated Environmental Vehicle	***Mycobacterium* Spp.**
Potable water used during bronchoscopy, instrument reprocessing	*M. chelonae*
Potable water, ice	*M. fortuitum, M. gordonae, M. kansasii, M. terrae, M. xenopi*
Intrinsically-contaminated laboratory solution	*M. gordonae*

Cluster Mycobacterium mucogenicum infections from water

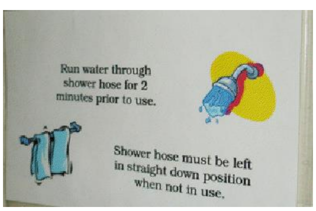






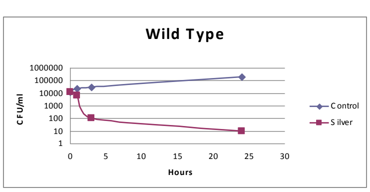


What to do about water in a clinical setting?

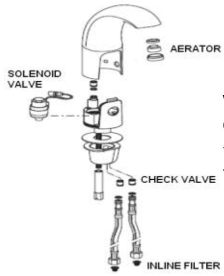


	Number of Samples	Mean (CFUs/ml)	Median (CFUs/ml)	Range (CFUs/ml)
Before Flush	16	49,471	25,050	110-196,000
After Flush	16	146	35	3-970

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



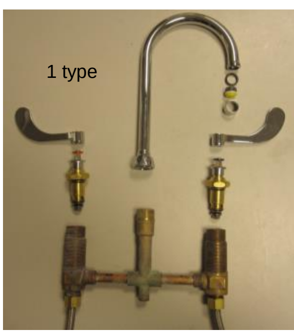
Automatic Faucets



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

Component parts harbor bacteria
Instant water no adjustment first drop water

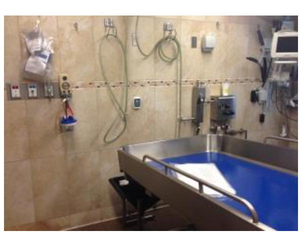
Manual faucet



All soft rubber or cellulose components harbor bacteria

Manual faucets require adjustment hence flushing fewer sources

Water Bacteria in a Burn Unit



Stenotrophomonas maltofilia
Pseudomonas putida

AER device after a backflow prevention device.
-should there be a flushing mechanism to cover periods of inactivity?
-should there be a way to disinfect this device?

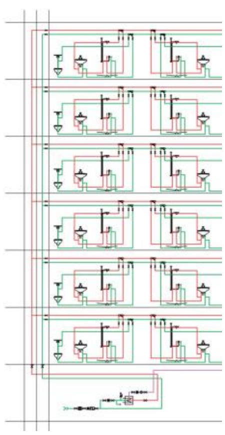
FLUSHING IS AN ANSWER??

Flushing mechanisms for complex water systems in hospitals.

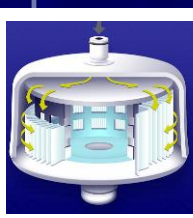
Avoid stagnant water in showers, sinks and other systems where stagnant water may affect patient exposure.

Reduced pressure zones attached to medical device process should not sit stagnant.

Questions:
-How often should we flush?
-How much should we flush?



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.

Impact of Monochloramine on Legionella colonization

Two year prospective study in San Francisco when monochloramine replaced chlorine for municipal water disinfection.

- Building Legionella colonization decreased from 60% to 4% in 53 buildings studied.
- Point of use outlets were tested in those buildings.

Chlorine results of 617 outlets 39% were colonized while 1% of the outlets were colonized after chloramine disinfection initiated.

Emerging Infectious Diseases • www.cdc.gov/eid • Vol. 12, No. 4, April 2006

Chlorine testing in Water

Advantages:
-Easy
-Relative inexpensive
-Real time

Disadvantage:
-Not definitive

Microbiology of Water

Advantages:
-More definitive

Disadvantages:
-Delayed results
-Expensive
-Complex

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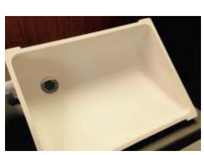
Sink Management
-aerators
-filters
-drains



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Questions and Answers

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