Welcome to Session #315

EHS Crossover Program
May 17th, 2006
10:00 – 11:30 am
Evaluation and Control of Microbiological Contamination in Domestic Water Systems

By Jennifer Carey
JLC Environmental Consultants, Inc.
Objectives

- Provide an overview of the types of microbiological problems that occur in domestic (potable) water systems;
- Evaluate factors that can influence domestic water quality;
- Examine disinfection technologies available to control microbiological problems.
Water Distribution Systems – provide myriad opportunities for growth of microorganisms like bacterium

Sources of Contamination – including biofilms and sediments

Microbiological Control – different types of disinfection methods available
Water in Developing Countries

- In developing nations waterborne pathogens are present in large numbers.
- Largely due to problems with inadequately maintained pipes, low pressure, poor hygiene standards and intermittent delivery, even municipal well water is unsafe.
Pathogens

V. cholerae

S. thypi
Water supply in Mozambique
Water distribution channels in underdeveloped countries
Water in Developed Nations

- The problems are different
- Water quality can be affected by:
  - Bacteria
  - Parasitic protozoa
  - Viruses
  - Helminthes
Water Systems

- Types of water systems that serve as breeding grounds for potentially pathogenic species:
  - Surface Water
  - Ground Water
  - Pipes and storage tanks
Various types of problems that occur in distribution systems

- Scaling
- Corrosion
- Biofouling
Factors that influence the quality of water in a water distribution system

- Legionella in Make-up
- Temperature pH
- Available Nutrients
- Amoebae
- Other Bacteria
- Biocide Control
- Unknown Factors
Microbes

- **Coliform bacteria** – common, generally not harmful, presence in drinking water is usually a result of a problem with the treatment system or the pipes which distribute water.

- **Fecal Coliform and *E. coli*** - bacteria whose presence indicates that the water may be contaminated with human or animal wastes. *E. coli* can be more pathogenic in immune compromised individuals.

- **Turbidity** - no human health effects, interferes with disinfection, provides a growth medium.
Enteropathogenic E. coli induces the formation of pedestals on the host cell surface.
More Microbes

- **Cryptosporidium parvum** - a parasite that enters lakes and rivers through sewage and animal waste. It causes cryptosporidiosis, a mild gastrointestinal disease.

- **Giardia lamblia** - a parasite that enters lakes and rivers through sewage and animal waste. It also causes gastrointestinal illness.

- **Legionella pneumophila** – a gram negative bacteria, causes Pontiac Fever and Legionnaires disease
Cryptosporidium parvum
Acceptable Microbial Levels in U.S.

- **Coliform**: <1 colony/100 ml
- **Cryptosporidium**: zero
- **Giardia lamblia**: zero
- **Viruses**: zero
- **Legionella pneumophila**: zero
- **Turbidity**: 0.5-1.0 nephelometric turbidity units (NTUs)
- **Heterotrophic plate count (HPC)**: No more than 500 bacterial colonies per milliliter
The Walkerton Outbreak

- seven people died
- 2,500 people taken ill, many of them children
The Cost of Good Water Quality

- A 60-page study released in November 2001 concluded that the Walkerton water tragedy cost at least $64.5 million.
- An estimated $155 million, if human suffering was factored in.
Some of The Types of Organisms Isolated from Dental Unit Water.

<table>
<thead>
<tr>
<th>Bacteria</th>
<th>Fungi</th>
<th>Protozoa</th>
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</table>
| Achromobacter xylooxidans  
Acinetobacter spp  
Actinomyces spp  
Alicalingens dentrificans  
Bacillus spp  
Bacteriodes spp  
Flavobacterium spp  
Fusobacterium spp  
Legionella pneumophila  
Legionella spp  
Micrococcus spp  
Mycobacterium avium  
Mycobacterium spp  
Pasteurella spp  
Proteus vulgaris  
Pseudomonas aeruginosa  
Streptococcus spp  
Staphylococcus aureus  
Xanthomonas spp | Phoma spp  
Penicillium spp  
Cladosporium spp  
Alternaria spp  
Scopulariopsis spp | Acanthamoeba spp  
Cryptosporidium spp  
Microsporidium spp  
Giardia spp |
Other Outbreaks

- **Legionaire’s Disease** - one of the biggest ever occurred in the Netherlands in late February to early March 1999. It involved 242 cases of illness and 28 deaths. The outbreak was blamed on a whirlpool spa displayed at a trade show.

- **Cryptosporidiosis** - The worst outbreak of the bacteria in drinking water was in Milwaukee, Wisconsin in the USA in 1994, when 5000 people were affected and 50 people died.

- **E. Coli** – causes gastroenteritis, people became sick after drinking contaminated water in Washington County, New York in 1999
Biofilms

- Bacteria in aquatic environments interacts with all types of surfaces to form a biofilm.
- The biofilm is derived of bacteria in the incoming water supply and is intrinsically resistant to biocides.
- Becomes a primary reservoir for continued contamination of the system.
Example of pipe corrosion caused by biofilm
By C. Abernathy and A. Camper
The Center of Biofilm Engineering at Montana State University
Common Amplification Site
Treatment Rules

- EPA's surface water treatment rules require systems using surface water or ground water under the direct influence of surface water to:
  - disinfect their water
  - filter their water or meet criteria for avoiding filtration so that contaminants levels are controlled
Disinfection Methods

- Super Heating and Flushing
- Chlorination (Cl)
- Monochloramines
- Ultraviolet (UV)
- Chlorine Dioxide (ClO₂)
- Ozonation (O₃)
- Copper Silver Ionization (Cu-Ag)
Super Heating and Flushing

Pro’s:
- Chemical Free
- By-Product Free
- No Maximum Ph
- No Residual Taste or Odor
Super Heating and Flushing

- **Con’s:**
  - Temperature is scalding hot;
  - Does not inhibit biofilm;
  - Potential for impact on building equipment due to high temperatures;
  - No long-term or short term residual effectiveness against Legionella;
  - Flushing at distal points is required, very labor intensive
Auto-Chlorinating Systems

Pro’s:

- Short-term Residual Effectiveness Against Legionella
- Effective Maximum pH of 7
Auto-Chlorinating System (cont.)

- **Cons:**
  - Minimal Breakdown of Biofilm (above 50ppm)
  - Produces carcinogenic THM By-Products
  - No Long-term Residual Effectiveness Against Legionella
  - Corrosion of Equipment and Systems
  - E. coli, Giardia and Crypto develop chlorine-resistance
  - Creates Taste & Odor problems
  - Negative health effects: Eye/nose irritation; stomach discomfort
Monochloramine System

- Pro’s:
  - Inactivates biofilm bacteria
  - persists longer than free chlorine when ammonia is added downstream from the initial chlorine application which forms monochloramine in-situ
  - International guidelines for drinking water quality suggest that no short-or-long-term health effects have been associated with chloramines in chlorinated drinking water.
Monochloramines (cont.)

Con’s:

- A weaker and slower acting disinfectant that free chlorine
- Departs pungent odor to water
- In water systems that use monochloramine as a residual disinfectant, chlorine is usually required to be used as the primary disinfectant so that microorganisms will be exposed for a suitable period of time
- Eye/nose irritation; stomach discomfort, anemia
Ultraviolet Light

Pro’s:

- No Chemicals Utilized
- No Taste, No Odor
- No Environmental & Health effects
- Inactivates cryptosporidium and Giardia
- Low capital and operating costs
Ultraviolet Light (cont.)

- **Con’s:**
  - UV irradiation does not penetrate biofilm
  - Does not exhibit a residual effect.
  - Performance of the UV depends on the clarity of the water, contact time and dose of light
  - Can’t pass water through too quickly or reduced effectiveness
  - Potential Corrosion Problems (if also using High Intensity Ozone Lamps)
  - Does not penetrate biofilm or exhibit a residual effect.
Types of UV Products
Chlorine Dioxide

Pro’s:

- Produces Chlorite and Chlorate By-products
- Effective Ph between 5 to 10
- No Taste, No odors (below 0.8ppm)
- Minimal Corrosion Problems
- No Environmental & Health Effects
- Breaks Down Biofilm and Inhibits Biofilm
- Microorganisms cannot built up any resistance against chlorine dioxide.
- Less expensive than ozone
Chlorine Dioxide (cont.)

- Con’s:
  - Chlorine dioxide gas is explosive.
  - Less effective for the deactivation of rotaviruses and E. coli bacteria.
  - Chlorine dioxide is generally effective for the inactivation of viruses and Giardia
  - Minimal Long-term Residual Effectiveness Against Legionella
  - Anemia in infants & young children, effects the central nervous system
  - Estimated Annual Maintenance costs could be high
  - 5-10X More expensive than chlorine
Ozonation

Pros:
- Has been shown to be very effective
- No Chemicals Used
- Produces Bromate By-products
- Works against the toughest bacteria and viruses
- No Environmental & Health Effects
- Breaks Down and inhibits Biofilm
Ozonation (cont.)

- **Con’s:**
  - Will add odor
  - Potential corrosion problems
  - No short-term or long term residual effectiveness against Legionella
  - Flushing is required
  - Chlorine shocking is required
Copper Silver Ionization

Pro’s:

- Breaks Down Biofilm
- Inhibits Biofilm
- Long and Short-term Residual Effectiveness Against Legionella
- Flushing Required (45 days dissipation waiting period)
- No Chlorine Shocking Required
Conclusion

- Pathogenic microorganisms are everywhere in free water and biofilm.
- Experts agree that water distribution systems should be regularly disinfected and kept clean and deposit-free.
- The conditions present in each situation will help to determine which type of disinfection system is appropriate.
Questions
and
Answers
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References

- Water Sanitation and Health (WSH), Managing water in the home: accelerated health gains from improved water supply, World Health Organization:
- Drinking Water and Disinfection, Michael Berney, Drinking Water Microbiology and ecophysiology: Okophysiologie
- Chemicals in Drinking Water: Chloramines, Scottish Centre for Infection and Environmental Health
- The Use of Ultraviolet Light to Disinfect Drinking Water: An Alternative to Chlorination, O.S. Mbuya et. al, Center for Water Quality, Florida A&M University, Tallahassee, Fl. 32307
- Decontamination Using Chlorine Dioxide, Testimony of Charles N. Haas, Hearings on the Decontamination of anthrax and Other Biological Agents”, Nov. 2001
- Effects of Ozonation of the Removal of Cyanobacterial Toxins during Drinking Water Treatment, Stefan J. Hoeger, et. al., Environmental Toxicology, University of Konstanz, Konstanz Germany
References

- E.coli 0157:h7 in Drinking Water, U.S. Environmental Protection Agency Groundwater and Drinking Water.
- Your Household Water Quality: Coliform Bacteria In Your Water by Paul F. Vendell and Jorge H. Atiles, The University of Georgia Cooperative Extension
- Jail Sentence follow Walkerton Saga by Tom Daly, Environmental Science and Engineering, Jan 2005
- Microbiological Safety of Drinking Water by U. Szewzyk1 R. Szewzyk2 W. Manz1 and K.-H. Schleifer3 1Technical University Berlin, Microbial Ecology Group, Secr. OE 5, Berlin, 10587 Germany
- Managing Risk of Waterborne Pathogens in Building Water Systems, M. Freije, HC Information Resources Inc.;
- Discovery of Legionella in Potable Water Distribution Center: Follow Up Investigation and Remediation, M. Gillie, GeoTrans Inc.;
- Control of Legioinella Growth in Distribution Systems, E. Dahlen, Chem Risk - AIHA Podium Sessions 101: Bioaerosols and Biosafety/ Biotechnology papers 1–6
References

- Legionnaires' Disease, by Paul Cochrane, Aerotech Laboratories, May 13, 1999
- Chlorine Disinfection of Recreational Water for *Cryptosporidium parvum*, Colleen Carpenter. et al., U.S. Department of Agriculture, Beltsville, Maryland, USA; and Centers for Disease Control and Prevention, Atlanta, Georgia, USA
- Domestic Water Quality: Service Level and Health, by G. Howard et al., WHO, 2003
- Safe Storage and Water Treatment in the Home: A practical New Strategy to Prevent Water Bourne Disease, E. Mintze et al., Center for Disease Control, Safewater Publications, 1995
- State Health Department and CDC epidemiologists complete case-control study of outbreak, State of New York Department of Health, Capital District E. coli Update, Sept. 1999
Websites

- www.swisscooperation.org
- http://www.aiha.org/abs05/po101.htm
- www.hopkinsmedicine.org/heic/ID/legionella/water_disinfect.xls
- www.finlaylab.biotech.ubc.ca/.../E.coli.html
- www.nature.com/.../020603/pf/020603-2_pf.html
- www.epa.gov/safewater/mcl.html
- http://www.who.int/water_sanitation_health/en