Purpose

Properly operated and maintained water treatment facilities and distribution systems can protect drinking water quality and minimize public health risks. This lesson examines water treatment and distribution system issues that impact drinking water and provides information about protecting public health.

Learning Objectives

• Identify water quality and distribution system issues that may impact public health

• Be able to describe the importance of distribution system as a barrier for protecting public health
Agenda

- History of public health protection and drinking water regulations
- Multi-barrier Approach to Drinking Water Safety
- Revised Total Coliform Rule (RTCR)
- Surface Water Treatment Rule (SWTR)
- Groundwater Rule (GWR)
- Stage 2 Disinfection Byproducts (DBP) Rule
- Lead & Copper Rule (LCR)
- Additional Resources

Milestones for Drinking Water Disinfection

- USA chlorine addition
  - Jersey City, NJ reservoir in 1908
  - Niagara Falls in 1912
  - Philadelphia in 1913
- 85% of US water plants used chlorine by 1941

Public Health Improvement:
Typhoid Fever in Louisville, KY

Source: Payne, 1934
Annual US Death Rates for Typhoid Fever 1900-1928

National Bureau of Economic Research

"between 1900 and 1936 clean water was responsible for nearly half of the total mortality reduction in major cities, three-quarters of the infant mortality reduction, and nearly two-thirds of the child mortality reduction." (Cutler and Miller, 2004)

Regulation of Public Health Protection Begins

- First drinking water rule promulgated by US Dept of Treasury in 1914 regulating drinking water in interstate commerce
- No water utility wanted to be unfit for interstate transportation use, so voluntary compliance with the Standards occurred
- Public Health Service Drinking Water Standards in 1962 set monthly total coliform limits
Safe Drinking Water Act or SDWA of 1974

- Authorizes USEPA to establish comprehensive national drinking water regulations to ensure drinking water safety.
- Requires promulgation of Primary Drinking Water Regulations
  - Applies to all US Public Water Systems
  - Covers both chemical and microbial contaminants.
  - Established specific roles for federal and state governments and public water suppliers
  - Primacy: Primary enforcement responsibilities to states, territories & tribes who meet EPA criteria

Drinking Water Regulations 1970-1990

Drinking Water Regulations 1990-2010

Developed by AWWA in partnership with RCAP and funded by USEPA, Published 2015
EPA Must Quantify Public Health Impacts for Every Regulation

- 1996 Amendments to SDWA -- EPA to regulate a contaminant when:
  - The contaminant can have an adverse effect on people’s health;
  - The contaminant is known to occur or is likely to occur in public water systems with a frequency and at levels of public health concern; **and**
  - Regulation of the contaminant presents a meaningful opportunity for health risk reduction for people served by public water systems

EPA Standards Setting Process

- Analytical
  - ID test methods, availability, quantitation levels, monitoring requirements & compliance reporting
- Occurrence
  - Assess concentration, # systems, source, populations, other contaminants affecting treatment or health
- Risk Assessment
  - Set health-based goal
- MCL
  - MCLG
- MCL and Techniques
  - Technologies
    - Assess performance, small system technologies, residuals, water use
    - Cost/benefit
      - Cost of treatment and administration to health benefits

Courtesy: USEPA
Who Makes the Regulations Work?

• EPA writes federal drinking water rules
• Primacy agencies (states, territories and tribes) adopt the rules and enforce them
• Utilities produce and deliver water that meets the rules

Operators carry the daily load in meeting the regulations and protecting public health

Knowledge Review

1. What chemical contributed to the major improvement in public health of drinking water in the early 1900s?
2. What was the major provision of the SDWA?
3. When a drinking water regulation is written, which of these is required by the SDWA?
   a. Contaminant is known by an acronym
   b. Contaminant has an adverse effect on public health
   c. Contaminant is in every water supply in the country
4. Check all that apply to setting an MCL
   ❑ Based on health risk assessment
   ❑ Measurements of occurrence and concentration
   ❑ Analytical testing methods
   ❑ Evaluation of small system technologies
   ❑ Cost of treatment

Multi-Barrier Approach to Drinking Water Safety

• Multiple barriers are needed to reliably provide high quality, safe drinking water

Protect and improve water quality at the source, treatment plant and in distribution
Source Water Protection Targets

Highest Quality Water

• Know your source characteristics through regular water quality monitoring
• Use best water quality whenever possible
• Understand sources of recharge to wells – can change seasonally
• Maintain well heads properly
• Control access to sources where possible

Treatment Barrier Must Remove Contaminants

• Biological contamination
• Chemical properties & contamination
• Physical properties & contamination

Distribution System Barrier Must Maintain Water Quality

Physical integrity + Water Quality

• Main breaks/leaks
• Cross connections
• Backflow
• Storage tank maintenance
• Pressure transients
• Corrosion and leaching
• Permeation

• Disinfectant residual
• Water age
• Monitoring
• Prevent changes in quality
  – DBP formation
  – Biological regrowth
  – Nitrification
  – Lead and copper
Distribution System Integrity is Critical to Protecting Public Health

- 30% of all waterborne disease cases originated from distribution system issues (CDC, 2006)
- Of the 42 reported waterborne disease outbreaks reported in 2013-2014 to CDC, one was a distribution system deficiency

Discussion

- What steps should you take if you notice a component of your distribution system is not functioning properly?
- What if it is more than you can handle yourself?
- What if it is not your responsibility?

Activity – Find Two Partners

- What distribution system issues have you faced that may have impacted public health?
- List all of the issues on a piece of paper
- Put check marks next to issues faced by more than one system in the group
- Groups report out three most common issues
Regulations Reviewed

- Revised Total Coliform Rule (RTCR) (2013)
- Surface Water Treatment Rule (SWTR) (1989)
- Any relevant state/local rule?

Any relevant state/local rule.

- Backflow/Cross Connections;
- Operator Training;
- WYPDES;
- Other(s)...

Health Impacts Defined by Regs

- Acute vs. chronic
  - Acute event – Immediate public health risk
    - Mostly microbial in nature (i.e. E. coli)
    - Contact regulatory agency immediately for an acute or potentially acute event
  - Chronic - Health risk from repeated exposures over a long period of time
    - DBPs
    - Lead
    - Arsenic
    - Radionuclides
Regulatory Levels Set by EPA

- **Maximum Contaminant Level (MCL)** = maximum permissible level of contaminant in water delivered to any user of a public water system

- **Maximum Contaminant Level Goal (MCLG)** = non-enforceable health-based goal set by EPA

Public Notification for Rule Violations

- **TIER 1 Public Notice** within 24 hours required for violations and situations with significant potential to have serious adverse effects on public health as a result of short-term exposure.

- **TIER 2 Public Notice** within 30 days required for violations and situations with potential to have serious adverse effects on public health.

- **TIER 3 Public Notice** within a year required for all other violations and situations not included in Tier 1 or Tier 2.

Total Coliform

- Indicator of pathogen contamination representing a family of organisms

- Regulations focus on:
  - Total Coliform (TC)
  - Fecal coliform or *E. coli*
Where do coliforms come from?

- Source water contamination
- Contamination during treatment and storage
- Infiltration from pipe leaks
- Inadequate cleaning of new and repaired pipes
- Cross connections
- Bacterial growth in distribution system

What is the Revised Total Coliform Rule (RTCR)?

- Protects public health
- Requires monitoring of total coliforms and *E. coli*
- Sets a maximum contaminant level (MCL) for *E. coli*
- Find-and-fix approach when TC results are positive

Concepts Changed in RTCR

- Presence of total coliform is
  - Not a direct health threat so TC MCL has been eliminated
  - An indicator of pathway for contamination into distribution system
  - A trigger for the treatment technique requirement
- Presence of *E. coli*, demonstrated through monitoring, IS a health threat
  - MCL of zero set for *E. coli*
  - Acute violation based on *E. coli*
RTCR Contaminant levels

- MCLG for *E. coli* is zero
- MCL for *E. coli* is based on sampling results
- System is out of compliance with *E. coli* MCL if:
  - A repeat sample is *E. coli*-positive following a total coliform-positive routine sample.
  - A repeat sample is total coliform-positive following an *E. coli*-positive routine sample.
  - The supplier fails to collect the required repeat samples following an *E. coli*-positive routine sample.
  - The supplier fails to analyze a total coliform-positive repeat sample for *E. coli*.

What does the RTCR require of water systems?

- Monitoring for TC
  - Must regularly monitor for presence of total coliform
  - Written sampling plans required
    - Sampling sites, schedule, repeat sampling locations
  - States may review, revise, and approve repeat sampling approach
Reduced monitoring requirements are very specific and can be found in the Appendices of the RTCR Small PWS Guide EPA815B15002 Oct 2015

Monitoring requirements diagram

• Take a routine TC sample

• If negative – continue with routine monitoring

Minimum Number of Routine Samples Required

<table>
<thead>
<tr>
<th>Population Served</th>
<th>Minimum Number of Samples/Month</th>
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<tr>
<td>&lt; 1,000</td>
<td>1</td>
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<tr>
<td>1,001 – 2,500</td>
<td>2</td>
</tr>
<tr>
<td>2,501 – 3,300</td>
<td>3</td>
</tr>
<tr>
<td>3,301 – 4,100</td>
<td>4</td>
</tr>
</tbody>
</table>

From EPA State Implementation Guidance Manual
Monitoring requirements diagram

• Take a routine TC sample

• If positive
  – Test for *E. coli*
  – Take 3 repeat samples
  – Take 3 routine samples the following month
  – In Wyoming – Return to Routine Sampling

Where to take repeat samples

• 1 sample at original TC+ location
• 1 sample within 5 connections upstream (or alternative location specified in sample sitting plan)
• 1 sample within 5 connections downstream (or alternative location specified in sample sitting plan)

Sending samples to the laboratory

• Use certified Laboratory
• Start the tests within 30 hours of sample collection
• Preserve sample below 10°C (50°F).
Seasonal systems

- Complete approved start-up procedures
- Certify completion of start-up procedures
- Designate vulnerable time period to take sample
  - If monitoring quarterly or annually

Special Purpose Samples

- Collected during:
  - repairs,
  - responses to complaints,
  - or for other maintenance reasons.
- Special samples are not included in compliance or assessment trigger calculations.

Activity – monitoring requirements

Fill in this column

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>What would you be expected to do?</th>
<th>What legal assessment would be required?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a. Internal, cross-connection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1b.</td>
<td></td>
<td></td>
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<tr>
<td>2.</td>
<td></td>
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<tr>
<td>3a.</td>
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<td>3b.</td>
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<td>5.</td>
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<td>6.</td>
<td></td>
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<tr>
<td>7.</td>
<td></td>
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</tr>
<tr>
<td>Special</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Level 1 Assessment

- Level 1 Assessment completed by utility when either of the following occurs
  - Two or more total coliform-positive samples in the same sampling period (include results of all routine and repeat samples)
  - Not all required repeat samples are collected after a routine total coliform-positive sample
- Looking for sanitary defects (problems)

Assessment Process

Assessment Includes Corrective Actions

<table>
<thead>
<tr>
<th>Common Sanitary Defect</th>
<th>Common Corrective Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failure to disinfect after maintenance</td>
<td>Disinfect</td>
</tr>
<tr>
<td>Main breaks</td>
<td>Disinfect</td>
</tr>
<tr>
<td></td>
<td>Replace/repair system components</td>
</tr>
<tr>
<td>Holes in storage tank, screens</td>
<td>Replace/repair system components</td>
</tr>
<tr>
<td>Loss of system pressure</td>
<td>Maintain adequate pressure</td>
</tr>
<tr>
<td></td>
<td>Add or upgrade on-line monitoring &amp; control</td>
</tr>
<tr>
<td>Biofilm accumulation in distribution system</td>
<td>Flushing</td>
</tr>
<tr>
<td></td>
<td>Maintain adequate pressure</td>
</tr>
<tr>
<td>Cross connections</td>
<td>Maintain adequate pressure</td>
</tr>
<tr>
<td></td>
<td>Implement cross connection control program</td>
</tr>
<tr>
<td>Inadequate disinfectant residual</td>
<td>Disinfect; Flush</td>
</tr>
<tr>
<td></td>
<td>Maintain appropriate hydraulic residence time</td>
</tr>
<tr>
<td></td>
<td>Add or upgrade on-line monitoring &amp; control</td>
</tr>
<tr>
<td>Sampling protocol errors</td>
<td>Sampler training; Develop &amp; implement Operations Plan</td>
</tr>
</tbody>
</table>
Level 2 Assessment

- Completed by state or state-approved 3rd party when
  - *E. coli* MCL violation occurs, or
  - System hits 2 Level 1 triggers in rolling 12 months, or
  - System monitors annually and hits 2 Level 1 triggers in 2 years

Follow-up Process for Assessments

- Complete assessment and deliver to State within 30 days
- Systems must correct all sanitary defects identified in assessments
- For corrections not completed when assessment form is delivered to State
  - Correct defect in accordance with State approved schedule
  - PWS must notify State when each scheduled corrective action is taken

Activity – assessment level

Fill in this column
### What to report and when - Monitoring

<table>
<thead>
<tr>
<th>What to report</th>
<th>When to report to the drinking water primacy agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitoring results</td>
<td>Within the first 10 days following the end of monitoring period</td>
</tr>
<tr>
<td><em>E. coli</em>-positive routine sample</td>
<td>By the end of the day when the system is notified of an <em>E. coli</em>-positive routine sample</td>
</tr>
</tbody>
</table>

### What to report and when - Violations

<table>
<thead>
<tr>
<th>What to report</th>
<th>When to report to the drinking water primacy agency</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>E. coli</em> MCL violation</td>
<td>By the end of the day when the system learns of an <em>E. coli</em> MCL violation</td>
</tr>
<tr>
<td>Coliform treatment technique violation</td>
<td>No later than the end of the next business day after the system learns of the violation. The public must be notified within 30 days.</td>
</tr>
<tr>
<td>Monitoring violation</td>
<td>Within 10 days after the system learns of the violation. The public must be notified within a year of the violation</td>
</tr>
</tbody>
</table>

### What to report and when - Assessments

<table>
<thead>
<tr>
<th>What to report</th>
<th>When to report to the drinking water primacy agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completed assessment form</td>
<td>Within 30 days after learning that the system has triggered an assessment</td>
</tr>
<tr>
<td>Corrective action(s)</td>
<td>When corrective action is completed</td>
</tr>
</tbody>
</table>
What to report and when –
Seasonal systems

<table>
<thead>
<tr>
<th>What to report</th>
<th>When to report to the drinking water primacy agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Certification of approved start-up procedure</td>
<td>Prior to serving water to the public.</td>
</tr>
<tr>
<td>Certification of public notice requirements</td>
<td>Within 10 days of completing the public notification</td>
</tr>
</tbody>
</table>

Recordkeeping

- Monitoring results - 5 years
- Assessment forms and documentation of corrective actions completed - 5 years
- Repeat samples - 5 years
- Copies of public notices - 3 years
- Sample siting plans - 5 years

Violations and public notification

- \textit{E. coli} MCL Tier 1 (within 24 hours)
- Treatment technique Tier 2 (within 30 days)
- Monitoring Tier 3 (within a year)
- Reporting Tier 3 (within a year)
### Activity 2 – RTCR Reporting Timeframes

Draw an arrow between the action and correct reporting timeframe

<table>
<thead>
<tr>
<th>Reporting timeframes</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within 30 days</td>
<td>Public Notification of an E. coli Violation</td>
</tr>
<tr>
<td>For 5 years</td>
<td>Notify state of an E. coli positive</td>
</tr>
<tr>
<td>Within 24 hours</td>
<td>Report monitoring results to the state</td>
</tr>
<tr>
<td>By the end of the day</td>
<td>Complete an assessment after one has been triggered</td>
</tr>
<tr>
<td>Within 10 days following the monitoring period</td>
<td>Retain monitoring records</td>
</tr>
</tbody>
</table>

For more information:


For more information for systems serving >1,000 people:

- “The Revised Total Coliform Rule (RTCR) State Implementation Guidance—Interim Final”
For more information:

- AWWA RTCR eLearning module

Surface Water Treatment Rule (SWTR) (1989)

- Requires specific disinfection levels for surface water and groundwater under the direct influence of surface water
- Uses the CT (disinfectant concentration x contact time) concept to define disinfection levels
- Requires all surface waters to filter unless filtration avoidance criteria are met

Disinfection Requirements of for SW and GWUDI Systems

- 3-log *Giardia* removal/inactivation
- 4-log virus removal/inactivation
- Obtain credit prior to first customer
**Distribution System Chlorine Residual Requirements for SW and GW**

- Disinfectant residual is measured at the entry point to the distribution system.
- Residual disinfectant concentration cannot be less than 0.2 mg/L entering the distribution system for more than 4 hours.
  - Contact regulatory agency whether or not the residual is restored.
- Cannot be undetectable in more than 5% of samples within the distribution system.

*State or local requirements may be more stringent.*

**Chlorine Residual**

- § 141.72 Disinfection.
- (4)(i) The residual disinfectant concentration in the distribution system, measured as total chlorine, combined chlorine, or chlorine dioxide, as specified in § 141.74 (a)(5) and (b)(6), cannot be undetectable in more than 5 percent of the samples each month, for any two consecutive months that the system serves water to the public. (…)

**Detectable Chlorine Residual**

- …Water in the distribution system with a heterotrophic bacteria concentration less than or equal to 500/ml, measured as heterotrophic plate count (HPC) as specified in § 141.74(a)(3), is deemed to have a detectable disinfectant residual for purposes of determining compliance with this requirement.
Maximum Residual Disinfectant Level (MRDL)

- MRDL for Chlorine or Chloramines is 4.0 mg/L
  - Unpleasant chlorine taste
  - Excessive disinfection byproduct formation
  - Eye/nose and stomach irritation

Maximum Residual Disinfectant Level (MRDL) (cont.)

- Many chloramine plants will have residuals at 4.0 mg/L at Point of Entry (POE)
- Chlorine residual **MUST** be measured along with RTCR sample collection
- Chlorine decay can be indicator of a distribution system issue

What is 4-log inactivation?

- 4-log = 99.99% inactivation or 1 surviving virus from an initial 10,000
- Level of inactivation depends on:
  - Chlorine residual (mg/L)
  - Contact time (min)
  - Water temperature and water pH
What is 4-log inactivation? (cont.)

- Not feasible to measure the level of virus inactivation in a real system
- Level of inactivation is estimated by the product of chlorine residual (C) and contact time (T) = CT (mg-min/L)
- CT is a measure of the effectiveness of the disinfection process

Chlorine Contact time

- Different tank configurations provide different contact time for chlorine
- A tank can be baffled in a number of ways to increase detention time and thus increase the baffling factor
- Additionally, tank level is also a significant factor in determining CT

Note to Instructor

- Slides 69 – 85 cover the calculation of CT and log removals. An alternative to using this module of slides is to obtain a copy of the CT calculation spreadsheet preferred by the State in which you are teaching, put it on the screen as an XLS File and demonstrate how it is used.
Tracer Activity

- Calculate the Baffling Factor for the tanks in the videos
- Known:
  - Use stopwatch to get T10 from videos (~ 5 sec unbaffled and ~ 80 sec baffled)
  - Tank dimensions: L = 2 ft, W = 2 ft, D = 0.2 ft (min water level)
  - Flow = 3 gal/min
Tracer Activity Solution Steps

- Calculate tank volume = 2 ft * 2 ft * 0.2 ft * 7.48 gal/ft³ = ____ gal
- Calculate TDT = 6 gal / 3 gal/min = ____ min
- Calculate BF = T10 / 2 min = _______ unbaffled
- Calculate BF = T10 / 2 min = _______ baffled

Disinfection Log Inactivation Calculations

- C = residual disinfectant concentration before or at first customer (mg/L)
- T = minimum disinfectant contact time (min)
- C x T (mg-min/L)
- CT_{calc} ≥ Ct_{req}
- Ct_{req} can be found in the SWTR Guidance Manual tables

A certain CT can be achieved by various combinations of chlorine dose and contact time
- [Cl₂] = 1 mg/L, T = 10 min → CT = 10 mg-min/L
- [Cl₂] = 2 mg/L, T = 5 min → CT = 10 mg-min/L

Disinfection Calculations

Information Needed:
- Peak (Hourly) Flow, Q (gpm)
- (Minimum) Residual Disinfectant Concentration, C (mg/L)
- (Lowest) Temperature (ºC)
- (Highest) pH
- Basin/Piping/Unit Process Volume
- Baffle Factor
- Disinfectant Type

<table>
<thead>
<tr>
<th>DATE</th>
<th>Daily Temp</th>
<th>Daily PH</th>
<th>Chlorine residual</th>
<th>Peak Flow in GPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/1/2006</td>
<td>18.4</td>
<td>7.5</td>
<td>1.01</td>
<td>22152.64</td>
</tr>
<tr>
<td>8/2/2006</td>
<td>17.2</td>
<td>7.6</td>
<td>1.35</td>
<td>18194.33</td>
</tr>
<tr>
<td>8/3/2006</td>
<td>17.3</td>
<td>7.4</td>
<td>0.84</td>
<td>17986.00</td>
</tr>
</tbody>
</table>
Disinfection Monitoring to Show Compliance with Inactivation Requirements

Log inactivation of Giardia and viruses impacted by:
- pH
- Temperature (°C)
- Residual Disinfectant Concentration (mg/L)
- Contact Time (minutes)

Chlorine injection

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Log Inactivation Calculation Steps

1) Calculate Detention Time
2) Calculate \( C_{\text{CALC}} \)
3) Calculate *Giardia lamblia* log inactivation
4) Calculate virus log inactivation

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Step 1: Calculate Detention Time

\[ TDT = \frac{V}{Q} \]

- \( TDT \) = Theoretical Detention Time (minutes)
- \( V \) = Volume, based on low water level (gallons)
- \( Q \) = Peak hourly flow (gpm)
Step 1: Calculate Detention Time

Based on low water level
- Pipeline: \( V = \pi x r^2 x l \)
- Pipeline: \( V = 0.785 x D^2 \)
- Rectangular: \( V = l x w x d \)
- Cylindrical: \( V = \pi x r^2 x d \)
- Cylindrical: \( V = 0.785 x D^2 x d \)

Step 1: Calculate Detention Time Including Baffling Factor

\[ T = TDT \times BF \]

- \( T \) = Actual Detention Time (minutes)
- \( T \) can also be determined using tracer studies
- \( BF \) = Baffling Factor (measure of short circuiting)

Step 2: Calculate \( CT_{\text{CALC}} \)

\[ CT_{\text{CALC}} = C \times T \text{ (minutes-mg/L)} \]

- \( C \) = Residual disinfectant concentration measured during peak flow (mg/L)
- \( T \) = Actual Detention Time (minutes)
Step 3: Giardia Log Inactivation

*Giardia Log Inactivation* = 3 × (CT\text{calc} / CT_{99.9})

- CT_{99.9} for *Giardia lamblia* 3-log inactivation = CT_{99.9}

### CT Values for 3-log inactivation of *Giardia* cysts by free chlorine

<table>
<thead>
<tr>
<th>Concentration (mg/L)</th>
<th>pH 5</th>
<th>pH 6</th>
<th>pH 7</th>
<th>pH 8</th>
<th>pH 9</th>
<th>pH 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.05</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
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<td>0.6</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>0.7</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>0.8</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>0.9</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>1.0</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Step 3: Virus Log Inactivation

- USEPA has developed CT table to assign virus inactivation credit
  - Function of temperature and water pH

*Virus Log Inactivation* = 4 × (CT\text{calc} / CT_{99.99})

- CT_{99.99} for Virus 4-log inactivation = CT_{99.99}

<table>
<thead>
<tr>
<th>CT (mg-min/L) required for 4-log virus inactivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature °C</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>0.5</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>25</td>
</tr>
</tbody>
</table>

Team Exercise

Need: 1-log Giardia inactivation
4-log virus inactivation

- Cylindrical Contact Tank
  - Inner tank diameter, D = 100 ft
  - Inner tank radius, r = 50 ft
  - Minimum tank water level, d = 20 ft
  - No baffling
- Measured at Peak Flow:
  - Peak Flow, Q = 2,500 gpm
  - Free chlorine residual, C = 0.8 mg/L
  - pH = 6.5
  - Temperature = 5°C

Questions:
1) Am I getting the log-inactivation I need?
2) If not, what can I do?
### Solution

**Step 1: Detention Time Calculations**

\[
V = \pi \times r^2 \times d = 3.14 \times (50 \text{ ft})^2 \times 20 \text{ ft} \times 7.48 \text{ gal/ft}^2 = 1,174,000 \text{ gal}
\]

\[
TDT = \frac{V}{Q} = \frac{1,174,000 \text{ gallons}}{2,500 \text{ gpm}} = 470 \text{ minutes}
\]

\[
T = TDT \times BF = 470 \text{ minutes} \times 0.1 = 47 \text{ minutes}
\]

**Step 2: Calculate CT_{CALC}**

\[
CT_{CALC} = C \times T = 47 \text{ minutes} \times 0.8 \text{ mg/L} = 37.6 \text{ minutes-mg/L}
\]

### Solution

**Step 3: Calculate Giardia inactivation**

\[
\text{Giardia CT}_{99.9} \text{ from EPA Table} = 122 \text{ min-mg/L}
\]

\[
\text{Giardia Log Inactivation} = 3 \times \left(\frac{CT_{CALC}}{CT_{99.9}}\right) = 3 \times \left(\frac{37.6 \text{ min-mg/L}}{122 \text{ min-mg/L}}\right) = 0.92 \text{ log}
\]

**Step 4: Calculate Virus inactivation**

\[
\text{Virus CT}_{99.99} \text{ from EPA Table} = 8 \text{ min-mg/L}
\]

\[
\text{Virus Log Inactivation} = 4 \times \left(\frac{CT_{CALC}}{CT_{99.99}}\right) = 4 \times \left(\frac{37.6 \text{ min-mg/L}}{8 \text{ min-mg/L}}\right) = 18.8 \text{ log}
\]

### What Can I Do?

**Insufficient CT – So What Can I Do?**

One option...

Increase chlorine residual from 0.8 to 1.0 mg/L

\[
CT_{CALC} = C \times T = 1.0 \text{ mg/L} \times 47 \text{ minutes} = 47 \text{ mg-min/L}
\]

\[
\text{Giardia Log Inactivation} = 3 \times \left(\frac{CT_{CALC}}{CT_{99.9}}\right)
\]

\[
= 3 \times \left(\frac{47 \text{ mg-min/L}}{125 \text{ mg-min/L}}\right) = 1.13 \text{ log}
\]
**USEPA Calculator**

EPA has a disinfection profile calculator
- Short form for one disinfection segment systems
- Long form for multiple disinfection segment systems

<table>
<thead>
<tr>
<th>Sample Date</th>
<th>Treatment Stage</th>
<th>Disinfectant</th>
<th>Residual Conc. (C) (mg/L)</th>
<th>pH</th>
<th>Temp. (Celsius)</th>
<th>Peak Flow (GPM)</th>
<th>Volume (gal)</th>
<th>TDT (min)</th>
<th>Contact Time (T) (min)</th>
<th>CT calc</th>
<th>Log Inactivation (Giardia)</th>
<th>Log Inactivation (viruses)</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 26, 2015</td>
<td>Treatment Stage</td>
<td>Free Chlorine</td>
<td>10.00</td>
<td>7.60</td>
<td>10.0</td>
<td>1</td>
<td>4</td>
<td>4.0</td>
<td>4.0</td>
<td>40.0</td>
<td>check residual</td>
<td>check residual</td>
</tr>
<tr>
<td>April 2, 2015</td>
<td>Treatment Stage</td>
<td>Free Chlorine</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>2</td>
<td>4</td>
<td>4.0</td>
<td>4.0</td>
<td>26.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>April 9, 2015</td>
<td>Treatment Stage</td>
<td>Free Chlorine</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>3</td>
<td>4</td>
<td>4.0</td>
<td>4.0</td>
<td>26.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>April 16, 2015</td>
<td>Treatment Stage</td>
<td>Free Chlorine</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>4</td>
<td>4</td>
<td>4.0</td>
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<td>26.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>April 23, 2015</td>
<td>Treatment Stage</td>
<td>Free Chlorine</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>5</td>
<td>4</td>
<td>4.0</td>
<td>4.0</td>
<td>26.67</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Disinfection Activity**

A conventional surface water treatment plant is assessing their disinfection process.

Clearwell dimensions with an approved baffling factor of 0.5:

**Disinfection Activity – Clearwell Dimensions**

Plan View

Section View

Developed by AWWA in partnership with RCAP and funded by USEPA, Published 2015
**Disinfection Question 1**

- **QUESTION 1:**
  - What is the Clearwell volume? _______ gallons
  - How much Log Inactivation is required for this facility? *Giardia________
    *Virus________

**Disinfection Question 2**

Use the *EPA CT Calculator spreadsheet*. In the table below, calculate log inactivation occurring at the facility. Which pathogen is most important? Which condition (8AM, 12PM or 4PM) has the lowest log inactivation? How can you improve disinfection?

<table>
<thead>
<tr>
<th>Time</th>
<th>Peak Hourly Flow (gpm)</th>
<th>Chlorine Residual (mg/L)</th>
<th>Temp °C</th>
<th>pH</th>
<th>Clearwell Volume (gallons)</th>
<th>Giardia Log Inactivation</th>
<th>Virus Log Inactivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>8AM</td>
<td>350</td>
<td>0.6</td>
<td>5</td>
<td>8</td>
<td>34,300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12PM</td>
<td>300</td>
<td>0.75</td>
<td>5</td>
<td>8</td>
<td>34,300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4PM</td>
<td>400</td>
<td>0.8</td>
<td>5</td>
<td>8</td>
<td>34,300</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Disinfection Question 3**

It is now summer time. Changing temperature only to 18 °C (don’t change flow), what would be the log inactivation achieved at the summer flow rates?

<table>
<thead>
<tr>
<th>Time</th>
<th>Peak Hourly Flow (gpm)</th>
<th>Chlorine Residual (mg/L)</th>
<th>Temp °C</th>
<th>pH</th>
<th>Clearwell Volume (gallons)</th>
<th>Giardia Log Inactivation</th>
<th>Virus Log Inactivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>8AM</td>
<td>350</td>
<td>0.6</td>
<td>18</td>
<td>8</td>
<td>34,300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12PM</td>
<td>300</td>
<td>0.75</td>
<td>18</td>
<td>8</td>
<td>34,300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4PM</td>
<td>400</td>
<td>0.8</td>
<td>18</td>
<td>8</td>
<td>34,300</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Disinfection Question 4**

Now change flow to the summertime conditions. Which operating condition (8AM, 12PM or 4PM) has the lowest log inactivation?

<table>
<thead>
<tr>
<th>Time</th>
<th>Peak Hourly Flow (gpm)</th>
<th>Chlorine Residual (mg/L)</th>
<th>Temp °C</th>
<th>pH</th>
<th>Clearwell Volume (gallons)</th>
<th>Giardia Log Inactivation</th>
<th>Virus Log Inactivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>8AM</td>
<td>1000</td>
<td>0.6</td>
<td>18</td>
<td>8</td>
<td>34,300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12PM</td>
<td>1200</td>
<td>0.75</td>
<td>18</td>
<td>8</td>
<td>34,300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4PM</td>
<td>1250</td>
<td>0.8</td>
<td>18</td>
<td>8</td>
<td>34,300</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Disinfection Question 5**

What is the minimum chlorine residual the system could use to comply at each operating time?

<table>
<thead>
<tr>
<th>Time</th>
<th>Peak Hourly Flow (gpm)</th>
<th>Chlorine Residual (mg/L)</th>
<th>Temp °C</th>
<th>pH</th>
<th>Clearwell Volume (gallons)</th>
<th>Giardia Log Inactivation</th>
<th>Virus Log Inactivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>8AM</td>
<td>1000</td>
<td></td>
<td></td>
<td>8</td>
<td>34,300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12PM</td>
<td>1200</td>
<td></td>
<td></td>
<td>8</td>
<td>34,300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4PM</td>
<td>1250</td>
<td></td>
<td></td>
<td>8</td>
<td>34,300</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The system realizes it can run at a finished water pH of 7.2. How would a lower pH affect the log inactivation? Would running at lower pH cause other concerns?

<table>
<thead>
<tr>
<th>Time</th>
<th>Peak Hourly Flow (gpm)</th>
<th>Chlorine Residual (mg/L)</th>
<th>Temp °C</th>
<th>pH</th>
<th>Clearwell Volume (gallons)</th>
<th>Giardia Log Inactivation</th>
<th>Virus Log Inactivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>8AM</td>
<td>1000</td>
<td>0.6</td>
<td>18</td>
<td>7.2</td>
<td>34,300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12PM</td>
<td>1200</td>
<td>0.75</td>
<td>18</td>
<td>7.2</td>
<td>34,300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4PM</td>
<td>1250</td>
<td>0.8</td>
<td>18</td>
<td>7.2</td>
<td>34,300</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
After performing a tracer study, it is determined that a new baffling factor of 0.7 is more appropriate for the clearwell. What would be the log inactivation improvement at the two baffle factors at the operating conditions described above?

March 1, 2017 Facility Operating Information:

<table>
<thead>
<tr>
<th>Baffle Factor</th>
<th>Peak Hourly Flow (gpm)</th>
<th>Chlorine Residual (mg/L)</th>
<th>pH</th>
<th>Temperature °C</th>
<th>Clearwell Volume (gallons)</th>
<th>Giardia Log Inactivation</th>
<th>Virus Log Inactivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>1000</td>
<td>1.2</td>
<td>5</td>
<td>7.2</td>
<td>36,300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.7</td>
<td>1000</td>
<td>1.2</td>
<td>5</td>
<td>7.2</td>
<td>36,300</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Measurements are Critical to Accurate CT Calculations

- pH, temperature and flow must be measured and recorded at appropriate intervals for CT calculations
- Are you measuring in the right place?
- Are your instruments calibrated properly?
- Do you meter flow using calibrated meters?

Contact Time Considerations

Contact volume (V) and resulting detention times (T) can include multiple basins if chlorine monitoring is downstream of last basin

Detention Time at Plant Design Flow

- T = 36 minutes
- T = 15 minutes
Giardia Inactivation by Chlorine - Sensitivity to pH

Example:
Direct filtration plant
1 log Giardia Inactivation
Temp = 7°C
Cl₂ = 1.1 mg/L
pH = 7.6
Need 58 minutes

If your pH measurement is low, you will underestimate how much time you need.
They think they need 48 minutes

pH is Difficult to Measure

- Sensitive to time, temperature, sample collection, probe care and maintenance, calibration, stirred vs. still
- Low ionic strength water from snowmelt (<100 µS/cm) needs special probe, hard to get consistent readings
- EPA updated method for continuous pH (82 FR 34861, 2017)

- Measure in the field
- Use consistent procedures (write down)
- Calibrate minimum 2 buffers (bracket)
- Verify with a different buffer
- Allow probe to stabilize on temp and pH - 5 min in water before taking final sample
- Probes degrade over time whether you use them or not

pH Meter Quiz
According to Standard Methods, when should you calibrate a bench top pH meter?

☐ A. Before every measurement

☐ B. Once a day

☐ C. Once a month

☐ D. Not needed

- Standard Methods 4500 H+
- New! EPA Method 150.3
- ASTM D1293
Giardia Inactivation by Chlorine Sensitivity to Temperature

Same example:
Direct filtration plant
1 log Giardia Inactivation
Temp = 7°C
Cl₂ = 1.1 mg/L
pH = 7.6
Need 58 minutes

If your temperature measurement is high, you will underestimate how much time you need. They think they need 50 minutes.

Analytical Methods: Temperature

• Standard Methods 2550 (22nd Ed)
  – Can detect temp changes of 0.1°C or less
  – +/- 0.4°C accuracy
  – Periodically check against NIST-certified precision thermometer (e.g. 1-2 x/year)

Plant thermometer:
Only marked in 1°F increments… reading six degrees low!

Temperature Quiz
According to Standard Methods, how accurate should your thermometer be?

- A. +/- 0.2°C
- B. +/- 0.4°C
- C. +/- 1.0°C
- D. +/- 2.0°C
Issues to Watch For: Measuring Chlorine Residual Grab Samples

- Wrong vial (high range)
- Sample vial cap off
- Low/high range setting
- Time — too soon or long with reagent
- Mixing: Swirl versus shake
- Condensation
- Stained or scratched vial
- Expired reagents

Issues to Watch for: Online Chlorine Analyzer Sample Flow

- Inadequate sample flow in as many as 73% of analyzers
  - Specifications: 200-500 mL/min
  - “Ideal” = 300 mL/min
- Low and high flow causes inaccurate readings
- How to measure:
  - From the drain during the 30 second flush (pink color)

  Example:
  - Grab sample = 0.81 mg/L
  - Flow = 50 mL/min → 0.54 mg/L
  - Adjusted flow = 300 mL/min → 0.83 mg/L

Online Chlorine Analyzer Quiz

According to CFR, how often should you verify the online instrument to a benchtop chlorine analyzer?

- A. Daily
- B. Twice a week
- C. Every 5 days
- D. Monthly
- C. Never
Key Components of Ground Water Rule (GWR)

- Source Water Quality
- Distribution System Water Quality

Why Regulate Ground Water?

Ref: Rose, et al., JAWWA 92:9:80

Purpose of the Ground Water Rule

- Provide increased protection against microbial pathogens in water systems that use ground water
- GWR consists of 4 major components:
  1. Sanitary survey
  2. Source water monitoring
  3. Corrective actions
  4. Compliance monitoring
Applicability

• All public water systems that use ground water
• Consecutive systems receiving ground water
• Exception: systems that blend all ground water with surface water or GWUDI prior to treatment

Sanitary Surveys by States

• Occur every 3 years
• Includes onsite review of wells and identification of sources of contamination
• 8 evaluation criteria

<table>
<thead>
<tr>
<th>Source</th>
<th>Pumps, facilities and controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>Monitoring, reporting, data verification</td>
</tr>
<tr>
<td>Distribution</td>
<td>Management and operation</td>
</tr>
<tr>
<td>Finished Water Storage</td>
<td>Operator compliance</td>
</tr>
</tbody>
</table>

Significant Deficiencies Identified during Sanitary Survey

• Defects in design, operation or maintenance
• Failure or malfunction of sources, treatment, storage, or distribution system
• Anything the State determines is causing or has potential for causing introduction of contamination
• If you have significant deficiencies, system must take corrective action
Four Options for Corrective Action – One or More May Be Required

1. Correct all significant deficiencies, such as
   - Repairs to well pads, sanitary seals, piping, tanks, treatment equipment
   - Control of cross-connections

2. Provide an alternate source of water
   - New well or connection to another PWS

Options for Corrective Action

3. Eliminate the source of contamination
   - Remove point sources
   - Relocate pipelines and waste disposal
   - Redirect drainage or run-off
   - Provide or fix existing fencing or housing of the wellhead

Options for Corrective Action

4. Provide Treatment Technology to Meet 4-log Virus Inactivation Before or at First Customer
   - Chlorine contact time – CT times based on the tables in the SWTR
   - UV disinfection – inactivation levels defined in the UV Guidance Document for the LT2ESWTR
   - Some types of membranes
Assessment Source Water Monitoring

- As a complement to triggered monitoring, a State has the option to require systems, at any time, to conduct source water assessment monitoring to help identify high risk systems.

Triggered Source Water Monitoring is Required if:

- All ground water is not treated to at least 4-log treatment of viruses before first customer, AND
- A routine total coliform sample taken in the distribution system is total coliform-positive (and not invalidated)

Treatment Technique Requirements

Treatment may be required by States for
- Systems that have fecal contamination in source water, OR
- Systems that have significant deficiencies identified by State

Treatment required could be disinfection with chlorine, ozone or UV light or filtration with membranes.
Compliance Monitoring to Show 4-log Inactivation

- Chemical disinfection monitoring at the entrance to distribution system

<table>
<thead>
<tr>
<th>Systems &gt; 3,300</th>
<th>Monitor continuously</th>
<th>Maintain State-specified residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systems &lt; 3,300</td>
<td>Monitor daily</td>
<td></td>
</tr>
</tbody>
</table>

GWR Reporting and Record Keeping

- Report in CCR: Significant deficiencies and positive ground water samples using health effects language for fecal indicators
- Record Keeping:
  - Documentation of corrective actions (10 years).
  - Public Notice documentation (3 years)
  - Records of decisions TCR distribution system samples were not indicative of source (5 years)
  - Records of invalidation of fecal indicator positive ground water source samples (3 years)
  - Documentation of policies of wholesale systems of TCR positive samples (5 years)
  - Records of State-specified minimum disinfectant residual (10 years)
  - Records of lowest daily residual disinfectant concentration with date and duration of failure to meet specified minimum (5 years)
  - Records of compliance for membrane filtration (5 years)

Useful Resources

- US EPA 2003 LT1ESWTR Disinfection Profiling and Benchmarking Technical Guidance Manual:
  http://www.epa.gov/safewater/mdbp/pdf/profile/lt1_profiling.pdf
- EPA Disinfection Profile Spreadsheet:
  http://www.epa.gov/safewater/mdbp/lt1eswtr.html
- https://www.epa.gov/region8-waterops
- EPA Quick reference guides
  - http://water.epa.gov/lawsregs/guidance/sdwa/qref/
Knowledge Review

1. Small GW systems that disinfect for 4-log removal of viruses must monitor residual
   a. Continuously  c. Every 4 hours
   b. Hourly      d. Daily
2. Name 5 of the 8 areas of evaluation for a sanitary survey.
3. Which is NOT a trigger for microbial monitoring of a well?
   a. TC+ in system and no 4-log disinfection
   b. Invalidated TC+ in system
   c. State directs triggered monitoring
   d. Significant deficiency found in sanitary survey
4. What is the purpose of the GWR? What prompted EPA to regulate groundwater?

Activity – Find a Partner

• If the State identifies a significant deficiency and does not specify a specific corrective action, what should the system do? Make a list with your partner for discussion with the group.

Stage 2 Disinfection Byproducts (DBP) Rule

• Two groups of regulated compounds:
  – Total (4) trihalomethanes (TTHM)
    • MCL = 80 µg/L
  – Five haloacetic acids (HAA5)
    • MCL = 60 µg/L
• Regulate to reduce cancer risk and other impacts
DBP Regulatory Strategy – Reduce All DBPs by Targeting THMs & HAAs

Stage 1 DBP Rule
- Minimize disinfectant levels
- Minimize exposure to DBPs on average across a system

Stage 2 DBP Rule
- Minimize exposure to DBPs at individual locations in a system
- Shave the peaks

DBP Formation in a Nutshell

Chemical Disinfectant + Precursor = DBPs

- Chlorine
- Monochloramine
- Ozone
- Chlorine Dioxide
- Organic Matter
- Bromide

Factors influencing DBP formation
- Disinfectant
  - Type and dose
- Source water total organic carbon (TOC)
  - Quantity and character
- Contact time and mixing conditions
- Water temperature
- pH
- Bromide
Impacts of Factors on DBP Formation

<table>
<thead>
<tr>
<th>Parameter (increasing)</th>
<th>TTHM</th>
<th>HAA5</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOC</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Time</td>
<td>↓</td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Disinfectant Dose</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>pH</td>
<td>↑</td>
<td>↓</td>
</tr>
<tr>
<td>Bromide</td>
<td>↓</td>
<td>↑</td>
</tr>
</tbody>
</table>

Simulation of DBP formation

TTHM Variability by Season: Monthly Peak Values
THM Variability Due to System Operation

Factors that Impact TTHM Formation

• TTHM and HAA5 formation depends on:
  - Water age in distribution system and storage
  - Temperature and pH
  - Natural organic matter (NOM) concentration
  - Chlorine dose (at WTP and boosting)

• TTHM and HAA5 will form at both WTP and distribution system as long as there is a chlorine residual and organic DBP precursors or organic matter are present

Changes in the Stage 2 DBP Rule (from Stage 1 DBPR)

• Compliance location selected based on Initial Distribution System Evaluation (IDSE) completed in 2009

• The IDSE characterizes DBP levels throughout the distribution system

• Compliance samples taken to equally cover distribution system

• Compliance based on locational running annual averages (LRAA) instead of RAA
Stage 2 DBP Rule

For small systems, monitoring frequency depends on water source and populations served.

1. Subpart H refers to systems using surface water or ground water under the direct influence of surface water.
2. Samples must be taken during the month of highest DBP concentration or highest temperature.

<table>
<thead>
<tr>
<th>Source Water Type</th>
<th>Population Size Category</th>
<th>Monitoring Frequency</th>
<th>Total Per Monitoring Period</th>
<th>Highest TTHM Locations</th>
<th>Highest HAA5 Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subpart H</td>
<td>&lt; 500</td>
<td>Yearly</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>500 – 3,300</td>
<td>Every 90 days</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>3,301 – 9,999</td>
<td>Every 90 days</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Ground Water</td>
<td>&lt; 500</td>
<td>Yearly</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>500 – 9,999</td>
<td>Yearly</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

LRAA vs. RAA

Stage 1 DBPR: RAA

1st Quarter

2nd Quarter

3rd Quarter

4th Quarter

Average of All Samples (RAA)

Running Annual Average (RAA) of Quarterly Averages

MUST BE BELOW MCL

Stage 2 DBPR: LRAA

1st Quarter

2nd Quarter

3rd Quarter

4th Quarter

LRAA

MUST BE BELOW MCL

LRAA

MUST BE BELOW MCL

LRAA

MUST BE BELOW MCL

LRAA

MUST BE BELOW MCL

LRAA

MUST BE BELOW MCL
Activity (LRAA vs. RAA)

A system has recorded the following TTHM (µg/L) concentration from their sampling sites (SS):

<table>
<thead>
<tr>
<th>SSite #1</th>
<th>SSite #2</th>
<th>SSite #3</th>
<th>SSite #4</th>
</tr>
</thead>
<tbody>
<tr>
<td>QTR 1</td>
<td>55</td>
<td>75</td>
<td>76</td>
</tr>
<tr>
<td>QTR 2</td>
<td>80</td>
<td>83</td>
<td>85</td>
</tr>
<tr>
<td>QTR 3</td>
<td>95</td>
<td>102</td>
<td>93</td>
</tr>
<tr>
<td>QTR 4</td>
<td>66</td>
<td>70</td>
<td>50</td>
</tr>
</tbody>
</table>

Locational Running Annual Average (LRAA)

Running Annual Average (RAA) = __?

Solution

A system has recorded the following TTHM (µg/L) concentration from their sampling sites (SS):

<table>
<thead>
<tr>
<th>SSite #1</th>
<th>SSite #2</th>
<th>SSite #3</th>
<th>SSite #4</th>
</tr>
</thead>
<tbody>
<tr>
<td>QTR 1</td>
<td>55</td>
<td>75</td>
<td>76</td>
</tr>
<tr>
<td>QTR 2</td>
<td>80</td>
<td>83</td>
<td>85</td>
</tr>
<tr>
<td>QTR 3</td>
<td>95</td>
<td>102</td>
<td>93</td>
</tr>
<tr>
<td>QTR 4</td>
<td>66</td>
<td>70</td>
<td>50</td>
</tr>
</tbody>
</table>

Locational Running Annual Average (LRAA)

Running Annual Average (RAA) = 76

Activity (LRAA vs. RAA)

1. What is the running annual average (RAA) under the Stage 1 DBP Rule?

2. What is the locational running annual average (LRAA) under the Stage 2 DBP Rule?
Lead and Copper Rule (LCR)

• Minimizes lead and copper in drinking water
• Action level (AL)
  – 0.015 mg/L for Lead (Pb) (15µg/L)
  – 1.3 mg/L for Copper (Cu)
  – Exceedance of the AL is based on 90th percentile level of tap water samples

LCR Minimizes Health Effects

• Lead
  – damage to brain, red blood cells and kidneys especially in children
• Copper
  – stomach/intestinal distress, liver/kidney damage, and complications of Wilson’s disease in genetically predisposed people.

Sources of Lead and Copper

• Corrosion
  – Solder
  – Lead and Copper pipes
  – Lead containing plumbing fixtures
Sampling requirements

- First draw samples at cold water taps in homes/buildings at high risk
- Number of samples based on system size
- Monitor every 6 months unless system qualifies for reduced monitoring
- Additional treatment technique and sampling if ALs are exceeded

<table>
<thead>
<tr>
<th>Size Category</th>
<th>System Size</th>
<th>Number of Pb/Cu Tap Sample Sites</th>
<th>Number of WQP Tap Sampling Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Standard</td>
<td>Reduced</td>
</tr>
<tr>
<td>Large</td>
<td>&gt;100K</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>50,001-100K</td>
<td>60</td>
<td>30</td>
</tr>
<tr>
<td>Medium</td>
<td>10,001-50K</td>
<td>60</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>3,301-10K</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>Small</td>
<td>501-3,300</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>101-500</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>&lt; 100</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Reduced Pb/Cu Monitoring

- Measure annually if
  - Serve ≤ 50,000 and Pb & Cu are less than ALs for two 6-month monitoring periods, or
  - Meet optimal WQ parameters for two 6-month monitoring periods
- Measure triennially if
  - Serve ≤ 50,000 and Pb & Cu are less than ALs for 3 years running
  - Meet OWQP for 3 years
  - 90th % Pb ≤ 0.005 mg/L and 90th % Cu ≤ 0.65 for two 6-month periods
LCR – What to do when the AL is exceeded

- Water quality parameter monitoring
- Corrosion control treatment
- Source water monitoring
- Public notification
- Lead service line replacement (LSL)

Potential Factors Affecting LCR Compliance (cont.)

- Change in water quality
- Change in treatment process
  - Installation of new processes
  - Use of new chemicals…like chloramines
  - Changes in pH leaving the plant
  - Changes associated with TOC removal, such as enhanced coagulation

For any treatment process change - notify regulatory agency

Water Quality Parameter Monitoring (WQP)

- Routine monitoring of WQP
- Systems serving ≤ 50,000 during monitoring periods in which either Cu or Pb AL is exceeded
- Used to determine water corrosivity and determine type of corrosion control technology (CCT)
- If you install CCT, must do follow-up monitoring
- State sets values of optimal WQPs
- Daily values are used to determine compliance
- Compliance based on 6 month intervals
Public Education (PE)

- Required if Pb AL is exceeded
- Informs customers about health effects and how to reduce exposure
- Delivery methods & mandatory language defined
- Deliver materials within 60 days of Pb AL exceedance
- Must submit letter to State demonstrating that PE requirements are met after each period

Source Water Monitoring and Treatment

- Systems that exceed Pb or Cu AL must sample source water to define contribution of source to Pb/Cu
- If State requires source water treatment, system has 24 months to install
- Follow-up Pb/Cu tap and entry point to distribution sampling
- State sets maximum Pb & Cu levels in source

Corrosion Control Treatment (CCT)

- Required for all large systems
- Required for medium & small systems that exceed either AL
- CCT study required for large systems; if for medium/small systems complete in 18 months
- 24 months to install CCT after State determines type
- Follow-up monitoring with State setting OWQPs
Lead Service Line (LSL) Monitoring

- Optional monitoring from LSL to determine need to replace line
- Required monitoring if partial LSL is replaced to determine impact from partial replacement

Lead Service Line Replacement (LSLR) for Systems Exceeding Pb AL after CCT Installed

- System must replace LSLs that contribute more than 0.015 mg/L to water
- Must replace 7% of LSL per year
- If only part of an LSL is replaced, notify customers about potential increase in Pb and collect samples after replacement
- Submit monitoring results from LSLR to the State

Knowledge Review

1. Which of these are actions to take when the Pb AL is exceeded?
   a. Install CCT    c. Public education
   b. Talk to the State d. Source water monitoring

2. Where and how are routine Pb/Cu samples taken?

3. Is LSL a good solution for reducing Pb in drinking water?
Local Issues Related to Regulations

- Discussion:
  - Are there any local issues unique to your area that may influence your approach to regulatory compliance?

Summary

- Quality of water produced at treatment plant can deteriorate in the distribution system
- Public health protection requires routine monitoring, and proper operation and maintenance of the distribution system

Additional Resources

- USEPA
  - [http://www.epa.gov/](http://www.epa.gov/)
- Local regulatory agency
  - Guidance documents
  - Annual monitoring requirements letter
  - Local/Regional Engineer
Parking Lot

- Next 2 slides provide examples for inactivation of groundwater by chlorine (chlorine contact time in pipes) and UV dose requirements for target pathogens

### Typical Pipe Lengths for Chlorine Contact Time

<table>
<thead>
<tr>
<th>Flow (gpm)</th>
<th>Pipe Diameter (in)</th>
<th>12</th>
<th>18</th>
<th>24</th>
<th>36</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200</td>
<td>Pipe Length (ft)</td>
<td>1,226</td>
<td>545</td>
<td>306</td>
<td>136</td>
</tr>
<tr>
<td></td>
<td>Velocity (ft/s)</td>
<td>3.40</td>
<td>1.51</td>
<td>0.85</td>
<td>0.38</td>
</tr>
<tr>
<td>800</td>
<td>Pipe Length (ft)</td>
<td>817</td>
<td>363</td>
<td>204</td>
<td>91</td>
</tr>
<tr>
<td></td>
<td>Velocity (ft/s)</td>
<td>2.27</td>
<td>1.01</td>
<td>0.57</td>
<td>0.25</td>
</tr>
<tr>
<td>300</td>
<td>Pipe Length (ft)</td>
<td>306</td>
<td>136</td>
<td>77</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>Velocity (ft/s)</td>
<td>0.85</td>
<td>0.38</td>
<td>0.21</td>
<td>0.09</td>
</tr>
</tbody>
</table>

### UV Dose Requirements – millijoules per centimeter squared (mJ/cm²)

<table>
<thead>
<tr>
<th>Target Pathogens</th>
<th>Log Inactivation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>Cryptosporidium</td>
<td>1.6</td>
</tr>
<tr>
<td>Giardia</td>
<td>1.5</td>
</tr>
<tr>
<td>Virus</td>
<td>39</td>
</tr>
</tbody>
</table>

Assumptions

- Minimum water temp (°C) 10
- pH 6 to 9
- Chlorine residual (mg/L) 1
- CT required (From SWTR Guidance Manual) 6
- Contact time required (min) 6