



The National Discussion about Disinfectant Residual in Distribution Systems

AQUASM

November 24, 2015

Outline

- History and Current Federal Framework
- Proposed State Framework
- What do we know now that we did not know then?
 - Public health impact
 - Increased knowledge about Distribution System water quality
- 2015 National Expert Panel on Distribution Disinfectant Residuals (AWWA Water Industry Technical Action Fund 262)
 - Recommendations to EPA for updating requirements
 - Research Needs and Next Steps

Federal Regulatory Framework - History

- 1975 – National Interim Primary Drinking Water Regulations

*“A supplier of water ... with the approval of the State ... [may] substitute the use of chlorine residual monitoring for not more than 75 percent of the (coliform) samples ... When the supplier of water exercises the option ... **shall maintain no less than 0.2 mg/L free chlorine throughout the public water distribution system ...**”*
- 1987 – Proposed Surface Water Treatment Rule – Subpart H Systems

*“Maintain a disinfectant residual in the distribution system (measured as **total chlorine, free chlorine, combined chlorine, or chlorine dioxide**) of no less than 0.2 mg/L in more than 5 percent of the samples each month, for two consecutive months”*
- 1989 - Surface Water Treatment Rule

“The residual disinfectant concentration in the distribution system, ... 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. ...”

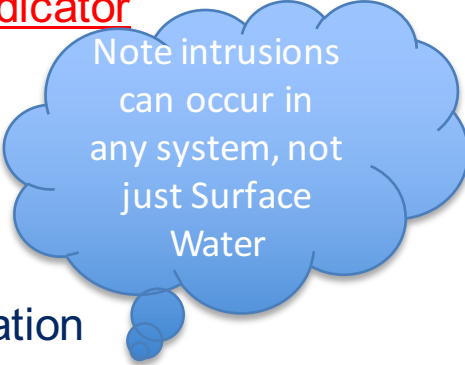
– Source: Pressman (WQTC 2014)

Federal Regulatory Framework - History

- Intent behind Surface Water Treatment rule residual requirements:
 1. Distribution System integrity
 - Ensure distribution system is properly maintained & have ability to identify and limit contamination from outside system
 2. Limit growth (regrowth) of HPC and *Legionella*, and
 3. Provide a quantifiable minimum target
- Comments on 1987 Draft
 1. *Many low HPC systems could not meet 0.2 mg/L throughout system*
 2. *Increasing chlorine would increase DBPs*
 3. *No evidence of any benefit*
 4. *Requirements should be different for different disinfectants*
- EPA revised rule
 - require “detectable” in lieu of 0.2 mg/L.
 - HPC <500/mL equivalent to detectable residual

Federal Regulatory Framework

- Summary of Current requirements, based on 1989 SWTR
 1. Residual – total chlorine, free chlorine, or chlorine dioxide
 2. Measured at same locations as TCR sites
 3. Cannot be “undetectable” in >5% of samples each month, for 2 consecutive months
 4. HPC <500/mL considered equivalent to a detectable residual
- EPA Comments on 1989 SWTR
 - Disinfectant residuals not a direct measure of performance but an **indicator** of system integrity
 - **Presence** of disinfectant, **regardless of strength**, is a useful indicator
 - Differences in disinfectant efficacy taken into account at Treatment Plant (primary disinfection)
 - Major purpose of maintaining residual is to indicate if local contamination occurring – intrusions into system

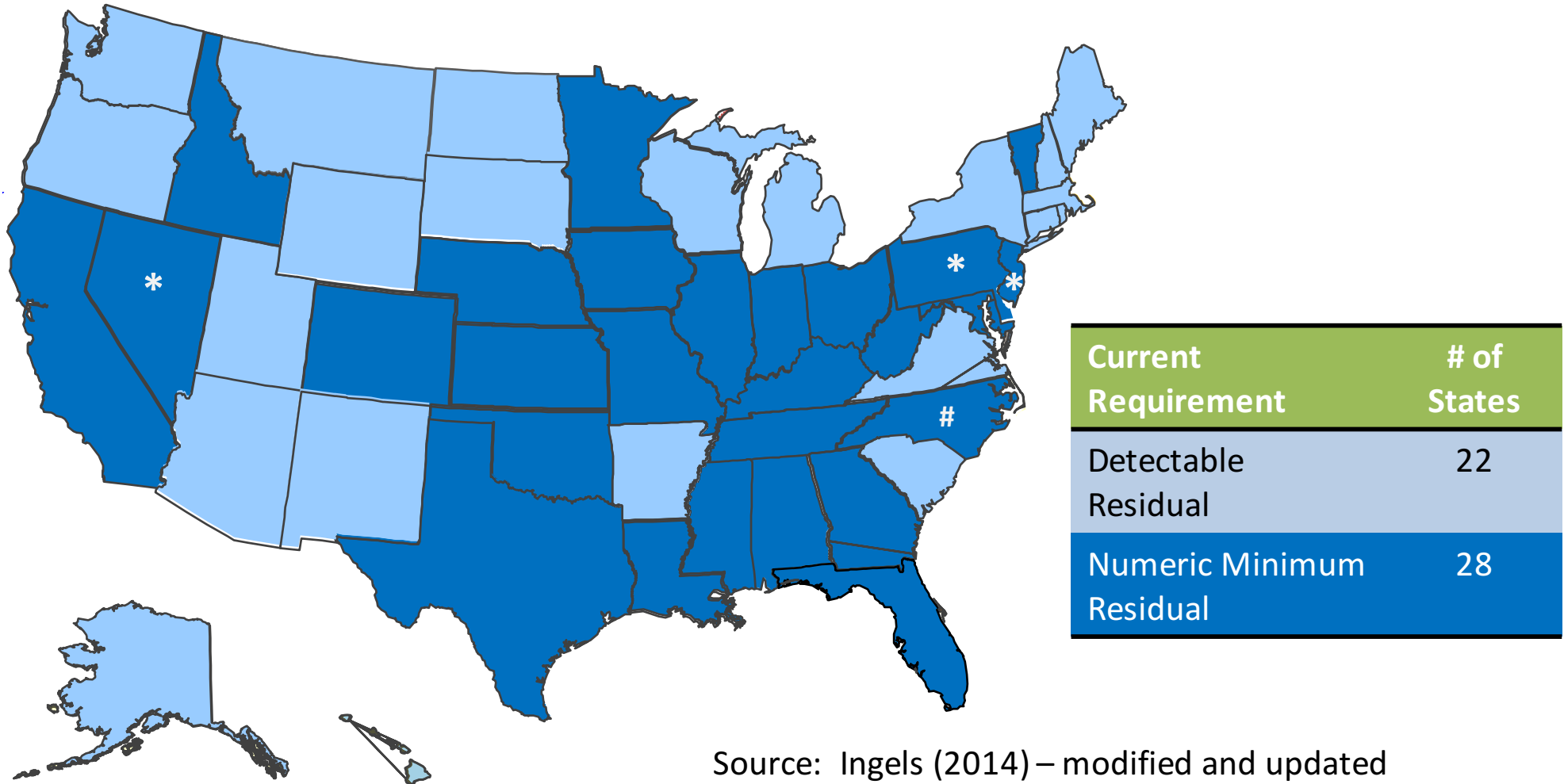


Note intrusions can occur in any system, not just Surface Water

State Regulatory Framework

What are current minimum numeric residual requirements set at?

DRAFT State Summary



Source: Ingels (2014) – modified and updated

Note: “*” indicates numeric minimum residual less than 0.2 mg/L; “#” numeric criteria limited to total chlorine

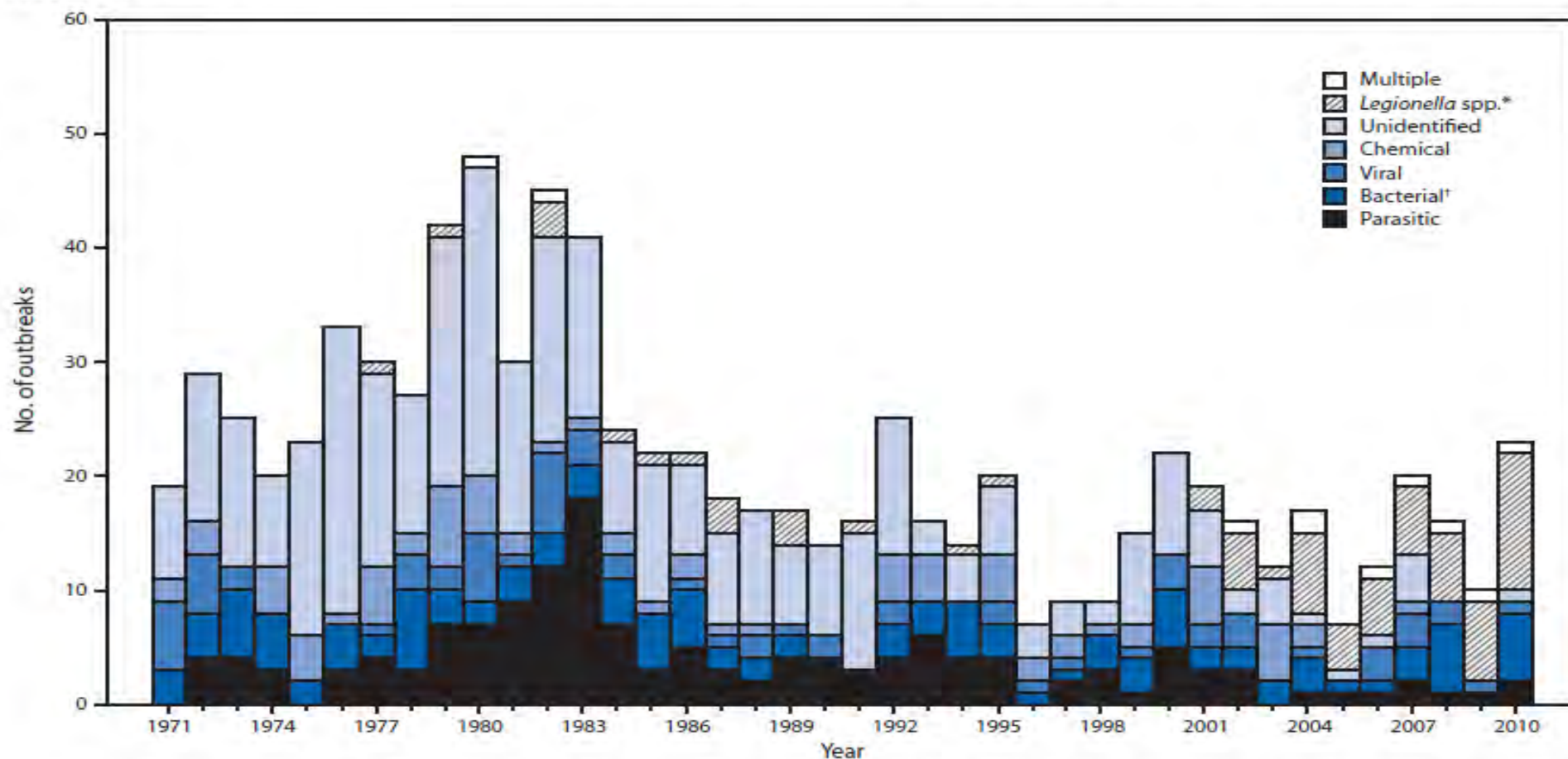
Proposed Regulatory Framework – PA

- Pennsylvania EQB proposal, passed November 17, 2015
- Disinfectant Residual Monitoring
 - Same time/locations as TCR
 - Representative locations are monitored once/week (TCR samples can count towards this)
 - Sample plan required and notification to DEP within 30 days of a change.
- Minimum disinfectant residual Limit → **0.2 mg/L** (or $\geq 0.15\text{mg/L}$)
 - Applies to CWS, NTNC, & TNC systems that use a chemical disinfectant
 - HPC out for measurement of $<500/\text{mL}$ will only apply to bottled water facilities
 - Measured as Total Chlorine for Chloramine Systems
 - Measured as Free Chlorine for Chlorine Systems
- Treatment Technique Violations:
 - PWS $\leq 33,000$ – have more than 1 sample below limit two consecutive months
 - PWS $> 33,000$ – have more than 5% samples below limit two consecutive months
 - Reporting: Notify DEP within 1 hour and Tier 2 PN
- Locations below limit two consecutive months
 - Root Cause/Corrective Action Reports required
- Nitrification control plan required for Chloramine systems (AWWA M56).

What has changed from Public Health Perspective?

- CDC, Morbidity and Mortality Weekly Report – September 6, 2013; Surveillance for Waterborne Disease Outbreaks Associated with Drinking Water and Other Nonrecreational Water — United States, 2009–2010

FIGURE. Number of waterborne disease outbreaks associated with drinking water (N = 851), by year and etiology — United States, 1971–2010



* Legionnaires' disease outbreaks were first reported to the Waterborne Disease and Outbreak Surveillance System in 2001; Legionnaires' disease outbreaks before 2001 were added retrospectively during the 2007–2008 reporting period.

† Includes all bacteria except *Legionella*.

What has changed from Public Health Perspective?

- CDC, Morbidity and Mortality Weekly Report – September 6, 2013; Surveillance for Waterborne Disease Outbreaks Associated with Drinking Water and Other Nonrecreational Water — United States, 2009–2010
- 33 drinking water outbreaks, 1040 illnesses, 9 deaths
- 58% of outbreaks *legionella*
- Most commonly identified deficiency
 - 57.6% *legionella* in plumbing systems
 - 24.2% untreated groundwater
 - 12.1% distribution system deficiencies
- Groundwater sources
- Cross connections

What has changed from Public Health Perspective?

- CDC also recently summarized the following for Waterborne hospitalizations and deaths
 - Enteric pathogens (e.g. *e. coli*) : lower
 - Biofilm pathogens (e.g. *legionella*): higher
 - Classic fecal-oral waterborne disease occurs, but seldom results in death in US
 - Patients infected with biofilm associated disease may have a more complex clinical picture than GI illnesses

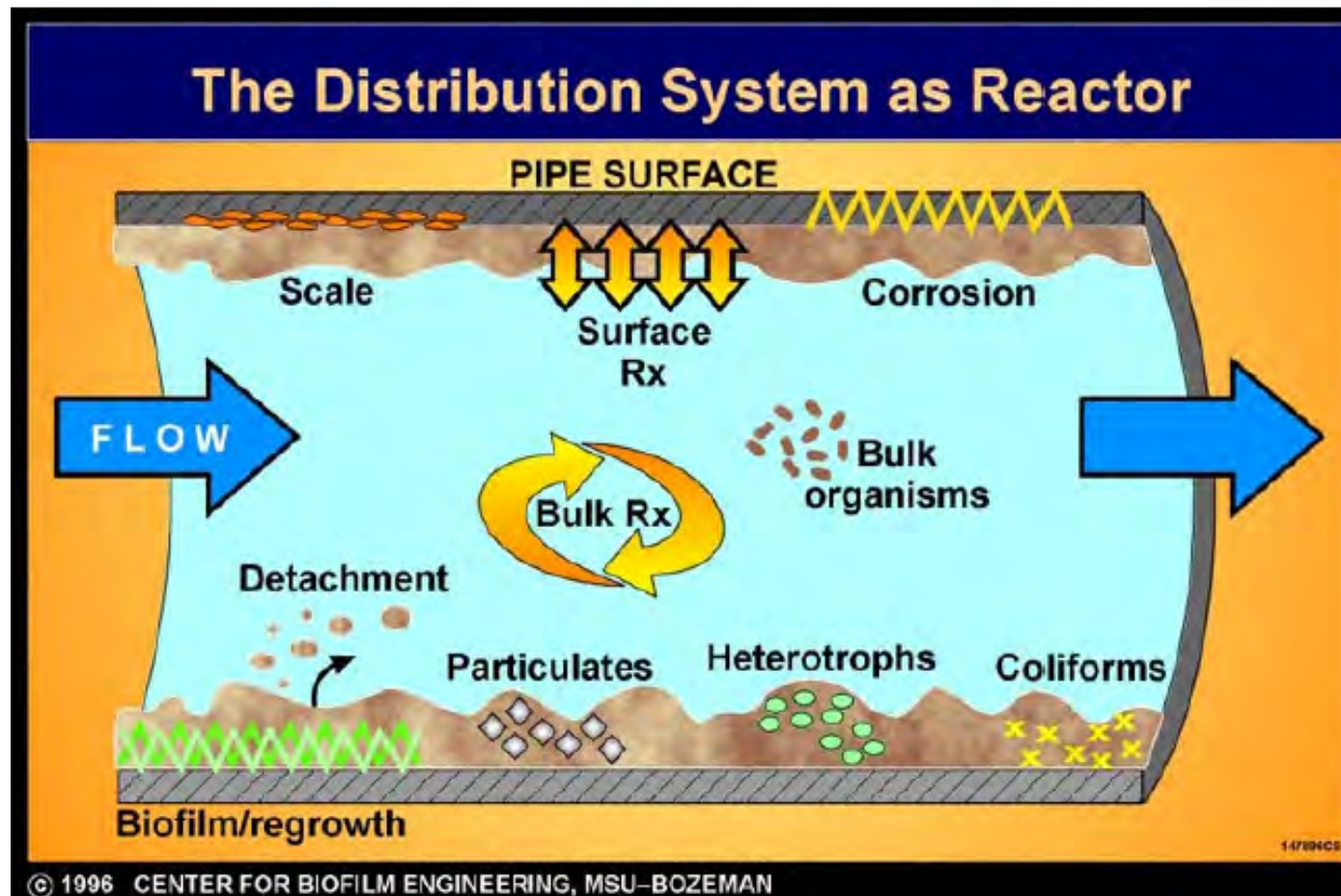
Source: Julie Gargano, CDC

WQTC 2014

Public Health Importance of Premise Plumbing Pathogens

What has changed from Public Health Perspective?

- Pipe/Distribution system as reactor, not just conveyance of water



What has changed from Public Health Perspective?

- Current Federal regulatory requirements tied to Surface Water or GUDI, but cross-connections and untreated groundwater involved in outbreaks
- Opportunistic pathogens (non-enteric) – present in soil can contaminate any distribution system, *legionella* others too such as *Mycobacterium avium* (MAC), thrive in biofilm; Aerosol exposure
- Pipe/Distribution system as reactor
 - Regrowth in Distribution systems and premise plumbing
 - Nitrification control minimum?

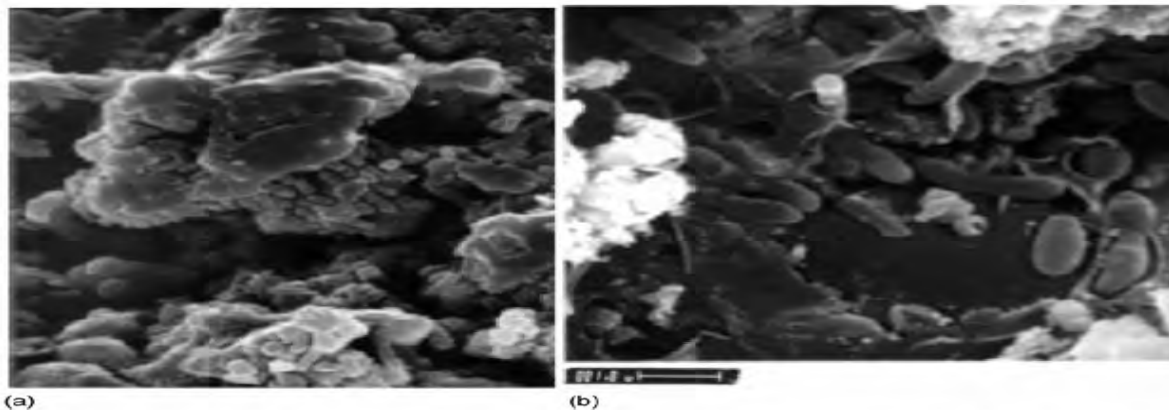
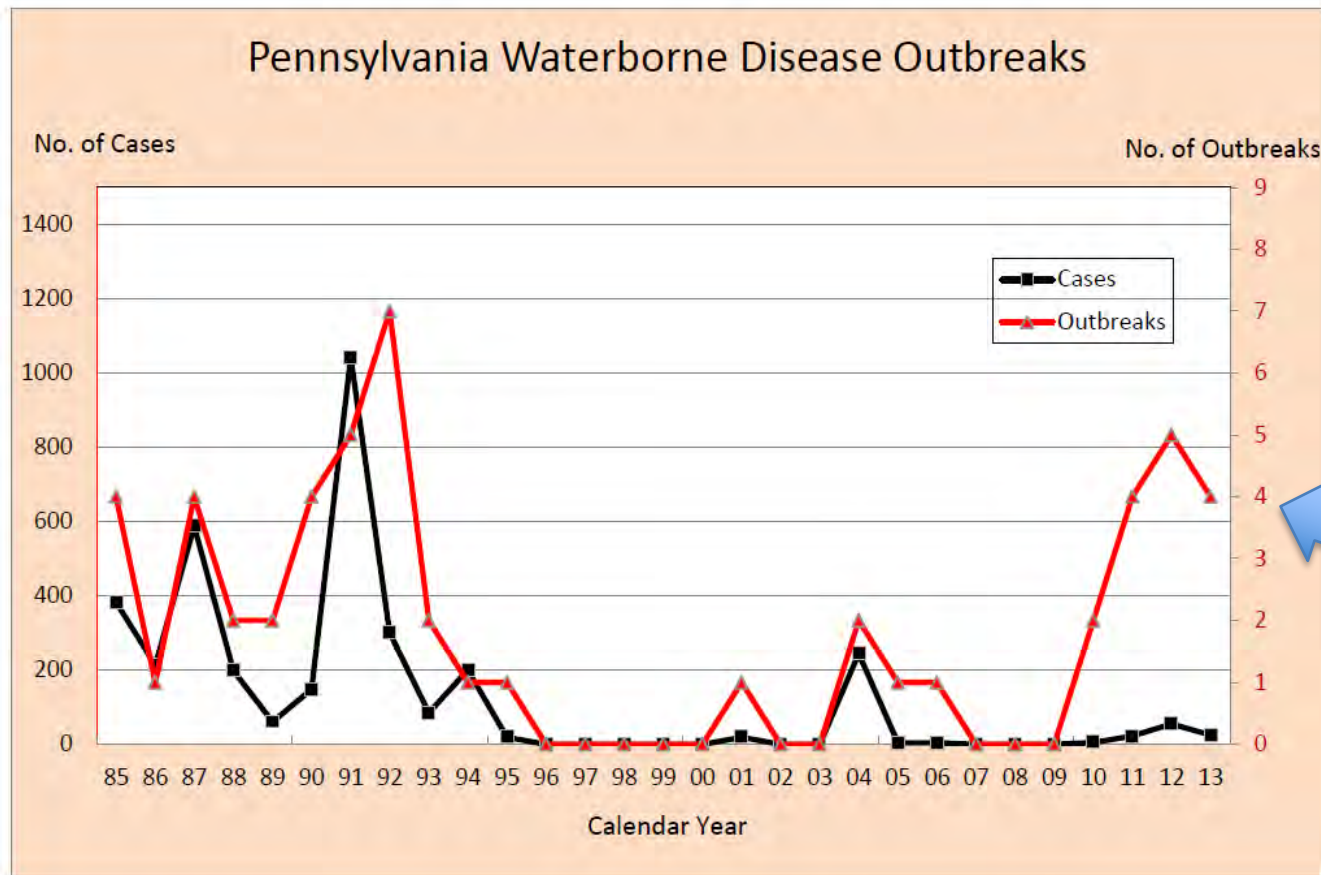


Figure 1. Scanning electron micrographs (SEM) showing bacteria colonizing a water main tubercles – New Haven, CT (Allen et al., 1980).

What has changed from Public Health Perspective?

Pennsylvania Public Water System Compliance Report, 2013



3 of 4 outbreaks
Legionella

*Also, PADOH Legionellosis fact sheet
April 2011*

What has changed from Public Health Perspective?

- Colorado Alamosa

- 2008 *Salmonella* Outbreak
- Up to 1200 illnesses; 1 fatality
- Unchlorinated groundwater;
- Distribution system deficiency – concrete in ground storage tank with holes and cracks

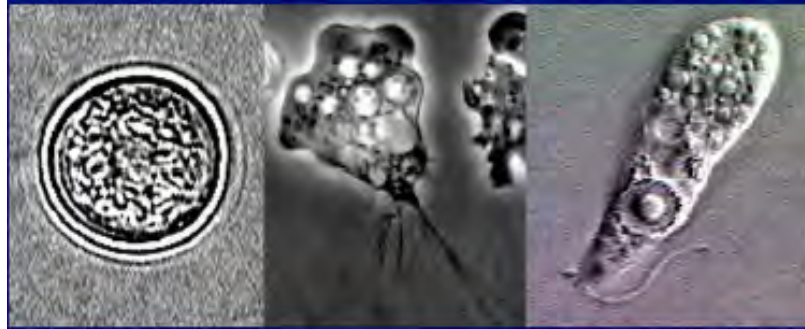


- Colorado Proposed Minimum Chlorine Residual Rule – April 2014

- Defines “detectable” as 0.2 mg/L, minimum 0.2 mg/L required for all systems
 - 0.15 mg/L rounds up to 0.2
 - 0.14 mg/L rounds down to 0.1 mg/L
- Require 95% of samples in a single month
- Cl₂ data paired w/TC – same as now
- Systems should measure chlorine BEFORE collecting TC
 - operationally get the chlorine up
- Violation if system cannot meet the level

What has changed from Public Health Perspective?

- Louisiana – *Naegleria fowleri*,



- Free living amoeba, ubiquitous in environment, potential high numbers in warm water
- Causes primary amoebic meningoencephalitis (PAM) – rare but lethal
- Found in drinking water in Australia in 1980s
- Recently found in drinking water in Arizona, and cause of two deaths in Louisiana in 2011 and one death in 2013
- Similar to *Legionella* – exposure pathway is from aerosol, not from drinking

What has changed from Public Health Perspective?

- Louisiana – *Naegleria fowleri*
 - Found in DeSoto and St. Bernard Parishes, Louisiana; Testing found amoeba in treated distribution system water
 - Both systems use conventional treatment and chloramine secondary disinfection to treat surface water
 - Common issue in both systems – low to no chlorine residual; nitrification
 - Secondary disinfection critical for *N. fowleri* control; Nitrification in chloramine systems poses significant control challenges
 - Readily attach & grow in biofilms



Source: JAWWA,
Bartrand et. al.
October 2014

What has changed from Public Health Perspective?

- Louisiana – Emergency Distribution Disinfectant Residual Rule
- All points in distribution system need to maintain a disinfectant residual
- Adequate monitoring
 - 25% more sites than TCR initially
 - By February 2014, 50% more sites
- 0.5 mg/L free chlorine or 0.5 mg/L total chlorine
- Chloramine systems required to develop and submit a Nitrification Control Plan

Source: Causey, et al, 2014 ASDWA Annual Conference

National Expert Panel on Disinfectant Residuals

- 24 Panelists including 3 Steering Committee members
 - Broad representation of interested expert stakeholders
 - 5 State Regulators
 - 10 Utilities – chlorine and chloramines, private & municipal throughout US
 - 9 Academics, Consultants, Researchers (Private, University, EPA, CDC, WRF)
 - Alan Roberson & Steve Via from AWWA
 - Facilitated by Ross Strategic Consultants
- Convened by AWWA early in 2015, seeking to answer:
 - Funded by Water Industry Technical Action Fund (AWWA Water Utility Council)
 - Should AWWA, on behalf of utilities, recommend EPA look at SWTR distribution residual requirements as part of 6 year review process – next one in 2016?



National Expert Panel on Disinfectant Residuals

- Two facilitated workshops, Winter 2015, Panel centered on 8 topics:
 - 1. NUMERIC DEFINITION FOR “DETECTABLE” DISINFECTANT RESIDUAL**
 - 2. ORGANIC CHLORAMINE METHOD ISSUES in TOTAL CHLORINE MEASUREMENT**
 - 3. TCR SAMPLING FRAMEWORK AND SAMPLE REPRESENTATIVENESS**
 - 4. HEALTH BASED NUMERIC RESIDUAL & ROLE OF DS PROTECTION PLANS**
 5. INSTITUTIONAL PREMISE PLUMBING RISK MANAGEMENT
 6. EXPAND BEYOND SWTR TO ALL WATER TYPES
 7. CROSS-CONNECTION CONTROL PLANS
 - 8. COMMUNICATION TO PUBLIC – PN & CCR REPORTING**

National Expert Panel on Disinfectant Residuals

- **T1: Numeric Definition of Detectable:**

Issue:

1. range of EPA-approved analytical methods and instruments available in uncontrolled field conditions
2. error associated with all available methods
3. what minimum level of disinfectant residual can be accurately quantified

Discussion points:

1. concern that quality of chlorine residual measurements at low levels are not adequate to support decision making
2. monitoring results may not provide an accurate portrayal of the actual level of disinfection capacity in the distribution system.
3. lack of “real” disinfectant residual compromises multi-barrier approach and creates a vulnerability to meeting intent of “detectable” in the 1989 SWTR.
4. “detectable” must take into account practical, individual method capabilities



National Expert Panel on Disinfectant Residuals

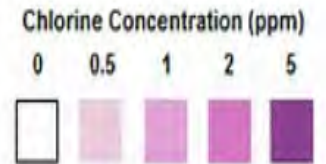
- **T1: Numeric Definition of Detectable:**

Recommendations for EPA 6 Year Review :

1. Determine Method Detection Limit (MDL) and/or Method Reporting Limit (MRL) by doing two studies:
 - a. Lab studies – *best possible conditions?*
 - b. Field studies – *actual practical conditions (including a comparison of well-trained and undertrained samplers) and in different water quality matrices?*
2. Establish numeric minimum residual for each test method (based on field performance)
3. Keep existing SWTR “detectable” terminology, but refine to depend on method (e.g., color wheels could have a higher detection limit than amperometric)
4. Conduct method trainings
5. Promote use of automated systems to alert operators to high or low secondary residual conditions

Challenges:

1. Less accurate methods (e.g., color wheels) would need to carry higher secondary disinfection residuals or switch to more expensive and intensive methods.
2. Simultaneous compliance issues e.g. disinfection byproducts (DBPs).



Diagrams are for illustration purposes only.
Always use the color blocks on the actual bottle label to interpret results.



National Expert Panel on Disinfectant Residuals

• *T2: ORGANOCHLORAMINE ISSUES in TOTAL CHLORINE*

Issue:

1. Existing total chlorine measurement methods can result in false (+)s (i.e., a residual is present, but not effective for disinfection)
2. Organic chloramines are not effective disinfectant but total chlorine methods measure both organochloramines and monochloramine

Discussion points:

1. Is detectable, using current total chlorine methods, meeting intent of secondary disinfection barrier, if organochloramine is present?
2. Chloraminated systems operating at 'detectable' may have a false sense of security relative to 'real' level of disinfection.
3. Test methods need to provide a more accurate reading in chloraminated systems:
 - a. measure organic chloramines; or
 - b. measure inorganic chloramines (for example, total Cl₂ – monochloramine = organochloramines).

National Expert Panel on Disinfectant Residuals



• *T2: ORGANOCHLORAMINE ISSUES in TOTAL CHLORINE*

Recommendations for EPA 6 Year Review :

Option 1: Measure monochloramines (inorganic chloramines) directly

- a. requires an update to current Federal regulation, as current supports only free and total chlorine measurement

Option 2: Support continued use of the total chlorine measurement with a compensation term that accounts for the presence of organic chloramines

Challenges:

Related to Option 1:

- a. Increase operation complexity related to monochloramine field test kits/increased analytical time.
- b. Need for operator understanding/training for use of the monochloramine test method.
- c. Recognition that the monochloramine test method can be potentially difficult and complicated.

Related to Option 2: Currently, no U.S. EPA-approved method to measure organic chloramines.

National Expert Panel on Disinfectant Residuals

- ***T3: TCR SAMPLING FRAMEWORK AND SAMPLE REPRESENTATIVENESS***

Issue:

1. Current sampling protocol tied to total coliform sampling sites as required under TCR/RTCR.
2. TCR/RTCR sampling may not provide an accurate assessment of when a disinfection residual is absent
3. Vulnerable areas not necessarily represented:
 - a. dead ends
 - b. areas near improperly functioning valves
 - c. pressure zone boundaries,
 - d. areas of system under lower flow conditions

Discussion points:

1. 1989 SWTR requirement for “real, detectable” residual underlies that this is critical to protecting public health
2. Concern that TCR/RTCR Sampling Framework is not optimized to find distribution system problem areas for residuals
3. Elements of a monitoring and sampling approach will be dependent upon the utility’s purpose (e.g., best practice and/or compliance).

• **T3: SAMPLING FRAMEWORK**

Recommendations for EPA 6 Year Review :

1. **Need for scientific-based monitoring/sampling**
2. **Starting points could include:**
 - a. **Creating system-wide digital interfaces for sampling locations**
 - b. **Leveraging existing information about system**
 - c. **Sampling to identify problem areas and control points**
3. **Following sampling locations would be considered:**
 - a. **Pressure zones;**
 - b. **Blending zones (undisinfected/disinfected, and chlorine/chloramine blending areas);**
 - c. **Sensitive population areas (e.g., near schools or hospitals);**
 - d. **Pipe type relative to corrosion (e.g., old, unlined cast iron);**
 - e. **Dead ends; and**
 - f. **Storage facilities**
4. **Candidate practices for sampling frequency:**
 - a. **Continuous monitoring strongly encouraged**
 - b. **Encourage sampling more often than monthly at sites where continuous monitoring is not taking place**
 - c. **Explore the creation of a waiver process for systems with high source water quality and low Cl₂ demand**

• **T3: SAMPLING FRAMEWORK**

Challenges:

1. Many areas in the distribution system do not allow for continuous monitoring.
2. A well constructed, risk based method for determining sampling locations would treat all members of the population equally and without bias.
3. Tools to address low residual may not apply/exist under certain conditions (e.g., how can low or no residual be addressed in dead ends where flushing is not an option?)



Distribution System Disinfectant Residuals

• **T4: HEALTH BASED NUMERIC RESIDUAL & ROLE OF DS PROTECTION PLANS**

Issue:

1. Set appropriate minimum for microbes of greatest concern.
2. Distribution system protection plans would be another regulatory approach
3. Distribution system integrity approach – set number so “changes” can be measured

Discussion Points:

1. Several state primacy agencies have developed numerical disinfectant residual requirements.
2. Overall sense that an *undermanaged public health vulnerability exists, related to growth of biofilm organisms* . Organisms include:
 - a. *Legionella*;
 - b. *Naegleria fowleri*;
 - c. non-tuberculousar tubercular Mycobacteria (NTMs);
 - d. *Pseudomonas*
3. 1989 SWTR had intent to address growth of *Legionella* and heterotrophic bacteria but the concept of pipes as “bio-reactors” has advanced since then
4. Six- Year Review based on “meaningful opportunity for public health protection”

• **T4: HEALTH BASED NUMERIC RESIDUAL & ROLE OF DS PROTECTION**

Discussion Points:

5. Disinfection residual is just one of a suite of tools
 - all tools must be managed effectively (e.g., cross-connection & backflow prevention, maintenance of pressure, leak detection, flushing)
6. Recognition that any approach to biofilm organisms will be *to manage, not eliminate*. Tap water is not sterile.
7. Any potential increase in disinfectant residual requirements presents simultaneous compliance issues.
8. Determining a “health-based residual” will require substantial data collection and research

• **T4: HEALTH BASED NUMERIC RESIDUAL & ROLE OF DS PROTECTION**

Recommendations for EPA 6 Year Review:

1. Numerical minimum residual based on targeting specific microbial pathogens, e.g . *E. coli*

2. Risk based protection plan
 - would allow systems to tailor both the minimum residual they carry, as well as all elements of the multi-barrier approach, to specific pathogens of concern and operational context

3. Set minimum numeric disinfection residual level, derived to support a distribution system integrity approach (i.e., carry a residual sufficient to detect integrity issues in the distribution system such as a pipe breach)

• *T4: HEALTH BASED NUMERIC RESIDUAL & ROLE OF DS PROTECTION*

Challenges:

1. **Option 1: Numeric minimum:**
 - a. **Unclear on how Ct values can be set in distribution system context**
 - b. **Inactivation time requirements for biofilm pathogens will likely be very high, relative to current residual levels, raising the prospect of unintended consequences**

2. **Option 2: Protection plans:**
 - a. **A program with acceptable level of operator accountability could be difficult**
 - b. **Capacity to implement and execute**
 - c. **Chemical and biological composition very different across systems making developing a minimum critical list of components for a protection plan difficult**

• ***T4: HEALTH BASED NUMERIC RESIDUAL & ROLE OF DS PROTECTION***

Challenges:

3. **Option 3: Integrity approach:**
 - a. **Residual level that would be needed to ensure integrity unclear.**
 - b. **Change in residual level that would indicate a breach is also unclear.**
4. **Nitrification is a risk that needs to be managed because it feeds growth of biofilm**
5. **An increase in residual will raise simultaneous compliance issues, eg. DBPs**

• ***T8: COMMUNICATION TO PUBLIC – PN & CCR REPORTING***

Issue:

1. Water systems must inform customers about ongoing water quality and whether a failure in performance may affect a customer's health.
2. Current communication requirements may cause unnecessary public concern or inaccurately represent water quality events.

Discussion Points:

1. Acute concerns (e.g., risk of microbial contamination) require immediate notification.
2. Failures in treatment process (non-acute) must be notified within 30 days.
3. Page 79 of EPA's 2010 Public Notification Guidance provides a template for PN after loss of a disinfectant residual, but not specific for distribution systems.
4. Consumer confidence reports can be use to educate the public
5. Public notification needs to warn customers when barrier has been breached and alert them to precautions they need to implement. This is not the time to educate the public.

Distribution System Disinfectant Residuals

- **T8: COMMUNICATION TO PUBLIC – PN & CCR REPORTING**

Recommendations for EPA 6 Year review:

1. Revise mandatory health effects language for failure to maintain a disinfectant residual in the distribution system.
2. Revise the Public Notification (PN) template language.
 - a. Current PN templates do not distinguish between failures in primary or secondary disinfection.
3. Consider a 'find and fix' approach (i.e., a first instance of low residual is not a violation (cause for PN), while a failure to take successful corrective action would be a basis for violation (and PN)).

Challenges:

1. Making near-term, specific changes to PN language may prove inadequate if underlying requirements change as a result of the Six-Year Review process.

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National Expert Panel on Need to Change Requirements

Summary:

- Five topics recommended as part of EPA's next 6 year review
 1. Numeric definition of detectable
 2. Organochloramine method issues for Total Chlorine
 3. Sampling Framework
 4. Health Based Numeric Residual
 5. PN Revisions
- Over 40 Research items identified to support EPA on moving forward with revisions. AWWA will be prioritizing these and convening workgroups to keep research agenda moving forward.
- AWWA letter to EPA on June 15, 2015 well received
- General agreement across Panel that a potential exists for *an undermanaged public health vulnerability related to biofilm growth* but significant research needed to support this and disagreement on most effective approach

Acknowledgements

- AWWA WITAF National Expert Panel on Distribution System Residuals
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