Microbial and Disinfection Byproducts
Rule Revisions Working Group

Meeting 3: September 20, 2022, 11:00am-6:00pm ET

EPA

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AND DRINKING WATER

WELCOME

Rob Greenwood, Ross Strategic
Elizabeth Corr, DFO, U.S.EPA OGWDW
Crystal Rodgers-Jenkins, U.S. EPA OGWDW

OPENING REMARKS

Lisa Daniels & Andy Kricun, WG Co-Chairs

Segment 1: Agenda Review & Meeting Procedures

Rob Greenwood, Ross Strategic

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Today's Virtual Meeting: Zoom Controls

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- Any comments you may have can be sent to **MDBPRevisions@epa.gov** or to Public Docket: www.regulations.gov / Docket ID Number: EPA-HQ-OW-2020-0486

EPA AND FACILITATION TEAM

Crystal Rodgers-Jenkins
EPA OGWDW, Associate Director, Standards and Risk Management Division

Ken Rotert
EPA OGWDW

Rich Weisman
EPA OGWDW

Ryan Albert
EPA OGWDW, Chief Standards and Risk Management Division

Rob Greenwood
Ross Strategic

Sarah Faust
Ross Strategic

Dana Stefan
Ross Strategic

Leeland Gotlieb
Cadmus

Erin Mateo
Cadmus

Taner Durusu
Cadmus

Abby Ulmer
Cadmus

Today's Agenda

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11:00-12:45	• Agenda Review and Meeting Procedures
	• Follow up on problem characterization discussions on opportunistic pathogens and disinfectant residuals
	60 Minute Lunch Break (12:45 – 1:45 pm ET)
1:45 – 4:25	• Regulatory and Policy Framework for D/DBPRs
	10 Minute Break (2:45 – 2:55 pm ET)
	• Problem Characterization on DBPs
	10 Minute Break (4:25 – 4:35 pm ET)
4:35 – 6:00	• Cont.: Working Group Discussion Problem Characterization on DBPs
	• Meeting 4 Agenda & Next Steps

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Topics

1. Principles, Priority Areas, Challenge Areas
2. Problem Characterization
3. Interventions
4. Implementation Mechanisms
5a. Findings
5b. Recommendations
6. Final Report

Meeting Series

1. Introductions, Priorities, & WG Goals
2. Problem Characterization Areas
3. Problem Areas in More Detail (Part 1) ← **We Are Here**
4. Problem Areas in More Detail (Part 2)
5. Stepping Back – Wrap Up of Problem Characterization
6. Intervention Scoping & Evaluation Approach
7. Intervention Characterization (Part 1)
8. Intervention Characterization (Part 2)
9. Connect Preferred Interventions to Implementation
10. Translate Interventions to Recommendations
11. Draft Recommendations
12. Final Refinements to Recommendations
13. Final Report

Segment 2: Follow up on problem characterization discussions on opportunistic pathogens and disinfectant residuals

Technical Presentation and Panel Discussion

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Problem Characterization on Opportunistic Pathogens and Disinfectant Residuals: Follow up information

- Technical analysts who provided input to the responses on the following slides
  - Mark LeChevallier – Dr. Water Consulting LLC. Formerly with American Water.
  - Nancy Love – The University of Michigan
  - Shawn McElmurry – Wayne State University
  - Andrew Jacque – Water Quality Investigations
  - Steven Duranceau – University of Central Florida
  - Zaid Chowdhury – Garver
  - Susan Teefy – East Bay Municipal Utility District
  - Stuart Krasner – formerly with the Metropolitan Water District of Southern California
  - Vanessa Speight – The University of Sheffield

Problem Characterization on Opportunistic Pathogens and Disinfectant Residuals: Follow up information

- What's being done in blended waters?
  - There's no indication that blended water (often performed seasonally or intermittently) is at any more risk for pathogen growth than surface or groundwater. However, when mixing two waters with differing water qualities, the disinfectant decays could be faster, and some systems may adjust or augment disinfectants at or near the points of blending. For example, when free chlorinated well waters are added to a DS with chloraminated water from a surface water plant, we could possibly see localized breakpoint chlorination and loss of residual. Most research studies on blended waters focus on non-pathogen parameters.
- What is the problem with disinfectant residuals?
  - Opportunistic pathogens can grow in distribution systems when disinfectant residuals are low, although more data may be needed. Some analysts suggested <0.1 mg/L as being low in this context while others suggested that level is too low for some OPs and is likely to be different for different OPs, reiterating the need for more data. Chlorine residuals levels that drop too low encourages biofilm growth which could also be the areas where OPs could grow.
  - Disinfectant residual testing by water utility personnel that use powder pillow testing kits continue to read free chlorine when monitoring combined chlorine within their system, a result of the testing, not reality. Hence regulations that require water purveyors to measure residuals at lower levels or take actions that require additional sophistication will be burdensome to small systems.
  - The current rules allow for 5% of the distribution system to not meet disinfectant residual targets. These sites can never have a disinfectant residual and the system still remain in compliance. Moreover, these requirements only apply to surface water systems.

Problem Characterization on Opportunistic Pathogens and Disinfectant Residuals: Follow up information

- What are the implications for oversized systems?
  - Oversized systems (and really all systems) can have areas of low flow and stagnation where disinfectant residuals can dissipate. Such systems will have increased water age that is associated with continued formation of DBPs (particularly for chlorinated systems) and loss of residuals which is connected with the growth of OPs and loss of protection against cross contamination.
  - Oversizing is sometimes necessary in order to meet fire flow requirements, noting that water quality is not the only driver in decisions about storage volumes.
  - Some analysts suggested considering oversized systems as a consequence of dramatic depopulation (including razed structures or abandoned structures) separately from other oversized systems, noting such systems are more vulnerable to contamination from the environment than other oversized system if backflow preventors are not maintained or present and if lines are not correctly plugged.
  - Many water systems often discover closed valves that has the same effect as oversizing.
  - Some analysts refer to a situation termed "flowing stagnation" in an oversized system where the water velocity is insufficient to prevent stagnation and biofilm growth at the pipe wall. They note this situation has been observed at the ends of a water system, in stagnant water main loops, in transmission mains sized for low head loss, in oversized building services sized for fire protection, in building plumbing sized for future expansion and in modern plumbing systems that are designed based on an outdated plumbing code.

Problem Characterization on Opportunistic Pathogens and Disinfectant Residuals: Follow up information

- What happens to the water in the distribution system?
  - As the water flows from the treatment plant to the customer, bacterial growth can occur under certain circumstances. Managing or preventing this growth is key to maintaining water quality including maintaining disinfectant residuals, ensuring good circulation in the pipe network, removing sediment, water with low turbidity and chemical stability, effective corrosion control, and biofilm control. Some analysts suggest that much of the so-called "sediment" in distribution systems is biologically active and a form of biofilm. Once biofilm establishes, it will defend itself against disinfection and proliferate unless it is prevented with nutrient removal at the source or controlled with preventative maintenance.
  - Storage tanks in the DS are also places where we typically see stagnant water. Most DS storage tanks in the U.S. have single inlet/outlet and many systems do not exercise (empty/fill) these tanks on a regular basis. This configuration is particularly worse for having stagnant water and sometimes is a source of nitrification in the DS (e.g., for a system with stagnant water in their tanks for days along with a WTP that is not effectively removing biodegradable organic carbon and chloramines in the DS).

Problem Characterization on Opportunistic Pathogens and Disinfectant Residuals: Follow up information

- What are the root causes for growth of opportunistic pathogens?
  - Situations where the microbes (or their amoebae hosts) can grow; factors that prevent these situations include maintaining effective disinfectant residuals, avoiding stagnation, and eliminating sediments in pipes and storage tanks. Stagnation also occurs in pockets formed by tubercles – due to aging and undermaintained infrastructure.
  - There must be some seed of the OP that is coming from the source water and that escaped treatment. Once that gets into the DS and finds a favorable environment as described above, they proliferate. Testing showed that filtered water system samples rarely remove all bacteria. This means that disinfection, while helpful, is not perfect. Once these OPs/bacteria get into the system, whether it be at the source, through a defect in the system, or inhaled into the system through a storage facility vent, they associate with biofilm for protection or become inactivated in the bulk by disinfection.
  - Bacteria can move through the system with protection if associated with a sloughed piece of biofilm – biofilm grows unhindered in oversized or stagnant parts of the system. Biofilms provide not only protection from disinfection, but also nutrients that nourish the bacteria.
  - Some European countries (e.g., Netherlands) which have no secondary residual maintenance in distribution systems were found to operate at much lower nutrient levels (measured as Assimilable Organic Carbon) than in the U.S. One study in the Netherlands found that 96.9% of the samples were positive for non-pneumophila *Legionella*, and only 2.1% contained *L. pneumophila*.

Problem Characterization on Opportunistic Pathogens and Disinfectant Residuals: Follow up information

- What is the water use in aerosol-generating devices?
  - Anything that produces a spray of water that people can breathe. Examples include showers, faucets, toilets, cool mist humidifiers, sprinklers, hot tubs, cooling tower blowdown, produce misters, swamp coolers, decorative fountains and water falls we see in many commercial facilities and some homes.
- Where is *Legionella* found in the treatment train?
  - *Legionella* are naturally found in raw water. Current surface water treatment practices (disinfection and filtration) effectively removes/inactivates *Legionella*, but even if minute levels are found in water, or enter the distribution pipe network through breaks or vents in distribution reservoirs, the bacteria can amplify in niches favorable for growth. Niches includes areas with low disinfectant residual, high water age, and corroding environments (such as associated with aging infrastructure).
  - Analysts suggested the benefit of seeking additional data on *Legionella* in finished water from plants that are meeting the SWTR/ESWTR disinfection requirements. Other analysts suggested such data are dependent on the analytical methods used and water volumes analyzed. Currently, there is no consensus on the most appropriate methods and volumes for analysis.
  - Maintenance of residual is one tool in the holistic distribution system management toolbox.

Problem Characterization on Opportunistic Pathogens and Disinfectant Residuals: Follow up information

- What clarity can be provided regarding the contribution of distribution systems versus plumbing on conditions that may allow for opportunistic pathogen growth?
  - The exact answer is unknown. It is likely that even with high-quality distribution system water, *Legionella* can grow in building plumbing if conditions are favorable. Even high-quality distribution system water is not sterile. Managing *Legionella* risk is a responsibility of the utility and the building owner/manager for their respective water system components. Some analysts suggested that managing this risk requires actions by the utility, by users, and that communication about the role of each is lacking and needs work.
  - Some analysts suggested that the way to answer this question is by looking at studies that reported on buildings/cases, particularly if they have measurements at the entrance to the building and in taps inside the building. Other analysts noted that research studies about this are ongoing with preliminary data showing that it appears water quality in buildings is demonstrably different from water coming into them.
  - Other analysts suggested that code-driven plumbing system design is the biggest contributor to OP growth, with commercial plumbing system requirements creating the highest risk. Commercial plumbing systems typically see oversized plumbing and code required hot water loops (energy efficiency code) leading to high water age which further promotes biofilm growth and loss of disinfection, even in systems with a low nutrient content.

Problem Characterization on Opportunistic Pathogens and Disinfectant Residuals: Follow up information

- What clarity can be provided regarding the contribution of distribution systems versus plumbing on conditions that may allow for opportunistic pathogen growth (continued)?
    - Other analysts noted the complexity of premise and building plumbing systems in terms of materials of construction, arrangement, and use patterns, and suggested that problems with disinfectant residuals and opportunistic pathogens are more of a function of the building/structure plumbing systems that are subject to building codes and impacted by construction methods means and materials when operated under a variety of differing conditions. They noted this as an extremely complex situation and issues related to legal significance should not be ignored.
- How would PCR results inform the risks that may be present if systems didn't maintain adequate disinfectant residuals?
    - PCR detects the DNA of the bacteria in water. It can indicate the presence but doesn't indicate if the cells are viable or infectious. PCR results are more rapid than culture techniques, allowing a system to quickly take action. Some analysts suggest that detecting DNA of certain bacteria would not necessarily imply any risk, noting that DNA do not make people sick, the living organisms do. They asked if the PCR test could be used as a screening technique and culture tests conducted for waters that have the DNA. Other analysts questioned the workability of this approach, suggesting that PCR's usefulness is for time-series data which can show trends. Additional analysts referred to the impact of HPC background on culturability limits for OPs.

Problem Characterization on Opportunistic Pathogens and Disinfectant Residuals: Follow up information

- How would PCR results inform the risks that may be present if systems didn't maintain adequate disinfectant residuals (continued)?
  - Other analysts noted that culture-based methods can also underestimate presence and that concentrations can change if conditions for growth occur. They noted that culturing is not highly sensitive for some highly infectious OPs (or OPs that can grow further downstream) and that DNA/culturing correlations are pretty poor and non-predictive. The analysts suggest that use of monitoring alone to infer risk is unwise and such considerations need to be included in communicating about risk (e.g., using clear communication about what we know and what we don't know, and how consumers can take actions to reduce their risk).
- How specific are PCR data?
  - PCR can be specific for the genus, species, or even strain of the bacteria, however, conventional techniques cannot indicate viability. Some viability PCR techniques exist, but they need further validation. There are culture techniques (e.g., Legiolert) that can quantify viable cells in a sample. Other analysts noted that they've seen Legiolert give false positives – e.g., a high prevalence of *Pseudomonas* will cause the media to turn with no Lp present. Some analysts have recommended that all presumptive Legiolert tests be confirmed by serotyping. False negatives may also result.

Problem Characterization on Opportunistic Pathogens and Disinfectant Residuals: Follow up information

- How are sampling locations chosen with regard to disadvantaged communities?
  - Unknown. To date, relatively little monitoring for *Legionella* has been done in distribution systems, so the characteristics that make system more vulnerable is still being researched. That said, systems without the Technical/Financial/Managerial capabilities to monitor, maintain and renew their systems have a host of water quality problems. Existing rules (e.g., total coliform rule, DBP rule) require sample collection from each pressure zone regardless of community served.
  - Some analysts suggested that challenges include the presumption that the pressure zones are known and monitored, noting that in communities with inadequate resources to maintain their overall DW system, having a validated and up-to-date hydraulic model of the distribution system is a big assumption, so sampling locations may not be in accordance with the greatest water quality risk. They referred to Flint prior to the crisis and said that TCR and DBP monitoring were in places that did not capture the highest water age. Other analysts described their efforts during the Flint water crisis to attempt to randomly sample homes in Flint and in two comparison areas and reported that the levels of *Legionella* in Flint were much higher overall, with a greater proportion of samples being observed in high-water age areas.

Problem Characterization on Opportunistic Pathogens and Disinfectant Residuals: Follow up information

- What is the ecology and life cycle of the opportunistic pathogens?
  - Unfortunately, little is known about the ecology and life cycle of OPs in full-scale DS. For example, managing the growth of amoebae in water systems could be a strategy for *Legionella* control, but research, methods, and analyses are lacking.
  - Many OPs associate with biofilm, which provides them with nutrients and protection from disinfection. Some analysts suggest that better OP control needs better control of biofilm formation, which means better nutrient removal prior to the entry point, optimal plumbing sizing to promote self-cleaning velocities on a routine basis, and better water system/plumbing maintenance.
  - Other analysts refer to preliminary unpublished data from low vs. high water age showing that the form of the nutrient changes with water age, and in ways that could be important for OP growth, suggesting that biogeochemical cycling that occurs in distribution systems is poorly understood but may be critically important to OP survival and proliferation.

Segment 2: Problem Characterization on Opportunistic Pathogens and Disinfectant Residuals

Discussion Topics

- Provide any needed report back on technical questions
- Discuss potential emergent findings related to opportunistic pathogens and disinfectant residuals
- How much does it meet a level that requires attention?
- Confirm sense of the root causes of the problem
- Confirm the nature of the gap that currently exists

60 Minute Lunch Break

12:45 – 1:45 pm ET

Segment 3: Regulatory and Policy Framework related to the D/DBPRs

Richard Weisman, U.S. EPA OGWDW

Rob Greenwood, Ross Strategic

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Presentation Overview

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- Overview of Key Existing Requirements for D/DBPR
- Number and Type of Public Water Systems Addressed by D/DBPRs

Key Existing Requirements for D/DBPRs

Today's Presentation

Drinking Water Value Chain	Contaminants of Concern		
	Microbials	Interdependencies	DBPs
Source Water			
Treatment			
Distribution			
Premise			

Key Existing Source Water Requirements for D/DBPRs

- Requires monitoring source water for total organic carbon (TOC) and alkalinity (per Stage 1 DBPR 1998).
  - Applies to all surface water (including GWUDI) treatment plants using a conventional coagulation/filtration treatment process (i.e., coagulation, flocculation, sedimentation, and filtration).

Key Existing Treatment Requirements for D/DBPRs

- Based on levels of TOC and alkalinity in source water, requires meeting specified percentage of TOC removal before delivering the water to distribution system, unless meeting alternative criteria (treatment technique [TT] requirement) (per Stage 1 DBPR 1998).
- Applies to all surface water (including GWUDI) treatment plants using a conventional coagulation/filtration treatment process (i.e., coagulation, flocculation, sedimentation, and filtration).

Key Existing Distribution System Requirements for D/DBPRs – Part 1 of 2

- Requires meeting maximum contaminant levels (MCLs) for total trihalomethanes (TTHM, 0.080 mg/L; TTHM is commonly referred to as THM4) and the sum of five haloacetic acids (HAA5, 0.060 mg/L).
- Requires meeting MCLs for bromate (0.010 mg/L, for systems that use ozone as a disinfectant) and chlorite (1.0 mg/L, for systems that use chlorine dioxide as a disinfectant).
  - The MCL for bromate must be achieved at the entry point to the distribution system while the MCL for chlorite must be achieved at both the entry point and within the distribution system.
- Requires meeting maximum residual disinfectant levels (MRDLs) for chlorine (4 mg/L as Cl_2), chloramines (4 mg/L as Cl_2), and chlorine dioxide (0.8 mg/L as ClO_2).
  - Applies to all community and non-transient noncommunity water systems that add a chemical disinfectant in any part of the drinking water treatment process and transient noncommunity water systems using chlorine dioxide (Stage 1 DBPR 1998).

Key Existing Distribution System Requirements for D/DBPRs – Part 2 of 2

- Requires systems to conduct an evaluation of their distribution systems, known as an Initial Distribution System Evaluation (IDSE), to identify the locations with high DBP concentrations as compliance monitoring locations.
- Requires systems to determine if they have exceeded an operational evaluation level (OEL), which is identified using their compliance monitoring results, and to review their operational practices and submit a report to their state that identifies actions that may be taken to mitigate future elevated DBP levels.
- Requires that compliance with the MCLs for TTHM and HAA5 be calculated for each monitoring location in the distribution system, referred to as the locational running annual average (LRAA). The number of monitoring locations are determined as a function of the population that a system serves.
    - Applies to all community and non-transient noncommunity water systems that add a primary or residual disinfectant other than ultraviolet light or deliver water that has been treated with a primary or residual disinfectant other than ultraviolet light (Stage 2 DBPR 2006).

Inventory of Disinfecting Public Water Systems Based on Population Served

Type of System	Count (Active Systems)	Percentages by Size		
		<10,000 (Small)	10,000 – 100,000 (Medium)	≥ 100,000 (Large)
Community water systems (CWSs)	*43,122*	38,773	3,907	442
Population Served – CWSs	308,338,043	51,330,438	112,367,837	144,639,768
Non-transient non-community water systems (NTNCWS)	*11,490*	11,451	38	1
Population Served – NTNCWSs	5,317,950	4,313,009	801,566	203,375
Transient community water systems (TNCWS)	*19,920*	19,910	9	1
Population Served – TNCWSs	5,215,290	3,056,835	158,455	2,000,000

Sources: SDWIS (calendar year 2019), U.S. Census (national population in 2019, from https://www.census.gov/newsroom/press-releases/2019/popest-nation.html)

Inventory of Disinfecting Public Water Systems Based on System Type

Number of Systems/ Population Served by System Type	Percentages by Size			
	Total	<10,000 (Small)	10,000 – 100,000 (Medium)	100,000 (Large)
	Ground Water Systems			
Number of systems	59,968	58,377	1,516	75
Population served	94,283,118	37,562,513	38,690,244	18,030,361
	Surface Water Systems			
Number of systems	14,564	11,757	2438	369
Population served	224,588,165	21,137,769	74,637,614	128,812,782

Data source: SDWIS 2019.

Segment 3: Regulatory and Policy Framework for D/DBPRs: **Discussion Topics**

- Clarifying Questions
- Based on your experience, are there further features or aspects of the rules that you would like to highlight for WG consideration?
- Are there other aspects of the D/DBPR regulatory and policy framework you would like to learn more about to inform Working Group discussions, and why?

10 Minute Break

2:45 – 2:55 pm ET

Segment 4: Problem Characterization – DBPs

EPA & Technical Panel
Rob Greenwood, Ross Strategic

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UNADDRESSED OR NEWLY EMERGENT HEALTH RISKS FROM DBPS – INCLUDES UNREGULATED HAAS (E.G. CARCINOGENICITY); RESIDUAL DBP RISKS (E.G. BLADDER CANCER); AND DEVELOPMENTAL/REPRODUCTIVE CONCERNS

Kirsten Studer, U.S. EPA OGWDW
Casey Lindberg, U.S. EPA OST

Presentation Overview

- Unaddressed or newly emergent health risks from DBPs – includes unregulated HAAs; remaining DBP risks; and developmental/reproductive concerns.
- Occurrence-related information.
  - Occurrence and co-occurrence of regulated and unregulated DBPs.
  - Occurrence of DBP precursors in source water (Br/TOC) and finished water (TOC).
  - DBP occurrence affected by disinfection practices and precursors.
- Overview of factors affecting DBP group formation; precursor occurrence.
- Concerns about compliance with current DBP regulations including for consecutive systems.

Consideration of THM4 and HAA5 as Indicators

- The four THMs (TTHM, also referred to as THM4) and five HAAs (HAA5) measured and regulated in the Stage 2 DBPR are intended to act as general indicators for DBP occurrence.
- There are other known DBPs in addition to a variety of unidentified DBPs present in disinfected water but THMs and HAAs typically occur at higher levels than other known and unidentified DBPs (McGuire et al. 2002; Weinberg et al. 2002).
- The presence of TTHM and HAA5 is generally representative of the occurrence of many other chlorination DBPs; thus, a reduction in the TTHM and HAA5 may indicate an overall reduction of DBPs.

Source: Economic Analysis for the Final Stage 2 Disinfectants and Disinfection Byproducts Rule (2005).
McGuire et al. (2002). Information Collection Rule Data Analysis. AWWA Research Foundation and AWWA, Denver.
Weinberg et al. (2002). National Exposure Research Laboratory, Office of Research and Development, US EPA.

Haloacetic Acids (HAAs)

- HAAs are one type of DBP group formed when chlorination is used for disinfection.
- Nine HAAs were monitored under the UCMR 4 and reported as HAA5, HAA6Br, and HAA9.

Haloacetic Acid (HAA) Species	Status	HAAs Reported in UMCR4		
		HAA5 (MCL)	HAA6Br	HAA9
Monochloroacetic acid	Regulated	X		X
Dichloroacetic acid		X		X
Trichloroacetic acid		X		X
Monobromoacetic acid		X	X	X
Dibromoacetic acid		X	X	X
Bromochloroacetic acid	Unregulated		X	X
Bromodichloroacetic acid			X	X
Chlorodibromoacetic acid			X	X
Tribromoacetic acid			X	X

Sources: https://www.epa.gov/dwucmr/fourth-unregulated-contaminant-monitoring-rule

Types of Health Effects Associated with DBPs

- Different DBPs in treated water may pose different health risks.
  - Cancers (e.g., bladder, colorectal, liver, kidney)
  - Reproductive and developmental toxicity (e.g., intrauterine growth restriction, low birth weight)
  - Cytotoxicity, genotoxicity, mutagenicity, and teratogenicity as indicated by *in vitro* bioassays

Source: Economic Analysis for the Final Stage 2 Disinfectants and Disinfection Byproducts Rule (2005).

DBP Exposure and Potential Risk for Bladder Cancer – Stage 2 Information

- In the Stage 2 D/DBPR economic analysis, EPA estimated the annual number of potential bladder cancer cases in the U.S. attributable to chlorination DBPs in drinking water and the expected reduction of these cases from implementation of the Stage 1 and Stage 2 D/DBPRs.
- EPA developed a dose–response function examining the relationship between THM4 concentrations in drinking water and increased bladder cancer risk based on a pooled-data analysis of six case–control studies.
- Using national THM4 occurrence data from 1997 to 1998 combined with this dose–response function, EPA estimated that the proportion of lifetime bladder cancer associated with chlorination DBPs in drinking water was 2 to 17.1% as a pre-Stage 1 D/DBPR baseline risk.
- In the Stage 2 D/DBPR economic analysis, EPA also noted that a causal relationship between bladder cancer and exposure to any individual DBP or combinations of DBPs had not yet been established and that the lower-bound of the potential risk estimates could be as low as zero.
- Health effects other than bladder cancer were not quantified under Stage 2 D/DBPR due to insufficient data at that time.

Source: Economic Analysis for the Final Stage 2 Disinfectants and Disinfection Byproducts Rule (2005).

DBP Exposure and Potential Risk for Bladder Cancer – Additional Information

- Although there is uncertainty as to whether THM4 is the most toxicologically relevant surrogate to gauge risks presented by the broad suite of chlorination DBPs in drinking water, many existing studies use it as a surrogate measure for chlorination DBPs.
- Regli et al. (2015) discussed the increased weight of evidence supporting causality with the improved understanding of the role of genetically susceptible populations due to specific polymorphisms for THMs and HAAs, and exposure routes for THMs (oral, inhalation, and dermal) that impact risk.
- Weisman et al. (2022) applied the dose-response information from Regli et al. (2015) with SYR3 data to estimate the potential number of bladder cancer cases associated with chlorination DBPs in drinking water.
  - Weisman et al. (2022) further found that the weight of evidence supporting causality further increased since Regli (2015).
- Hrudey et al. (2015) suggested more work is needed to understand the possible mechanisms involved in relationships between effects seen in epidemiological studies and animal bioassays, clarify different sources of uncertainty, and address the use of THM4 as a surrogate measure of risk from the most relevant DBP mixtures of toxicological interest.

Sources: Regli et al. (2015). Environmental Science & Technology 49.22: 13094-13102.
Weisman et al. (2022). Environmental Health Perspectives Vol. 130, No. 8
Hrudey et al. (2015). Journal of Toxicology and Environmental Health, Part B Vol. 18, No. 5

DBP Exposure and Potential Risk for Reproductive and Developmental Effects – Stage 2 Information

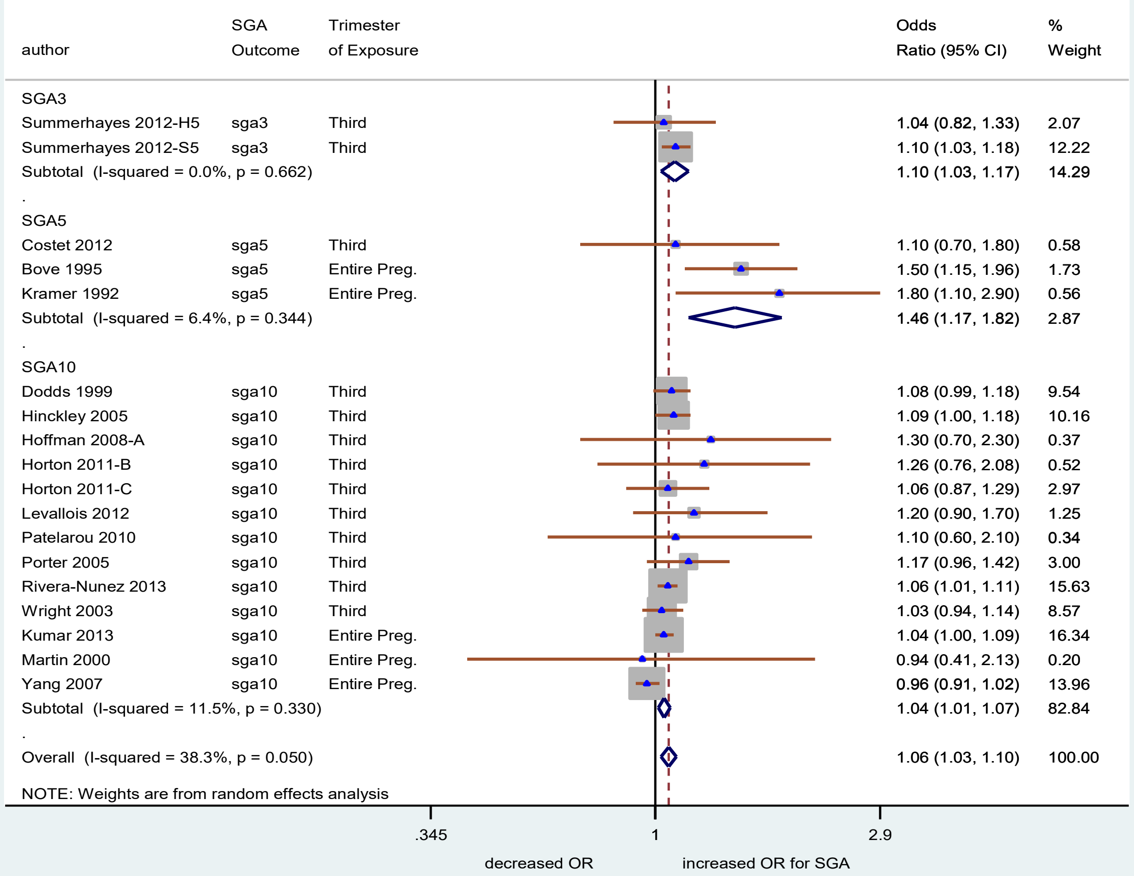
- For Stage 2 D/DBPR, "the reproductive and developmental health effects data did not support a conclusion at that time as to whether exposure to chlorinated drinking water or disinfection byproducts causes adverse developmental or reproductive health effects, but do support a potential health concern ..."
- Stage 2 D/DBPR also found epidemiology studies that pointed to possible adverse reproductive and developmental health effects when using THMs as a surrogate for chlorinated drinking water, These health effects included:
  - Fetal growth (i.e., small for gestational age, low birth rate, and pre-term delivery)
  - Fetal viability (i.e., spontaneous abortion and stillbirth)
  - Fetal malformations (i.e., neural tube, oral cleft, cardiac or urinary defects, and chromosomal abnormalities)

Source: Economic Analysis for the Final Stage 2 Disinfectants and Disinfection Byproducts Rule (2005).

DBP Exposure and Potential Risk for Reproductive and Developmental Effects – Additional Information

- Small for Gestational Age (SGA)
  - Multiple studies have found associations between trihalomethanes and SGA.
  - The indirect DBP exposure assessment was based on mother's residential location.
  - Summerhayes et al. (2021) found a small increased risk of SGA based on 18 THM4 study populations and an increased risk for other THM and HAA measures not previously examined.
- Birth Weight
  - Prospective cohort study found that high water intake may be associated with higher mean birth weight following adjustment for confounding. (Wright et al. 2010)
  - Elevated trihalomethanes were associated with increases in gestational duration and a reduced risk of preterm delivery. (Wright et al., 2004).

THM4 Exposure and Risk for SGA3, SGA5 & SGA10



Source: Summerhayes et al. (2021). Environmental Research. Vol. 196, No. 110280
Wright et al. (2010). BMC Pregnancy and Childbirth. Vol. 10, No. 48
Wright et al. (2004). Environmental Health Perspectives. Vol. 112, No. 8

In vitro Assay: CHO bioassay

- Chinese hamster ovary (CHO) cell assay
  - Over 100 DBPs compared for relative cytotoxicity
  - Has been used to support hazard assessments when used in conjunction with animal dose-response or human exposure studies
  - Relative trends in potency observed for single chemical studies:
    - I>Br>>Cl
    - Nitrogenous > Carbonaceous

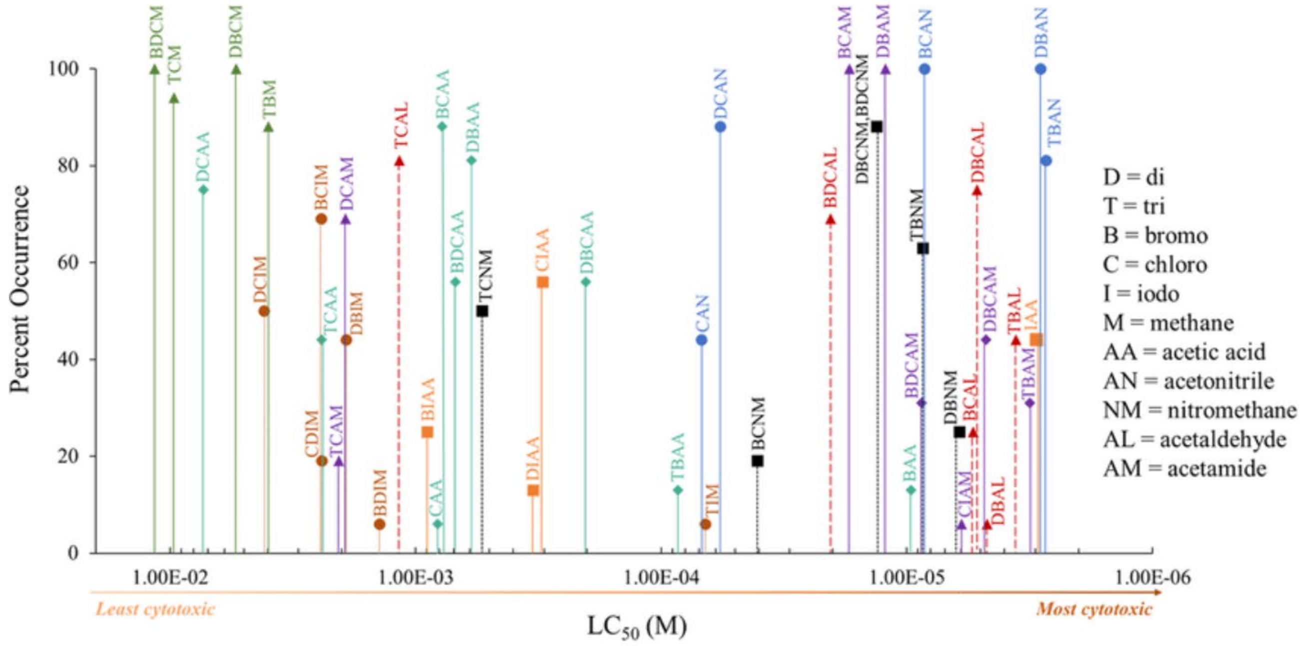


Figure source: Allen et al. "Drivers of disinfection byproduct cytotoxicity in US drinking water: should other DBPs be considered for regulation?." Environmental Science & Technology 56.1 (2021): 392-402.

Casey Lindberg, U.S. EPA OST

History of HAA Health Effects Analyses Under SDWA

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- Three chlorinated and 2 brominated HAAs are currently regulated as a group (HAA5) under Stage 1/2 D/DBPRs
  - MCLGs were derived for the three chlorinated HAAs in HAA5
  - As stated in 2005 Drinking Water Criteria Document for Brominated Acetic Acids, "no adequate studies of suitable design and/or duration were identified to serve as the basis for [quantitative assessments of] monobromoacetic acid, bromochloroacetic acid, or dibromoacetic acid."
- Under Six Year Review 3 (2016), EPA reevaluated the available data for HAA5 and evaluated data for 4 additional unregulated brominated HAAs
  - Unregulated HAAs: bromochloracetic acid (BCAA), bromodichloroacetic acid (BDCAA), dibromochloroacetic acid (DBCAA), and tribromoacetic acid (TBAA)
  - Identified several National Toxicology Program (NTP) bioassays in rodents

Haloacetic Acid (HAA) Species	Status	MCLG (mg/L)
Monochloroacetic acid	Regulated as HAA5 (MCL = 0.060 mg/L)	0.07
Dichloroacetic acid		0
Trichloroacetic acid		0.02
Monobromoacetic acid		--
Dibromoacetic acid		--

- In 2017, EPA initiated a systematic literature review of health effects information for the 4 unregulated brominated HAAs.
  - Goals: Support efforts to evaluate the health effects associated with the four unregulated HAAs and to consider the extent to which available information might support development of an MCLG for one or more of those HAAs.

Sources: Six Year Review 3 Technical Support Document for Disinfectants/Disinfection Byproducts Rules (2016); Drinking Water Criteria Document for Brominated Acetic Acids (2005)

Systematic Literature Reviews of Health Effects Information and MCLG Development: Processes

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Literature Search
- Develop search strategies
- Query databases (e.g., PubMed)
- Search gray literature

Literature Screen
- Develop screening (PECO) criteria
- Screen studies for relevancy at title/abstract and full-text levels
- Identify potentially useful supplemental materials

Study Quality Evaluation
- Evaluate relevant human, animal, and PBPK studies for sensitivity, biases, and other factors
- Assign ratings for confidence in the quality and reliability of the data

Data Extraction and Synthesis
- Collect key information from relevant human and animal studies
- Analyze study results to assess strengths and weaknesses of the databases

Evidence Integration
- Summarize the strength of evidence within each evidence stream (human, animal, mechanistic)
- Make inferences and judgments about the strength of the evidence across evidence streams

- Systematic review process informs final hazard considerations, study selection for quantification of toxicological effects (i.e., development of reference doses [RfDs] and cancer slope factors [CSFs]), and carcinogenicity assessments based on the weight of evidence
- If sufficient data are available, the toxicity values and carcinogenicity assessments may be used to determine the MCLG per SDWA
  - For non-carcinogens and non-linear carcinogens, the MCLG is typically based on the non-cancer RfD
  - For linear carcinogens, the MCLG is set to zero

Source: ORD Staff Handbook for Developing IRIS Assessments (2020); USEPA, 1998 FR 69390-69476; USEPA, 2000 FR 76708-76753; USEPA, 2001 FR 28342

Efforts Underway – Systematic Review of Health Effects Literature on Four Unregulated HAAs

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Literature Search

- Number of unique records identified through database searching: **N = 605**

Literature Screen

- Number of studies identified as relevant after title/ abstract review: **N = 437**
- Number of studies identified as relevant after full-text review: **N = 15**

Study Quality Evaluation

- Number of studies that underwent study quality evaluation:
- **4 human studies**
- **7 animal tox studies**

Data Extraction and Synthesis

- Number of studies that underwent data extraction:
- **1 human study**
- **7 animal tox studies**

Evidence Integration

- Ongoing

Example Visualizations – Study Quality Evaluation and Data Extraction Results

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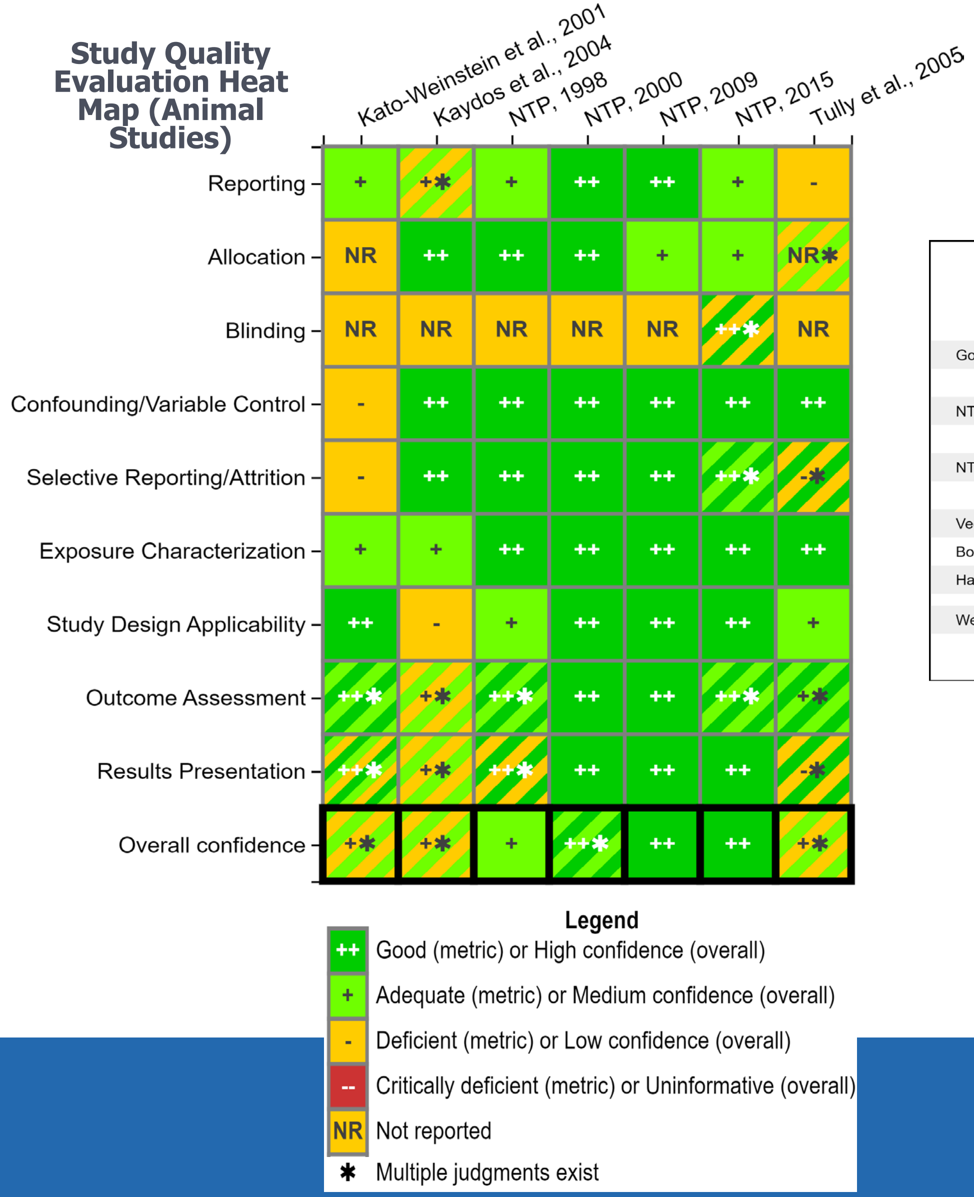

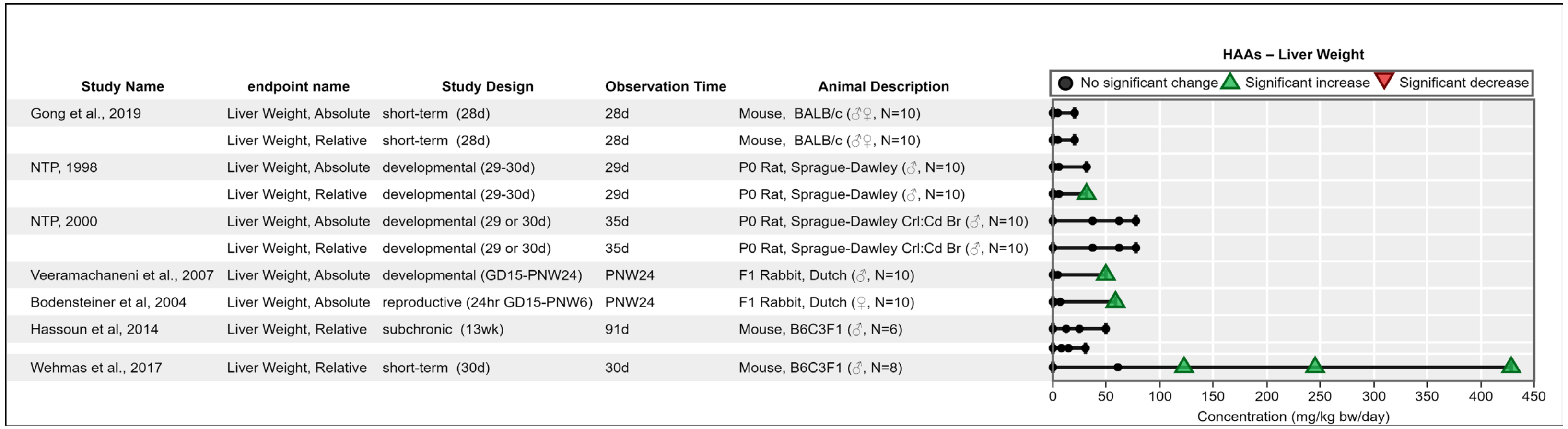

Extracted Data "Pivot"

Visualizations created using EPA's Health Assessment Workspace Collaborative (HAWC)
https://hawc.epa.gov/portal/

Following EPA's *Guidelines for Carcinogen Risk Assessment* to determine cancer classifications

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- NTP concluded that the unregulated brominated HAAs are "reasonably anticipated to be human carcinogens based on sufficient evidence from studies in experimental animals and supporting mechanistic data that demonstrate biological plausibility of its carcinogenicity in humans"
  - Evidence of liver cancer in animals for all 4 unregulated brominated HAAs
- Findings: 2 oral exposure toxicity studies in rodents and 1 epidemiology study that address carcinogenicity of unregulated brominated HAAs in the database
- Ongoing work:
  - Assess carcinogenicity of the unregulated HAAs using EPA's *Guidelines for Carcinogen Risk Assessment* (2005) to evaluate the weight of evidence across epidemiological and animal toxicity studies, as well as mode of action analyses to determine human relevance
  - For contaminants determined to be human carcinogens, SDWA specifies that the MCLG = 0 (unless EPA determines that they are non-linear carcinogens)

Source: Extracted from Report on Carcinogens Monograph on Haloacetic Acids Found as Water Disinfection By-Products, 2021
https://ntp.niehs.nih.gov/ntp/roc/content/profiles/haloacetic_acids.pdf
Guidelines for Carcinogen Risk Assessment (2005)

Additional DBPs: Nitrosamines

- Six nitrosamine compounds were monitored in national drinking water systems between 2008-2010 under the Second Unregulated Contaminant Monitoring Rule (UCMR2).
- EPA classified NDMA as *likely to be carcinogenic to humans by a mutagenic mode of action* under the Guidelines for Carcinogen Risk Assessment, based on evidence for human carcinogenicity in epidemiologic studies and substantial animal data demonstrating carcinogenicity.
- The UCMR2 dataset indicated that approximately 7.5% of public water systems had a mean concentration of NDMA exceeding the health reference level (HRL) of 0.6 ng/L which was derived at the risk level of one cancer case per one million of general population (i.e., 10^{-6} risk level).
- While drinking water is a potential source of exposure, there are other nitrosamine dietary contributors that may account for a greater percentage of exposure.

Source: Six-Year Review 3 Technical Support Document for Nitrosamines (2016)

Additional DBPs: Chlorate and Chlorite

- Chlorate and chlorite form when chlorine dioxide disinfection is used, and chlorate forms when hypochlorite disinfection is used, especially from bulk hypochlorite solutions (after storage) or on-site chlorine generation.
  - Chlorate and chlorite can co-occur in treated water.
  - Under the Stage 1 and 2 D/DBPRs, water systems using chlorine dioxide are required to meet the MCL for chlorite at 1 mg/L.
  - Chlorate was nationally monitored between 2013-2015, under the UCMR3.
- Potential health effects of chlorate (unregulated) and chlorite (regulated):
  - Both may have common health effects (e.g., thyroid effects).
  - Health effects of chlorate include hemolysis and interference of iodine uptake by the thyroid.
- Consideration of relative source contribution for chlorite in drinking water.

Sources: https://www.epa.gov/sites/production/files/2016-12/documents/810r16013.pdf and https://www.epa.gov/sites/production/files/2016-12/documents/810r16012.pdf

OCCURRENCE OF REGULATED AND UNREGULATED DBPS IN DRINKING WATER – INCLUDES UCMR4 DATA FOR HAA9 AND SYR4 DATA FOR THM4

Stuart Krasner, Metropolitan Water District Of Southern California (Retired)

Inventory Information Relevant to DBP Occurrence

- An estimated 87% of all community public water systems (CWSs) in U.S. were disinfecting in 2019, serving ~ 310 million people.
  - Representing ~94% of national total population (328 millions) in 2019 that were impacted by the D/DBP rules.
- An estimated 24% and 14% of 310 million people were served by partially and 100% purchased water, respectively.
  - Purchased water is delivered by consecutive systems.
- An estimated 83% of all disinfecting CWSs delivered chlorinated water, serving ~ 200 million people; 17% delivered chloraminated water, serving ~ 110 million people.

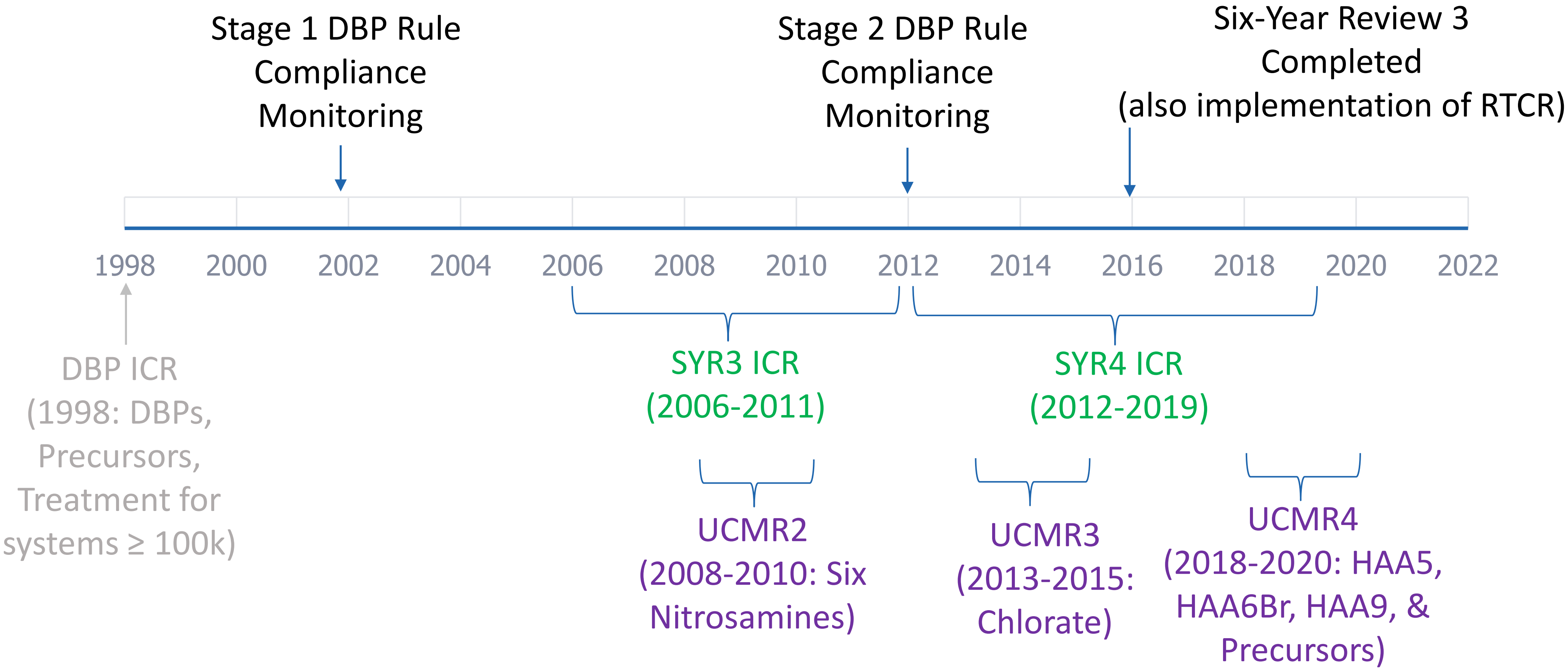
Data sources: Based on the data records from 2019 SDWIS, UCMR4, and SYR4 ICR.

Acronyms: SDWIS: Safe Drinking Water Information System

DBP Occurrence-related Information

- Timeline of national datasets relevant to DBP occurrence information
- Occurrence and co-occurrence of haloacetic acid groups and THM groups
- Temporal variations
- Precursor occurrence and effects on DBP occurrence
- Effects of water quality entering distribution system

Timeline of National M/DBP Datasets



Acronyms:

RTCR: Revised Total Coliform Rule; DBP ICR: Disinfection Byproducts Information Collection Rule ; SYR3 ICR: Information Collection Request for Third Six-Year Review; SYR4 ICR: Information Collection Request for Fourth Six-Year Review; UCMR4: Fourth Round Unregulated Contaminant Monitor Rule.

Issue Area: Regulated vs Unregulated DBP Occurrence & Co-Occurrence

Relevant Requests from Working Group:

1. Occurrence data on the prevalence of unregulated DBPs in distribution systems is a priority (e.g., unregulated HAAs, NDMA, and chlorate).
2. Occurrence information should be gathered, and consideration given to expanding regulation to other DBPs, including HAA9 (including brominated compounds) and DBPs formed by chloramination.
3. Co-occurrence data on DBP mixtures in distribution systems as function of source water quality and treatment (including disinfection practices) is a priority.

Supporting Analysis:

1) Co-occurrence of HAA9 vs HAA6Br with UCMR4.
2) Assessment of contribution from HAA6Br to high levels of HAA9 (w/ HAA6Br/HAA9 ratios).
3) Co-occurrence of THM4 vs HAA9 with UCMR4 and SYR4 ICR

Acronyms:

HAAs: Haloacetic acids; NDMA: N-nitrosodimethylamine, one of nitrosamine compounds; Sum of nine HAA species; HAA6Br: Sum of six brominated HAA species; THM4: Sum of four trihalomethane species; THM3Br: Sum of three brominated trihalomethane species;

DBP Occurrence-related Information – Major Observations

- Co-occurrence of HAA9 and HAA6Br appear to be independent of system size and disinfectant residual type used.
- Among systems in compliance with the existing HAA5 MCL (60 µg/L), ~ 2% of systems had HAA9 > 60 µg/L. In most cases of high HAA9 levels, HAA6Br was not a major contributor.
- High bromide levels in source water contribute to high levels of HAA6Br, but not necessarily to high HAA9 where the three chlorinated HAAs are the major driver of elevated HAA9.

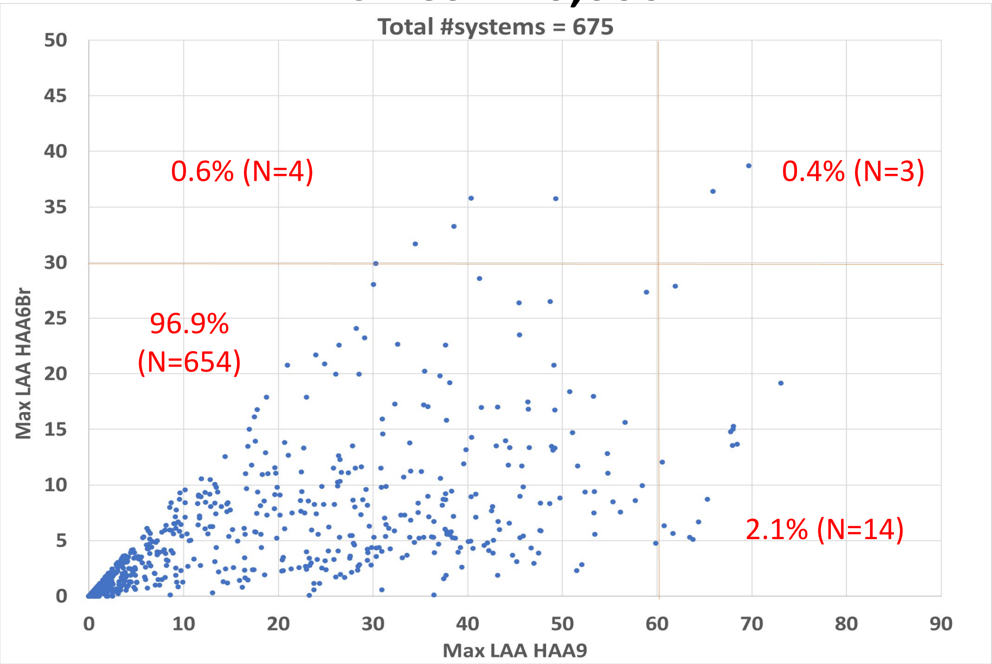
*Cutoffs are for illustration only and are not suggestive of potential regulatory limits. HAA5 was regulated at 60 ug/L based on what was determined to be technically and economically feasible.

Co-Occurrence of HAA9 vs HAA6Br by System Size

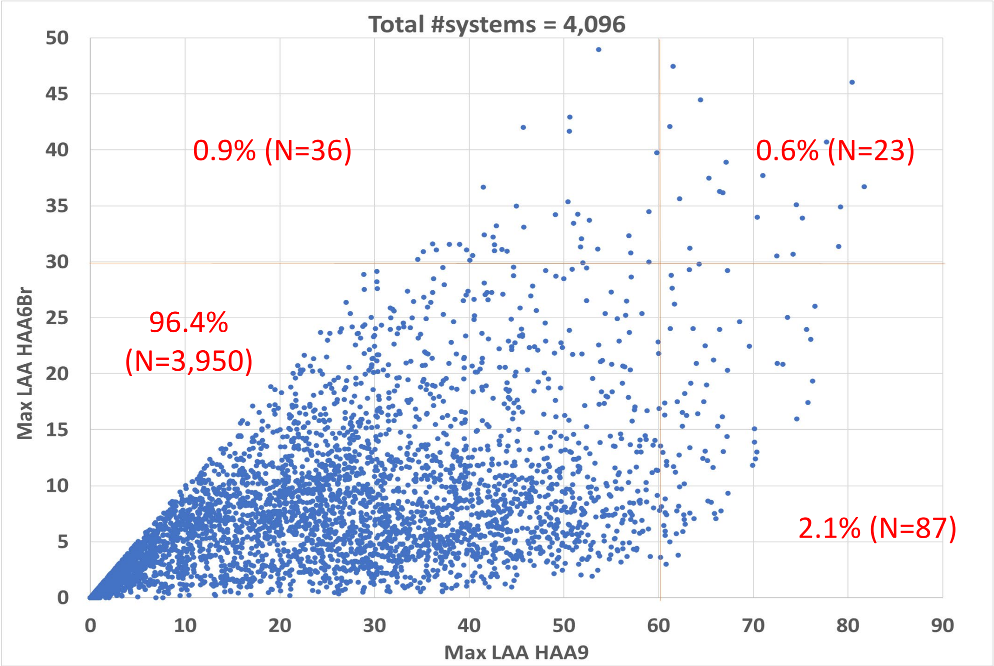
Observations:

- Co-occurrence appears to be independent of system size.
- Over 96% of measurements are below combined thresholds of 30 ug/L Maximum HAA6Br and 60 ug/L Maximum HAA9.

CWSs < 10,000



CWSs ≥ 10,000

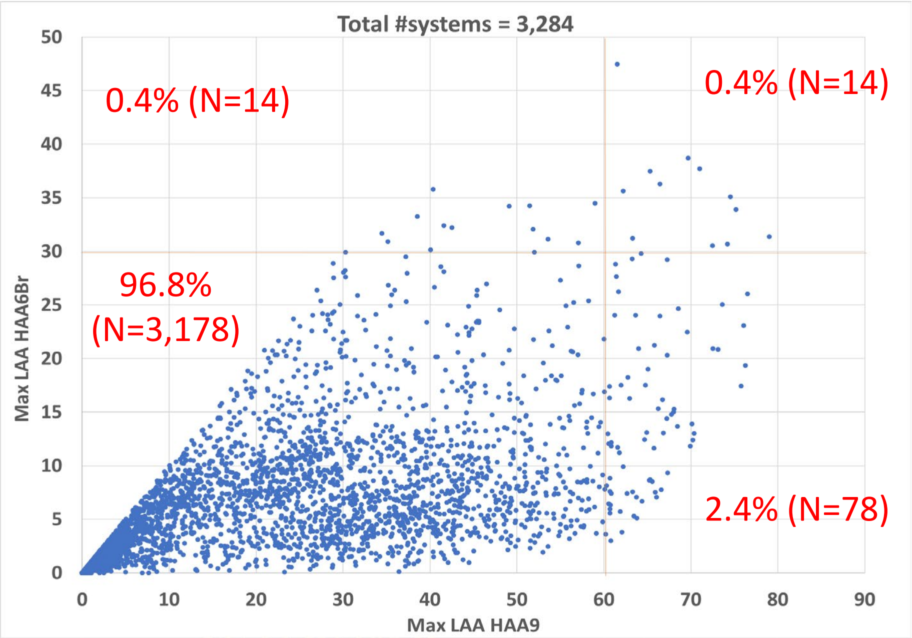


*Cutoffs are for illustration only and are not suggestive of potential regulatory limits. HAA5 was regulated at 60 ug/L based on what was determined to be technically and economically feasible.

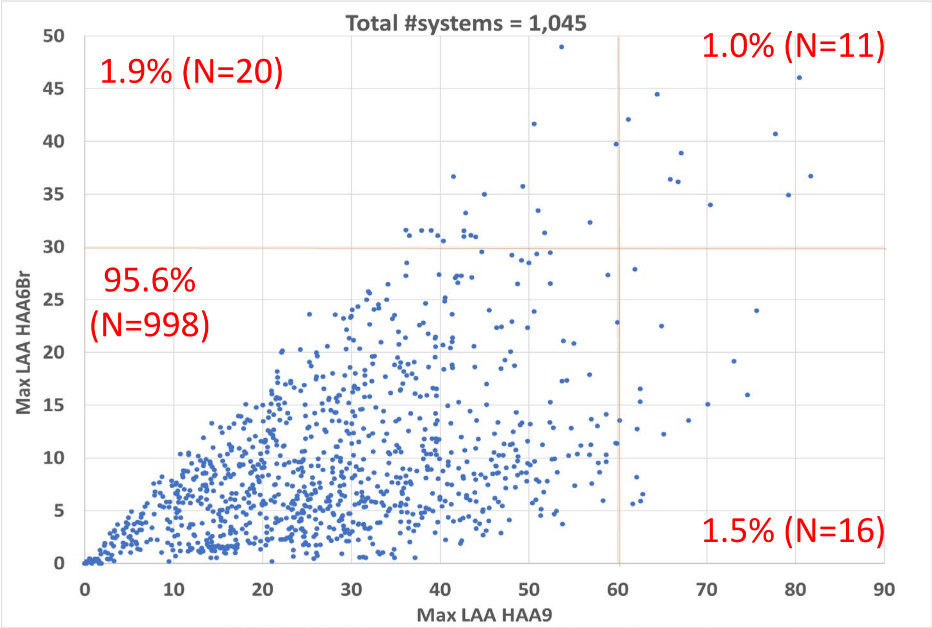
Co-Occurrence of HAA9 vs HAA6Br by Disinfectant Residual Type

Observations:
- Co-occurrence appears to be independent of disinfectant residual type.
- Caveat to co-occurrence results: chloraminating systems typically treat source waters with higher TOC and bromide than do chlorinating systems.

CWSs with Chlorine



CWSs with Chloramine

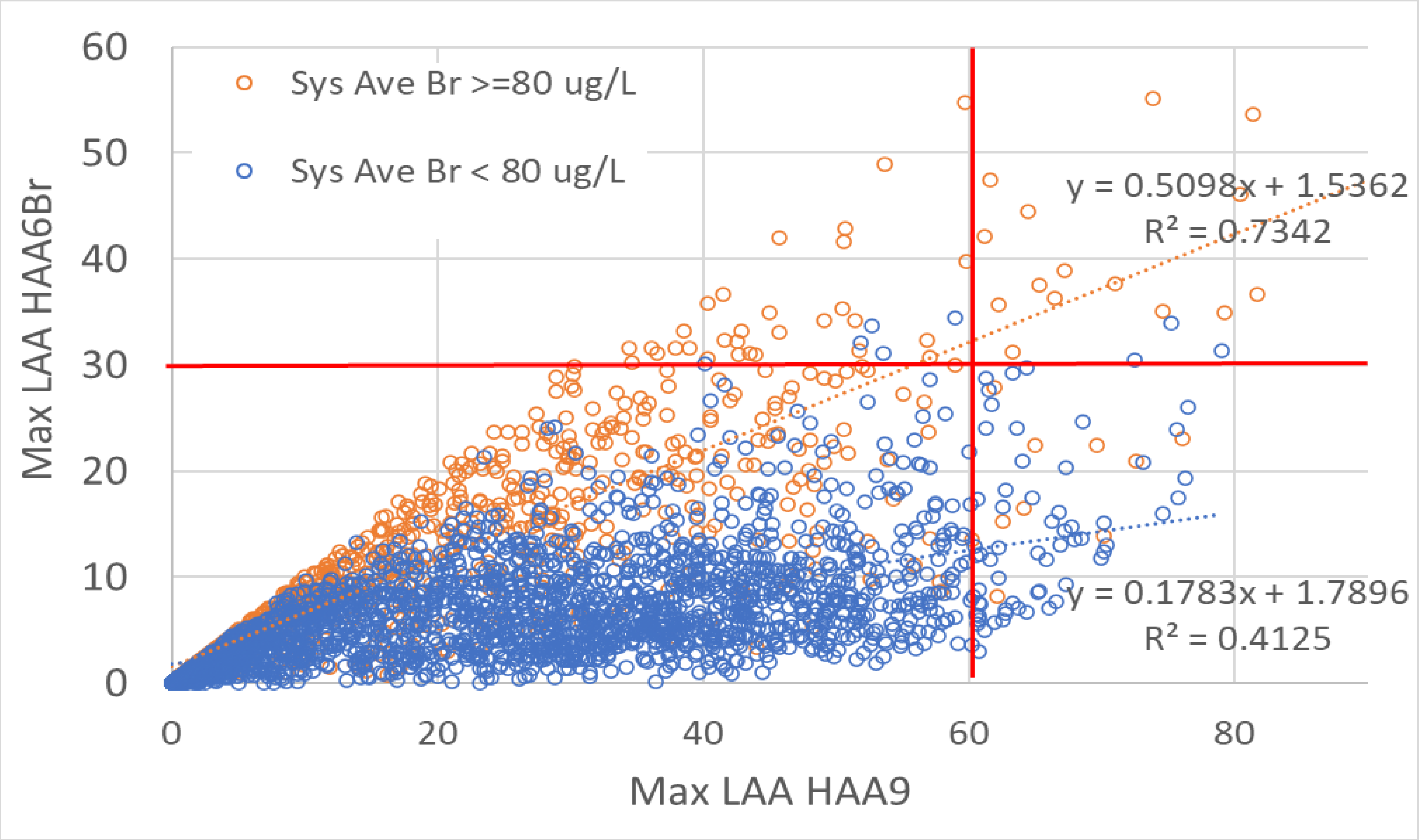


*Cutoffs are for illustration only and are not suggestive of potential regulatory limits. HAA5 was regulated at 60 ug/L based on what was determined to be technically and economically feasible.

Co-Occurrence of HAA9 vs HAA6Br by Bromide Level in Source Water

Observation:

- HAA6Br vs HAA9 trend line has greater slope for high Br- waters.

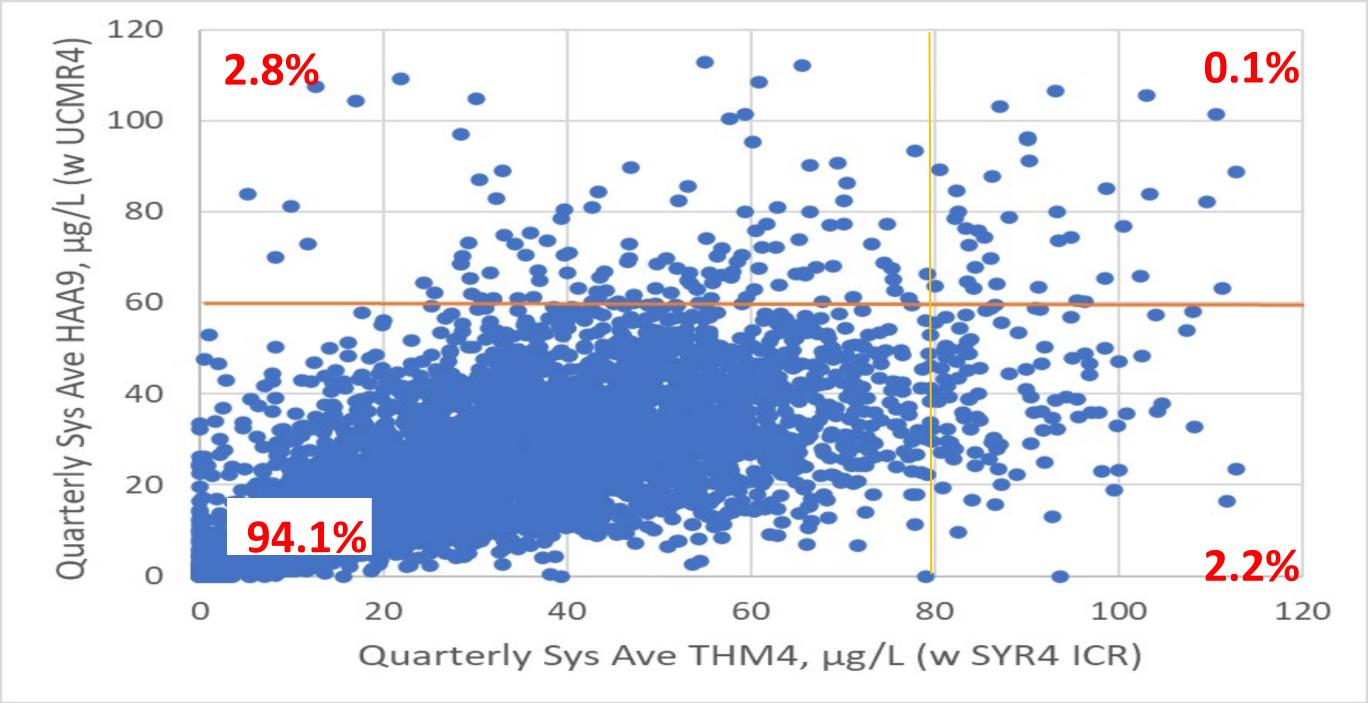


*Cutoffs are for illustration only and are not suggestive of potential regulatory limits. HAA5 was regulated at 60 ug/L based on what was determined to be technically and economically feasible.

Co-occurrence between THM4 vs HAA9
(N = 8,391)

Observations:

- No close relationship observed between THM4 and HAA9 occurrence, however this is not unexpected since these DBPs have different precursors.
- Historically EPA has looked at reliably complying with a 20% safety factor (i.e., 64 ug/L THM4).



*Cutoffs are for illustration only and are not suggestive of potential regulatory limits. HAA5 was regulated at 60 ug/L based on what was determined to be technically and economically feasible.

Jimmy Chen, U.S.EPA OGWDW

Issue Area: Change in DBPs over Time

Relevant Requests from Working Group:

1) Summarize the availability of data from the NCOD, industry surveys or other datasets. Provide trend analysis of microbial, disinfection byproduct, and DBP precursor levels.
2) Reexamine Treatment Technique requirements for TOC to ascertain effectiveness in avoiding DBP formation.

Supporting Analysis:

1) Yearly trends of THMs/HAA5 levels before and after implementation of Stage 2 D/DBPR and RTCR. Yearly trend of TOC included in Appendix.

Acronyms: NCOD: National Contaminants Occurrence Database; TOC: Total Organic Compound

DBP Temporal Trend Analyses – Major Observations

- During past 10 years of implementation of Stage 2 (and RTCR), the following temporal trends were observed:
  - Decreased levels of THMs/HAA5 (including THM3Br), particularly among systems with high DBP levels (as disinfectant residual levels were increased – shown from Meeting #2).
  - Slightly increased TOC removal and slightly decreased finished water TOC levels.
  - Increased use of chloramine (6%) and advanced disinfectants, such as ozone, UV, and chlorine dioxide (160%).
- Some large systems may have made changes related to DBP control prior to the 10-year period addressed by the available data. In particular, some large systems may have made changes when the Stage 1 rule was proposed in the early 1990s and thus are not captured in this temporal analysis. Similarly, temporal variations for small systems would likely be more pronounced in this 10-year period.

THM4, THM3Br, and HAA5 Concentrations among Community Surface Water Systems

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Observations

1. There was a 4-7% reduction of DBP levels among large systems, and an 8-10% reduction among small systems at the 90th percentile.*
2. Caveat to results: reductions in large systems may have been less after Stage 2 because many of those systems implemented treatment changes in anticipation during Stage 1 of the D/DBPRs.

System Size	Systems ≥ 10k				Systems < 10k			
Time Period	2009-2011	2013-2015	2017-2019		2009-2011	2013-2015	2017-2019	
Regulatory Period	Before Stage 2 DBPR	After Stage 2 DBPR & before RTCR*	After RTCR	%Reduction from 2009-2011 to 2017-2019	Before Stage 2 DBPR	After Stage 2 DBPR & before RTCR*	After RTCR	%Reduction from 2009-2011 to 2017-2019
Mean and (90th percentile) of Sys Avg THM4 (N=2,397)	30 (57)	31 (56)	30 (53)	0.4% (7.2%)	41 (73)	39 (70)	38 (66)	8.2% (9.0%)
Mean and (90th percentile) of Sys Avg THM3Br (N=1,218)	12 (27)	13 (28)	12 (25)	1.4% (5.6%)	16 (38)	16 (38)	14 (34)	8.1% (10.1%)
Mean and (90th percentile) of Sys Avg HAA5 (N=2,258)	16 (35)	16 (35)	16 (34)	-1.5% (3.6%)	21 (44)	21 (42)	20 (41)	4.9% (7.6%)

Changes of Disinfectant Types Used after Implementation of Stage 2 D/DBPR

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Observation:

- After implementation of Stage 2 DBPR (& RTCR), there were 6% increase in use of chloramines and more than double the use of other disinfectants.
  - Such changes could inform NDMA exposure characterization from 2008-2010 to 2018-2020. Similar analysis can be done for chlorate (w UCMR3).

Common Systems = 648	Chlorine only	Chloramine only	Chlorine w Others**	Chloramine w Others**	Others Only**	All w Chlorine	All w Chloramine	All w Others**
UCMR2 (2008-2010) **(Before Stage 2 DBPR)**	63%	26%	2%	7%	1%	65%	33%	10%
UCMR4 (2018-2020) **(After Stage 2 DBPR & RTCR)**	47%	17%	16%	18%	1%	63%	35%	35%

* ttps://www.epa.gov/dwsixyearreview/support-documents-epas-third-review-existing-drinking-water-standards

** Others may include O3, ClO2, or UV

Overall Summary of DBP Occurrence

- Multiple datasets enable the following understandings at a national level:
  - Number of systems and associated population affected by DBP rules
  - Occurrence and co-occurrence of regulated and unregulated DBPs, along with occurrence of DBP precursors in source water.
  - Yearly trend of MDBP-related water quality along with changes on disinfectant types used after implementation of Stage 2 DBP rule (& RTCR).
  - Factors affecting DBP occurrence/co-occurrence, particularly TOC and Br levels in source water, and TOC levels in finished water.
- Related literature can be analyzed to help develop further understanding of DBP occurrence/co-occurrence (including those for iodinated DBPs).

OCCURRENCE OF DBP PRECURSORS IN DRINKING WATER – IN RAW WATER PLUS TOC IN TREATED WATER

Stuart Krasner, Metropolitan Water District Of Southern California (Retired)

Disclaimer – Materials Not Developed or Provided by EPA

The following nine slides were developed by Stuart Krasner, who is not employed by EPA. The content of these slides do not necessarily reflect EPA policies or positions.

Overview of Factors Affecting DBP Formation

Precursors	Example DBPs Formed	Miscellaneous
Organic Matter		
Natural organic matter	THMs, HAAs	Humic substances
Algal organic matter	Haloacetonitriles (HANs)	Amino acids
Wastewater effluent	Nitrosamines (e.g., NDMA)	Chloramine by-product
Inorganic		
Bromide	Brominated DBPs, bromate	Saltwater, connate water, oil field brines
Iodide	Iodinated DBPs	Chloramine by-product
Anthropogenic		
Certain pharmaceuticals	NDMA	Chloramine by-product
X-ray contrast agents	Iodinated DBPs	Chloramine by-product

Overview of Factors Affecting DBP Formation

- Formation of DBPs occurs during treatment and distribution after application of chemical disinfectants (~ 700 DBPs have been identified).
- Multiple factors affecting formation of DBPs:
    - DBP precursor types and levels (including biofilm and microbial by-products).
    - Disinfectant types/doses and application points.
        - Contact time or residence time.
        - Switching from chlorine to chloramines effective for controlling THMs and HAAs, but may lead to formation of other DBPs.
            - Use of strong pre-oxidant (e.g., chlorine, ozone) can minimize formation of NDMA and iodinated DBPs.
    - Water chemistry (including temperature and pH).
- In chemically disinfected water systems, source water quality, treatment operation, and distribution system management practices collectively affect site-specific conditions for formation of DBPs.

Specific Factors Affecting Formation of DBPs

Chlorine-Related DBPs (e.g., THMs, HAAs):

- Chlorine application locations and doses (e.g., plant influent vs before or after filtration [before or after TOC removal]).
- In presence of bromide, brominated THMs (Symons et al., 1993) and HAAs can be formed.
  - Also forms brominated emerging DBPs (Krasner et al., 2022).
- Chlorine forms used (e.g., liquid bleach vs gaseous chlorine).
  - Storage of liquid chlorine and on-site generation of chlorine can lead to elevated levels of chlorate (factors include storage duration and temperature, etc.) (Gordon et al., 1995).
  - Liquid chlorine contains bromate (Stanford et al., 2013).

Chlorine Dioxide-Related DBPs: (i.e., chlorite, chlorate) (by-products from decomposition) (Aieta & Berg, 1986).

Ozone-Related DBPs: Bromate (formed from bromide) (Krasner et al. 1993).

- AOC (van der Kooij et al., 1982), which can result in regrowth in distribution system (however, can be removed with biofiltration).

Specific Factors Affecting Formation of DBPs

Chloramine-Related DBPs (e.g., Nitrosamines, Iodinated DBPs):

- Chloramines are generally formed with sequential applications of chlorine and ammonia.
- Wastewater effluent organic matter (Krasner et al., 2009) and certain pharmaceuticals (Shen & Andrews, 2011) in source waters, some polymers used for enhanced coagulation (e.g., polyDADMAC) (Park et al., 2009), and some resins (Flowers & Singer, 2013) can be precursors for nitrosamines.
- Iodide (Jones et al., 2011) and organic iodine (X-ray contrast agents [Duirk et al., 2011]) can be precursors of iodinated DBPs.
- Pre-oxidation with chlorine or ozone before addition of chloramines may significantly reduce formation of nitrosamines (Krasner et al., 2018) or iodinated DBPs (Krasner, 2011) (however, forms THMs, HAAs or bromate [Shah et al., 2012]).

Issue Area: Precursor Occurrence and Their Effects on DBP Occurrence

Related Requests:

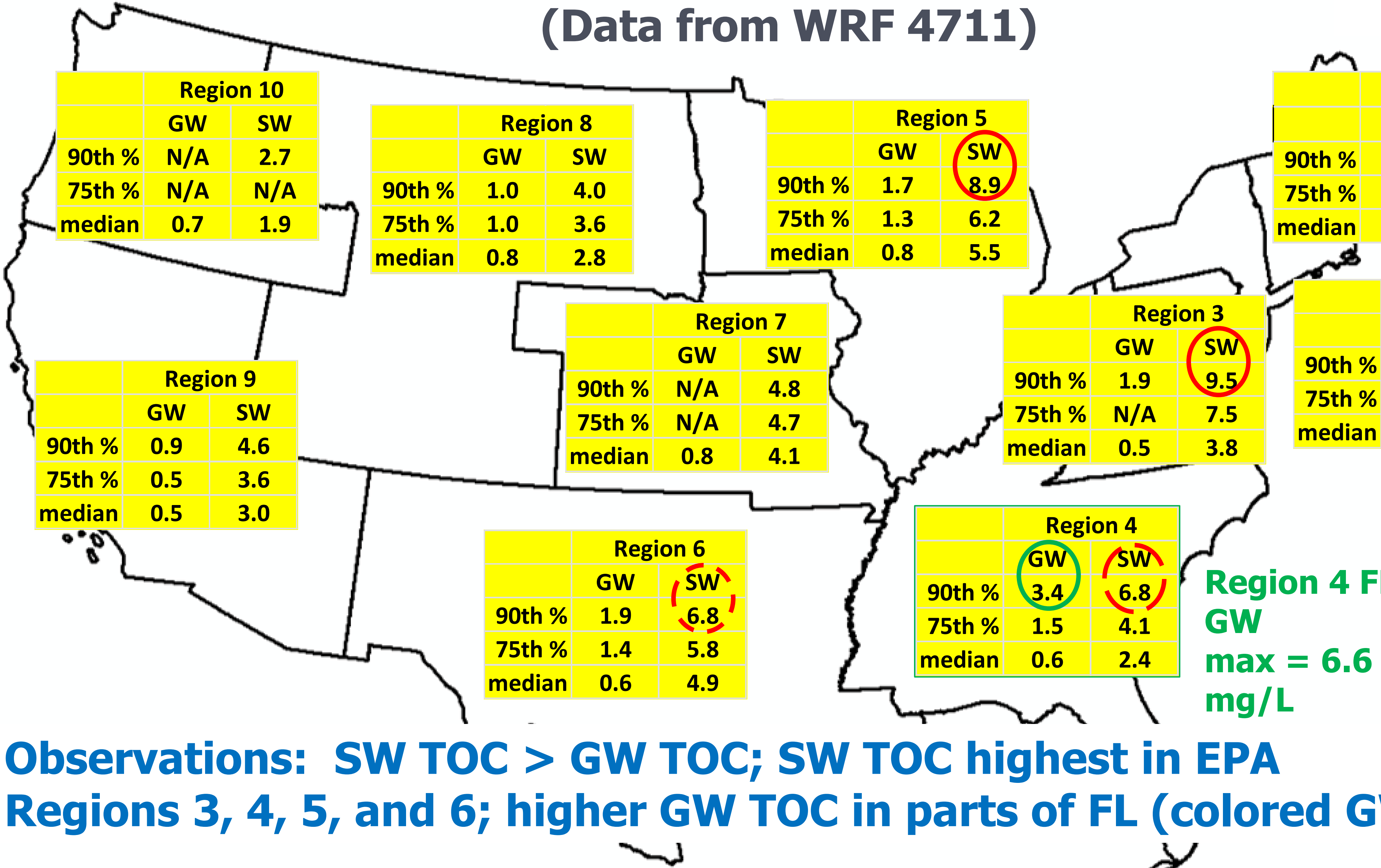
1. How well can we measure/characterize precursors across system types and throughout the country?

Supporting Analysis:

1) Characterizing occurrence of source water Br and TOC by system size and source water type.

Geographical Distribution of TOC (mg/L) in Continental U.S

(Data from WRF 4711)



	Region 10	
	GW	SW
90th %	N/A	2.7
75th %	N/A	N/A
median	0.7	1.9

	Region 8	
	GW	SW
90th %	1.0	4.0
75th %	1.0	3.6
median	0.8	2.8

	Region 5	
	GW	SW
90th %	1.7	8.9
75th %	1.3	6.2
median	0.8	5.5

	Region 1	
	GW	SW
90th %	1.3	4.4
75th %	0.7	3.5
median	0.6	3.4

	Region 7	
	GW	SW
90th %	N/A	4.8
75th %	N/A	4.7
median	0.8	4.1

	Region 3	
	GW	SW
90th %	1.9	9.5
75th %	N/A	7.5
median	0.5	3.8

	Region 2	
	GW	SW
90th %	0.6	3.8
75th %	0.5	3.0
median	0.5	2.5

	Region 9	
	GW	SW
90th %	0.9	4.6
75th %	0.5	3.6
median	0.5	3.0

	Region 6	
	GW	SW
90th %	1.9	6.8
75th %	1.4	5.8
median	0.6	4.9

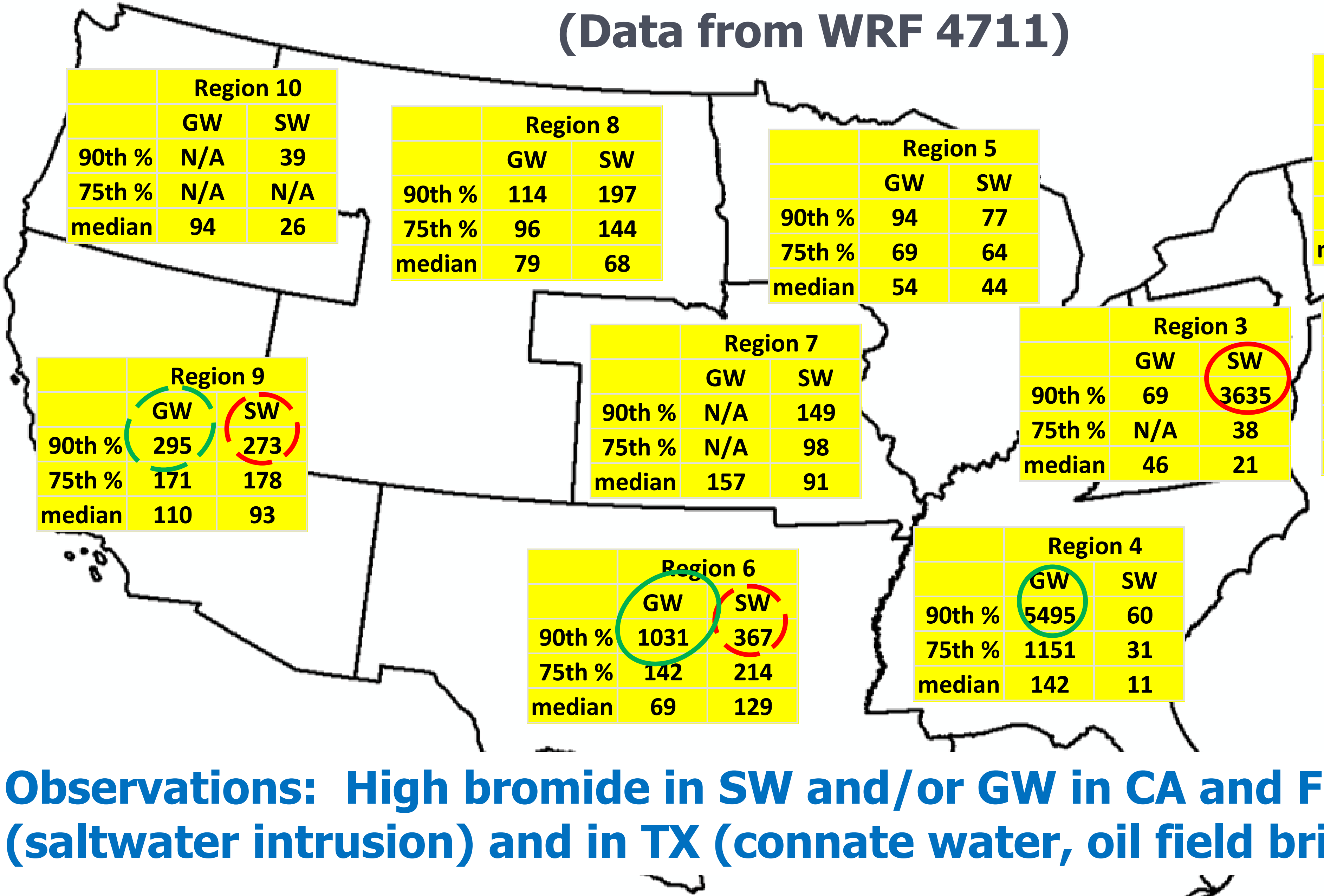
	Region 4	
	GW	SW
90th %	3.4	6.8
75th %	1.5	4.1
median	0.6	2.4

Region 4 FL GW max = 6.6 mg/L

Observations: SW TOC > GW TOC; SW TOC highest in EPA Regions 3, 4, 5, and 6; higher GW TOC in parts of FL (colored GW)

Geographical Distribution of Bromide (µg/L) in Continental U.S.

(Data from WRF 4711)



	Bromide	
	Region 1	
	GW	SW
90th %	106	342
75th %	64	76
median	57	75

	Region 2	
	GW	SW
90th %	129	75
75th %	65	59
median	54	44

	Region 3	
	GW	SW
90th %	69	3635
75th %	N/A	38
median	46	21

	Region 4	
	GW	SW
90th %	5495	60
75th %	1151	31
median	142	11

	Region 5	
	GW	SW
90th %	94	77
75th %	69	64
median	54	44

	Region 6	
	GW	SW
90th %	1031	367
75th %	142	214
median	69	129

	Region 7	
	GW	SW
90th %	N/A	149
75th %	N/A	98
median	157	91

	Region 8	
	GW	SW
90th %	114	197
75th %	96	144
median	79	68

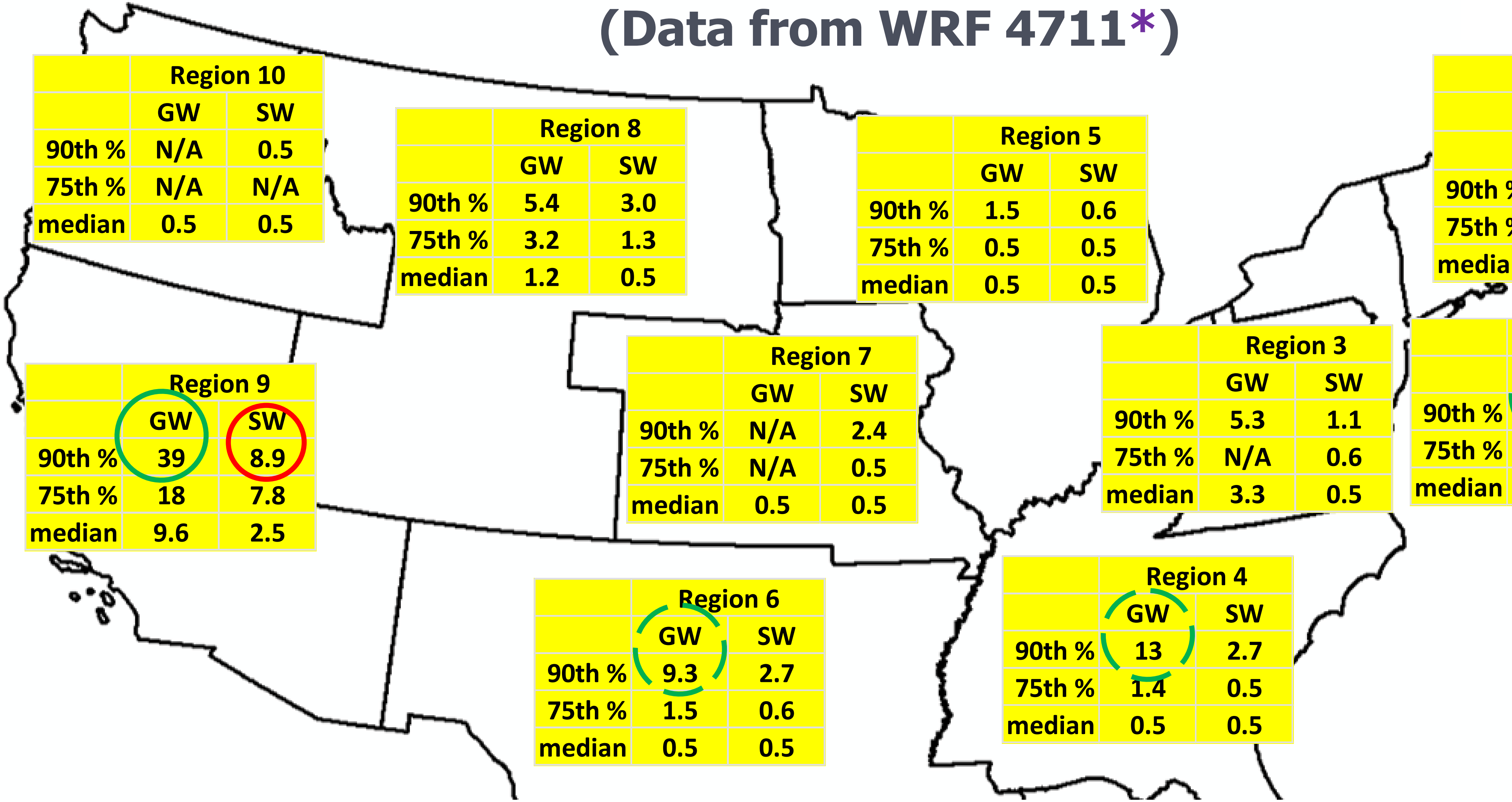
	Region 9	
	GW	SW
90th %	295	273
75th %	171	178
median	110	93

	Region 10	
	GW	SW
90th %	N/A	39
75th %	N/A	N/A
median	94	26

Observations: High bromide in SW and/or GW in CA and FL (saltwater intrusion) and in TX (connate water, oil field brines)

Geographical Distribution of Iodide (μg/L) in Continental U.S.

(Data from WRF 4711*)



	Region 10	
	GW	SW
90th %	N/A	0.5
75th %	N/A	N/A
median	0.5	0.5

	Region 8	
	GW	SW
90th %	5.4	3.0
75th %	3.2	1.3
median	1.2	0.5

	Region 5	
	GW	SW
90th %	1.5	0.6
75th %	0.5	0.5
median	0.5	0.5

	Iodide	
	Region 1	
	GW	SW
90th %	3.7	0.5
75th %	2.7	0.5
median	1.8	0.5

	Region 9	
	GW	SW
90th %	39	8.9
75th %	18	7.8
median	9.6	2.5

	Region 7	
	GW	SW
90th %	N/A	2.4
75th %	N/A	0.5
median	0.5	0.5

	Region 3	
	GW	SW
90th %	5.3	1.1
75th %	N/A	0.6
median	3.3	0.5

	Region 2	
	GW	SW
90th %	8.9	4.0
75th %	1.2	2.8
median	0.5	0.5

	Region 6	
	GW	SW
90th %	9.3	2.7
75th %	1.5	0.6
median	0.5	0.5

	Region 4	
	GW	SW
90th %	13	2.7
75th %	1.4	0.5
median	0.5	0.5

Observations: High iodide in SW and/or GW in CA, FL, and TX

***Organic iodine also found in certain waters (Westerhoff et al., 2022)**

Working Group Question Related to Chloroform Regulation

- Possibly look at establishing an MCL for chloroform separate of the DBP grouping. What is the relevant risk data? May be able to add additional THMs to the group for monitoring while also lowering the group standard.
- Response: A MCL goal (MCLG) is the level of a contaminant in drinking water below which there is no known or expected health risk to humans. If there was a separate MCL for chloroform--assuming the MCLG were to remain unchanged--the MCL would be 0.070 mg/L (70 µg/L) or higher.
- Chloroform is regulated with the other 3 THMs at 80 µg/L for the sum of the 4. In low-bromide waters, chloroform is ~80-90% of the sum. Chloroform would be less than 64-72 µg/L in low-bromide waters that comply with the MCL. A separate MCL for chloroform would not result in a lower chloroform level in drinking water.

	MCLG--mg/L (µg/L)	MCL—mg/L (µg/L)
Chloroform	0.07 (70)	
Bromodichloromethane	0 (0)	
Dibromochloromethane	0.06 (60)	
Bromoform	0 (0)	
Total Trihalomethanes		0.080 (80)

CONCERNS ABOUT COMPLIANCE WITH CURRENT DBP REGULATIONS INCLUDING CONSECUTIVE SYSTEMS – INCLUDES RESULTS FROM DEEP DIVE

Jimmy Chen, U.S.EPA OGWDW

Compliance with Current DBP Regulations: Overview

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- Per the request of the working group, we have gathered information about compliance with current DBP regulations. This information includes:
  - EPA compliance monitoring data.
  - “In-Depth” analysis of D/DBPRs.
  - State-specific compliance experience.

EPA Compliance Monitoring Data – D/DBPRs

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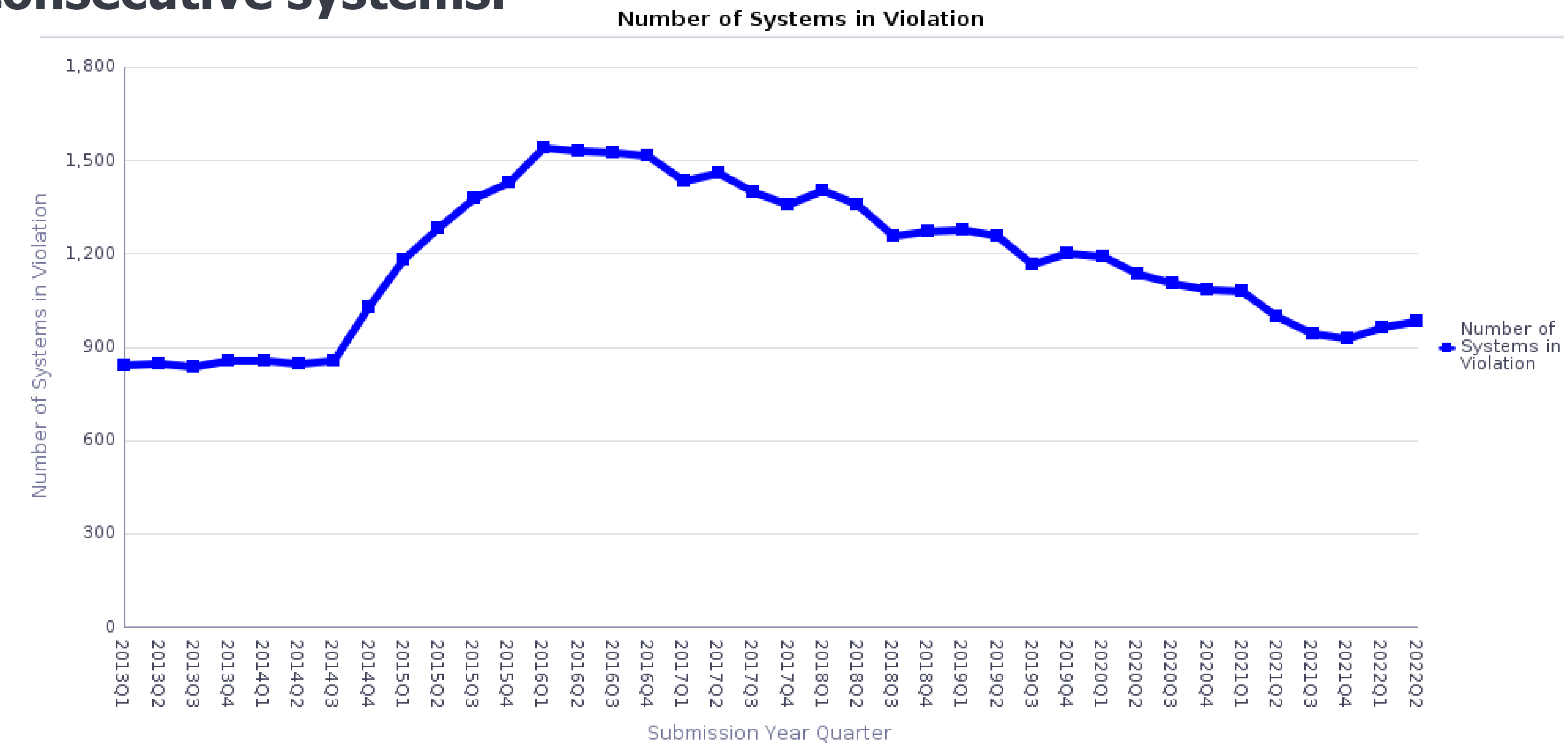
- The Safe Drinking Water Act requires states to report drinking water information periodically to EPA and this information is maintained in the Safe Drinking Water Information System (SDWIS) Fed Data Warehouse.
- SDWIS includes basic information about each public water system including system name and ID number; violation data; and enforcement information.
- Over the past 6 years, the number of systems in violation have been decreasing.
- For FY 2021 (Compliance Period Date), SDWIS reported approximately 3,000 health-based violations of the D/DBPRs for CWSs comprising the following approximate number of violations:
  - MCL: 2,641;
  - Treatment technique: 264; and
  - MRDL: 22.

EPA Compliance Monitoring Data – D/DBPRs

Observation: Number of systems in violation have been decreasing since a peak in early 2016. Data cover both consecutive and non-consecutive systems.



Source: SDWIS. Criteria: PWS_TYPE_CODE is equal to CWS, NTNCWS, TNCWS; and PWS_TYPE_CODE is equal to CWS; and RULE_CODE is not equal to / is not in 500; and NPM_CANDIDATE is equal to / is in Y; and VIOLATION_CATEGORY_DESCRIPTION is equal to Maximum Contaminant Level Violation, Treatment Technique Violation; and RULE_CODE_NAME is equal to Stage 1 Disinfectants and Disinfection Byproducts Rule, Stage 2 Disinfectants and Disinfection Byproducts Rule.

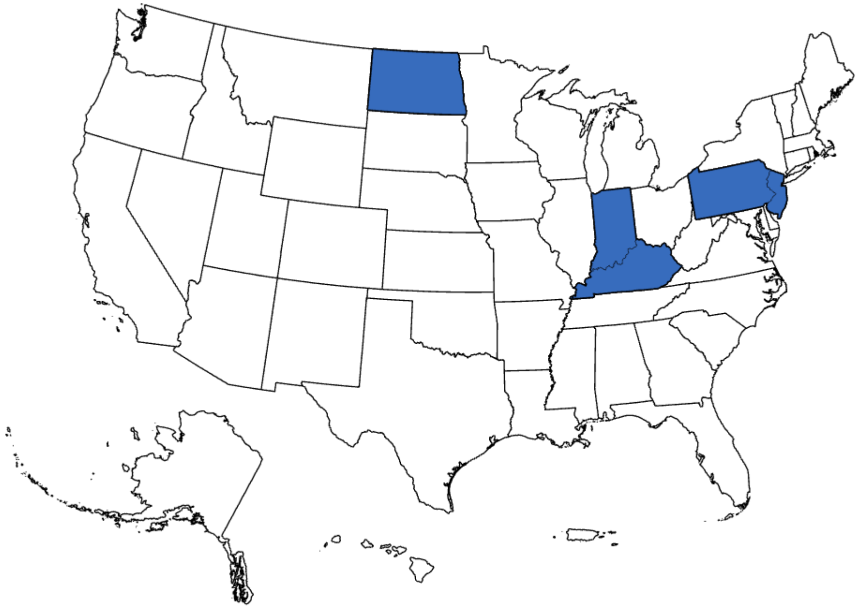
Stage 2 Disinfectants and Disinfection Byproducts Rule and Consecutive Systems In-Depth Analysis: Overview

- Consecutive systems and their challenges
- Evaluation of health-based violations

Source: Final Report: Stage 2 DBPR and Consecutive System In-Depth Analysis; July 2019; EPA 815-R-19-001.
https://www.epa.gov/dwreginfo/diving-regulations#report

EPA's Approach for In-Depth Analysis

- Identified challenges with the Stage 2 D/DBPR in consecutive systems
- Conducted a national data analysis
- Site visits to state partners
  - Indiana
  - Kentucky
  - New Jersey
  - North Dakota
  - Pennsylvania



- Additional input from other states provided through ASDWA
- Final report on lessons learned and best practices

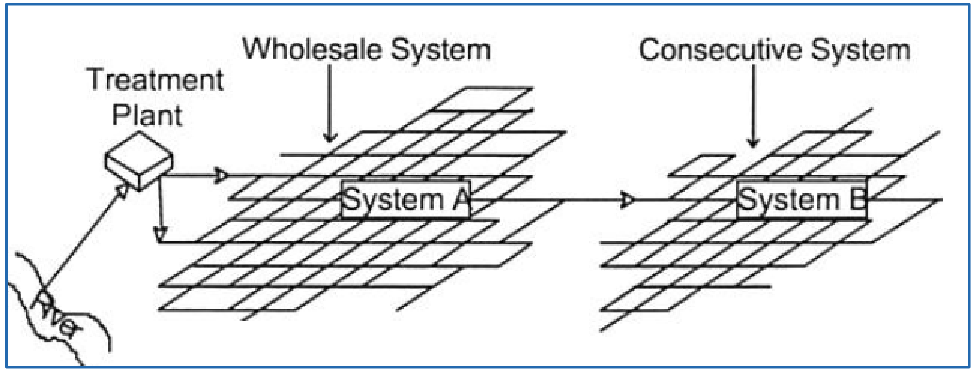
Identifying Consecutive Systems

- **Consecutive CWS:** A CWS that receives some or all of its finished water from one or more wholesaler systems

- Identified using facilities report in SDWIS/Fed

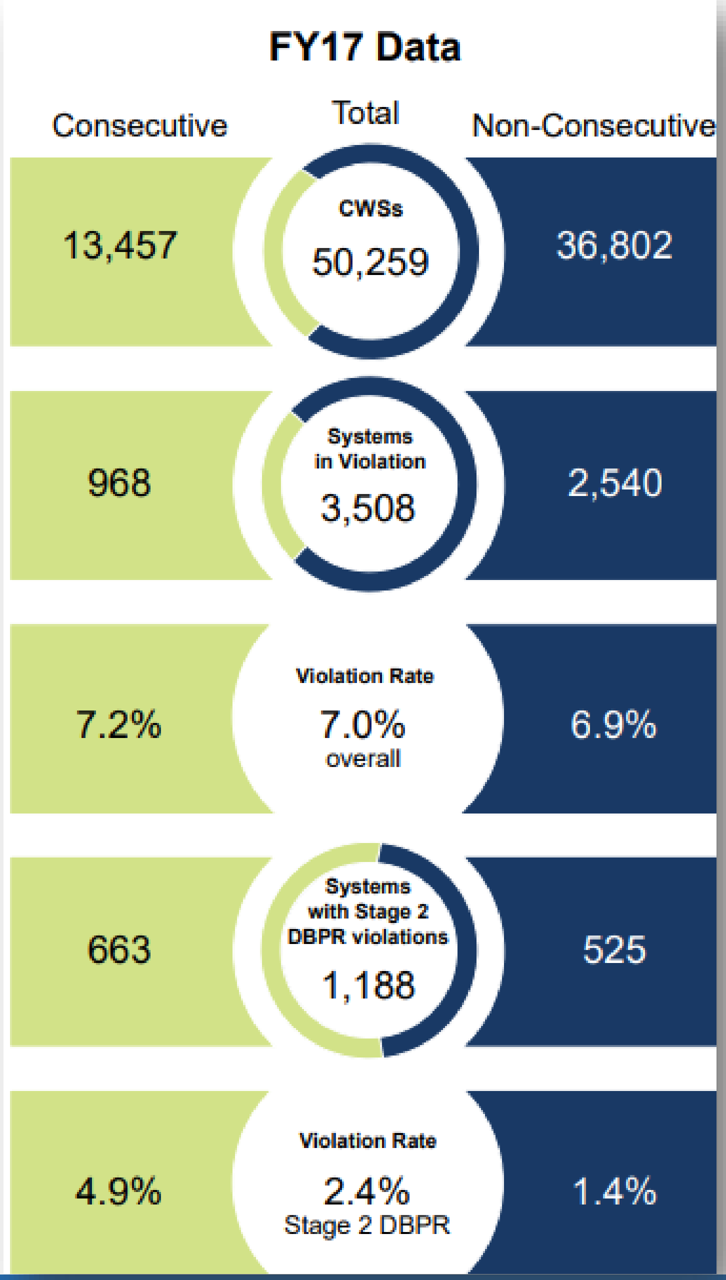
- Excluded emergency connections

- ~13,500 consecutive systems nationwide (~27%)



Identifying Consecutive System Challenge

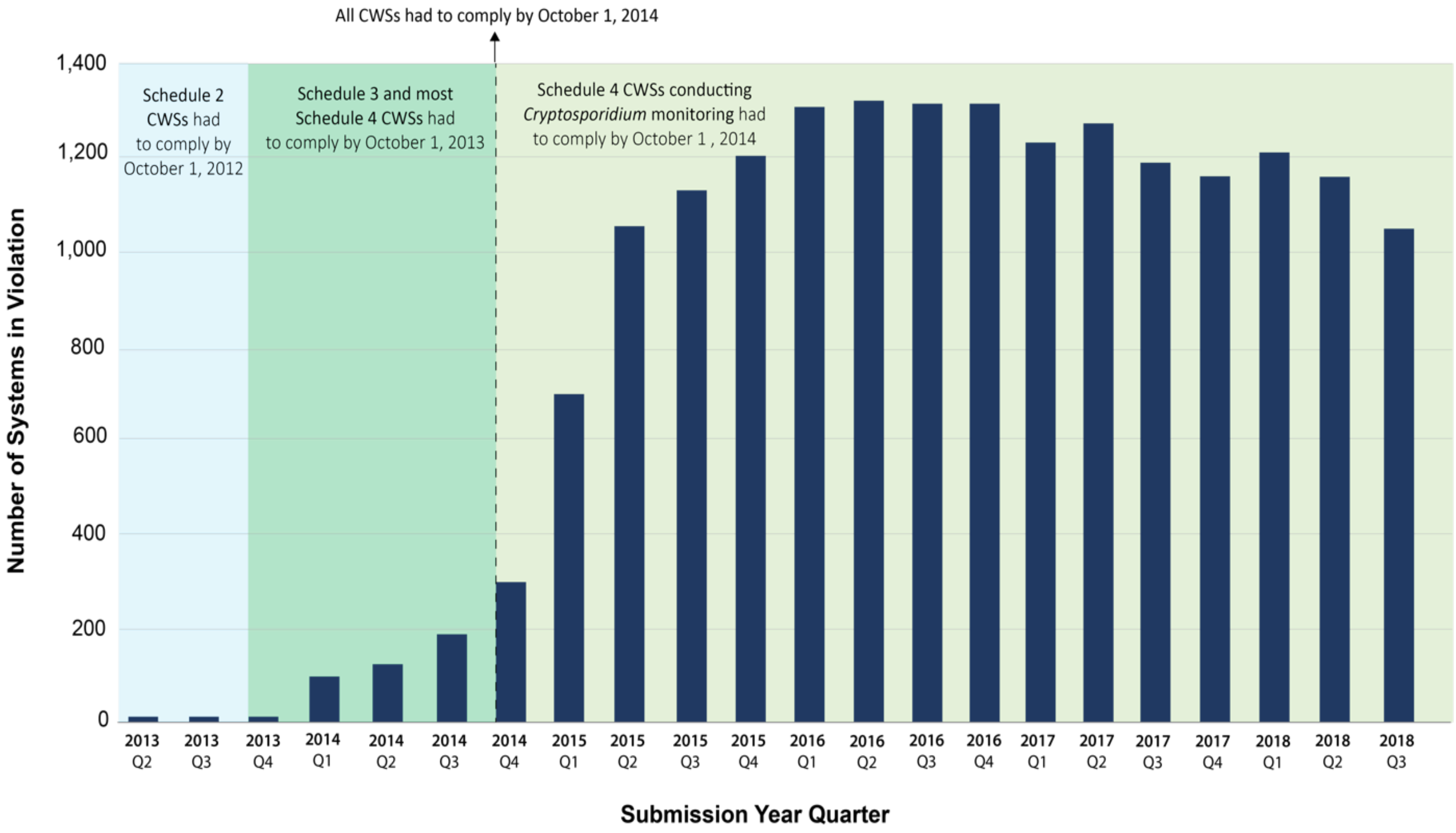
- Proportions of CWSs with health-based violations in 2017.
- The Stage 2 DBPR violation rate for consecutive CWSs is 3.5 times greater than non-consecutive CWSs.



Consecutive Systems and Challenges

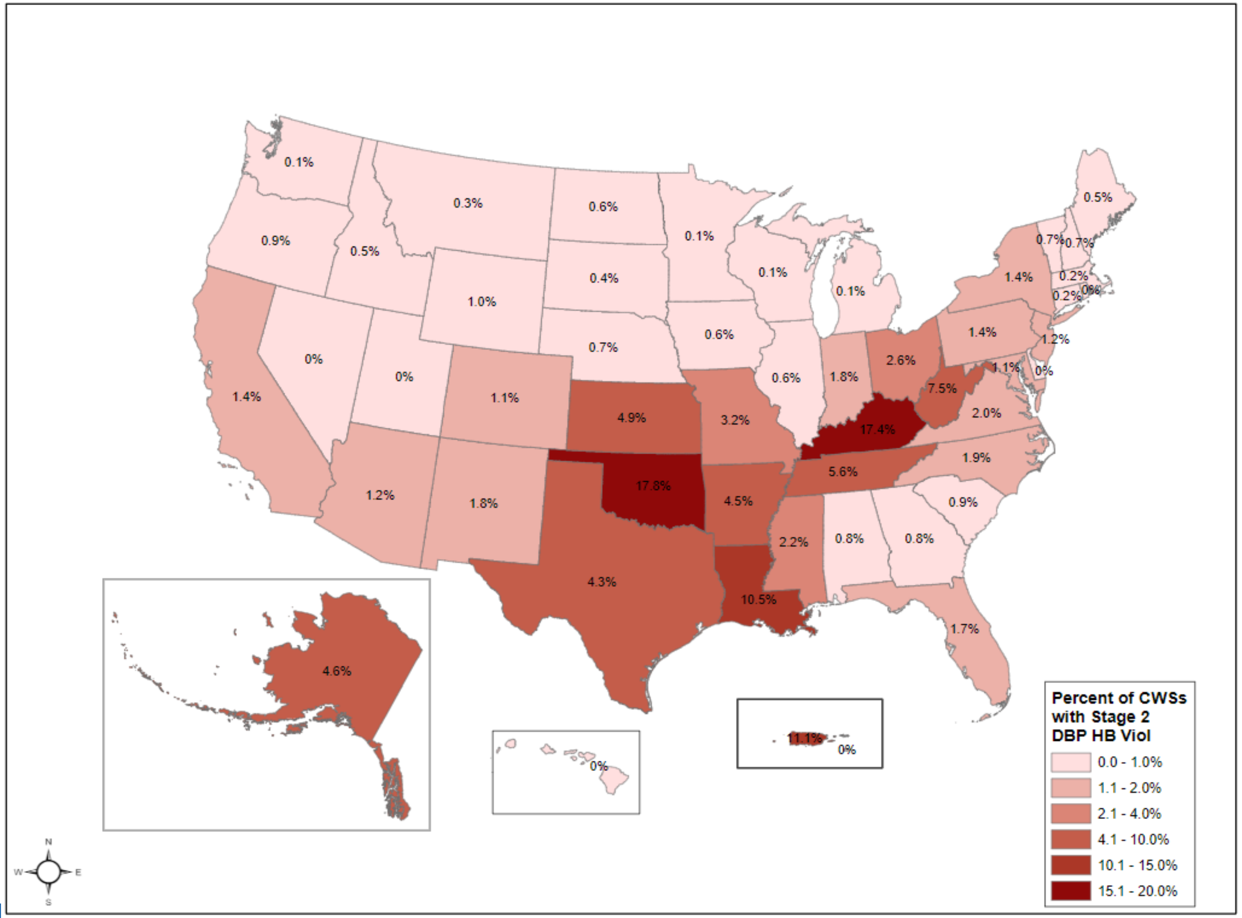
- Consecutive systems were not regulated under Stage 1 DBPR.
- Stage 2 DBPR extends to consecutive systems.
- Challenges include that purchased water:
  - Has already been treated.
  - May contain high levels of DBP precursors (e.g., TOC).
  - May contain high levels of DBPs.

How have Stage 2 D/DBPR health-based violations changed over time?

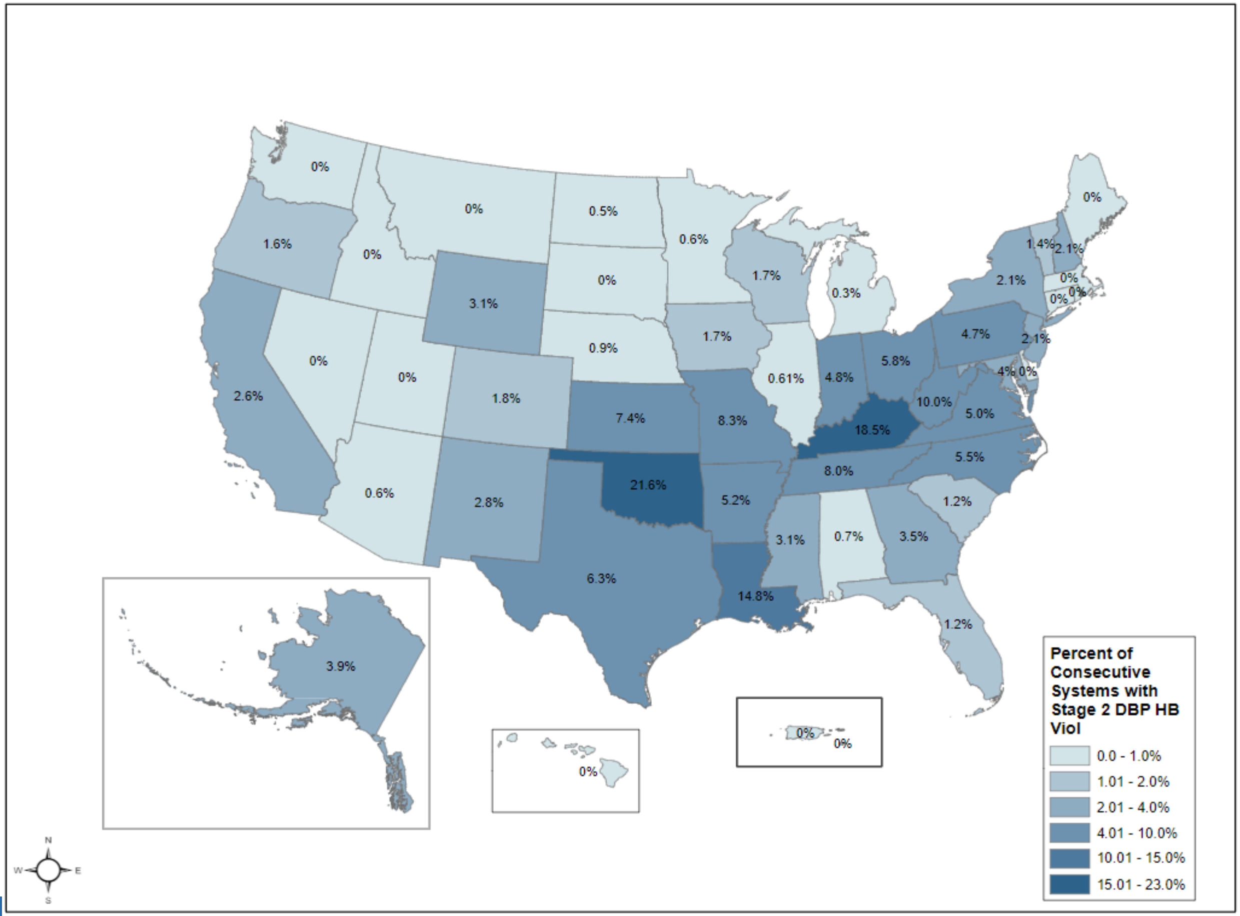


Geographic Areas with Stage 2 D/DBP Health-based Violations – CWSs and Consecutive Systems

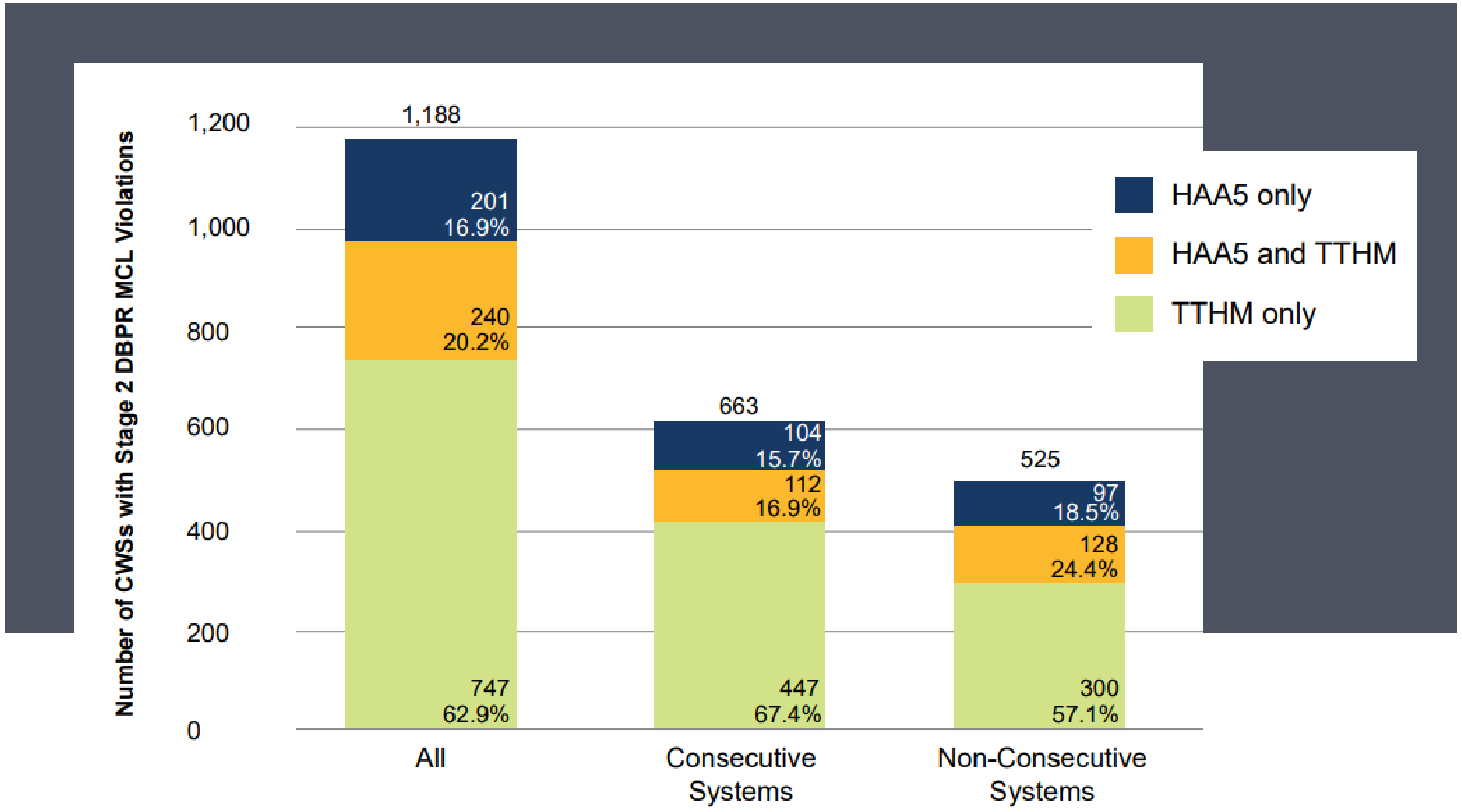
Percent of CWSs with Stage 2 D/DBP Health-based Violations



Percent of Consecutive Systems with Stage 2 D/DBP Health-based Violations



Frequency of Stage 2 D/DBPR MCL Violation Types at Consecutive and Non-consecutive CWSs (FY17)



Frequency of Stage 2 D/DBPR health-based violations at consecutive and non-consecutive CWSs of different system size categories in FY17

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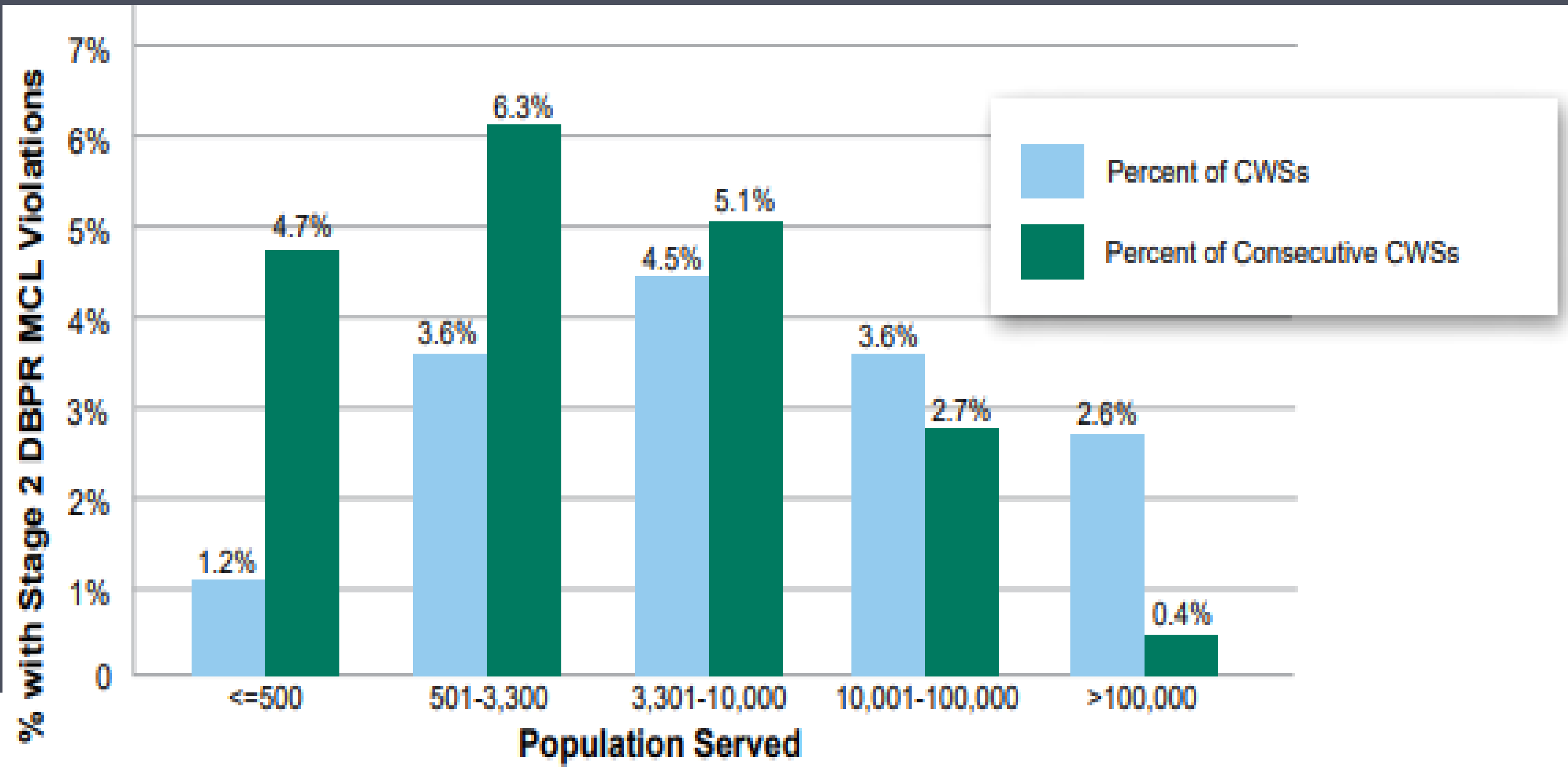

Jackie Logsdon, Kentucky Department for Environmental Protection

Disclaimer – Materials Not Developed or Provided by EPA

The following **5** slides were developed by Jackie Logsdon, who is not employed by EPA. The content of these slides do not necessarily reflect EPA policies or positions.

Kentucky Compliance with Current DBP Regulations

Consecutive Systems

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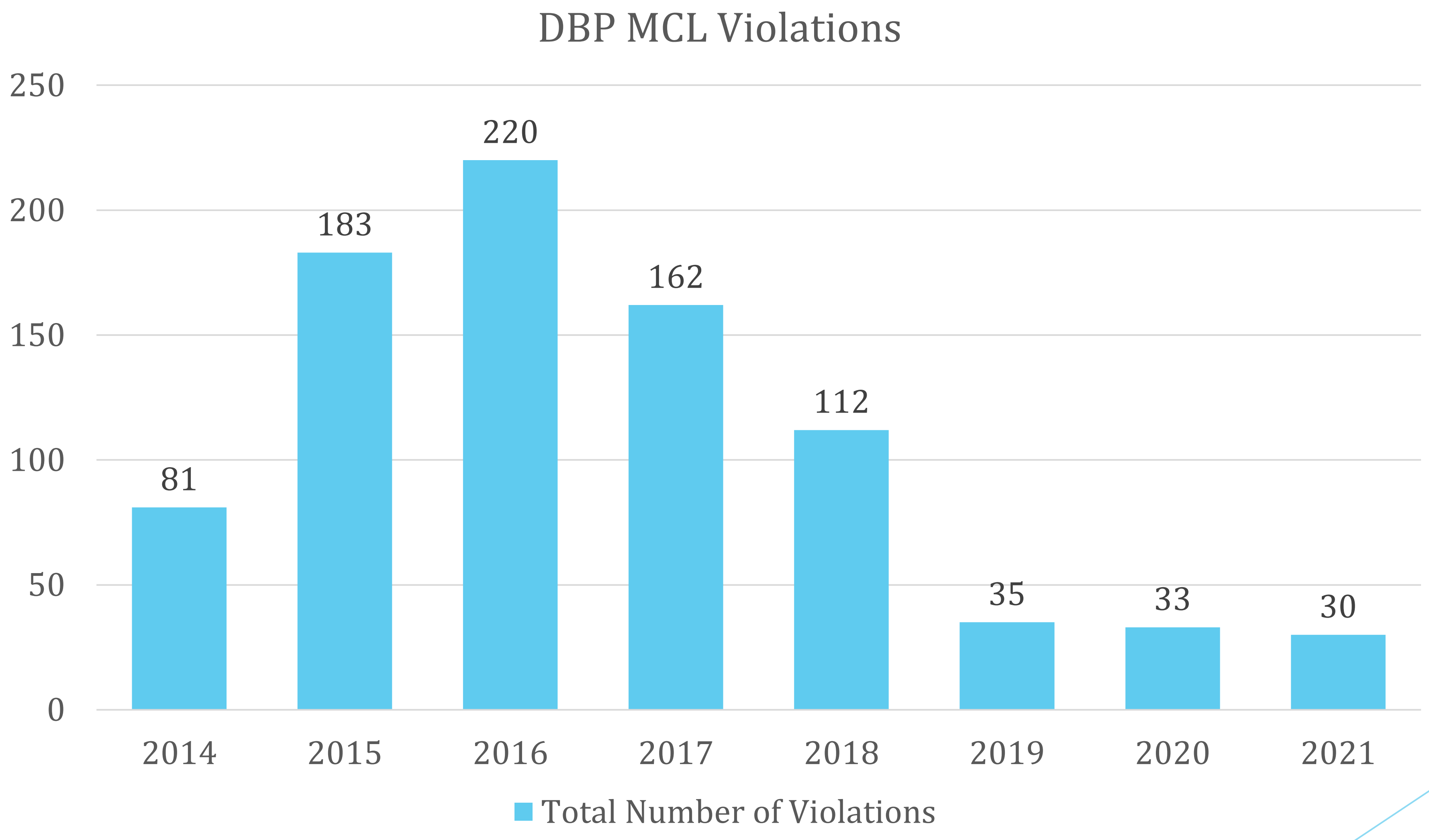
DBP MCL Violations
250
200
150
100
50
0
81
183
220
162
112
35
33
30
2014
2015
2016
2017
2018
2019
2020
2021
Total Number of Violations

Consecutive Systems

- High percentage of systems out of compliance were Consecutive Systems
  - 47% of PWS required to comply with Stage 2 DBPR were Consecutive Systems
  - Overall high percentage of Consecutive Systems in KY
    - Regionalization efforts
- Area-Wide Optimization Program
  - Modular Distribution System Optimization Training
    - Operator Training
      - Empower smaller systems
    - Include Parent System when possible to encourage coordinated efforts
    - Separate out the systems that needed small tweaks vs the systems that needed more intensive Targeted one-on-one Technical Assistance

Enforcement Actions with Parent & Consecutive Systems

- Agreed Order (AO) requires master meter monitoring
  - No KY regulatory requirement for master meter monitoring
- Identify root cause and employ additional AWOP tools if needed
  - Work needed at Parent System?
    - Targeted one-on-one Technical Assistance
- Move compliance site if the Parent System is in compliance, but Consecutive System is out of compliance due to elevated DBPs at the master meter.
  - 40 C.F.R. 141.622(c) "The State may require modifications in your monitoring plan".
  - Master meter data available due to requirement of the AO

Jackie Logsdon

Jackie.Logsdon@ky.gov

270-871-9194

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Problem Characterization on Disinfection Byproducts: **Panel Discussion**

Zaid Chowdhury, Susan Teefy, Stuart Krasner

10 Minute Break

4:25 – 4:35 pm ET

Discussion Topics

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- Clarifying questions
- Do you have additions or refinements to characterization of DBP problems?
- What additional information will be helpful to further understand DBP related problems?
- Within the drinking water value chain, what do you believe are the most prominent root causes of DBP problems?
- Given the information presented today, how do you perceive the magnitude of the public health concern?

Segment 5: Meeting 4 Agenda & Next Steps

Co-Chairs Andy Kricun & Lisa Daniels

Ryan Albert, U.S. EPA OGWDW

Rob Greenwood, Ross Strategic

EPA
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Presentation Overview – Teeing Up Interdependencies (Preliminary)

- Sanitary Surveys
- Surface Water Treatment Rule Compliance
- Nitrification
- Details on legionellosis cases
- Finished water storage related problems
- DBP tradeoffs and water quality entering distribution systems
- Additional unregulated DBPs

Discussion Topics

- Do you have additions or refinements to the proposed topics?
- What background materials, presentations, or other resources will be helpful to you to prepare for the Meeting 4 discussions?
- Mindful of time and resource limitations prior to the next meetings, what supplemental technical analyses would you like on the topics to help inform discussions?

MEETING CLOSURE

ELIZABETH CORR, U.S.EPA, DFO

Appendix

- Major National Datasets Relevant to MDBP Contaminants.
- Relevant Disinfection Inventory Information in 2019.
- National Precursor Analysis

Relevant National Data Sources - UCMR

- Unregulated Contaminant Monitoring Rule (UCMR): Nationally representative monitoring program for selected unregulated contaminants, including DBPs:
  - *UCMR 2 (2008-2010):* National occurrence of six nitrosamines (including NDMA) by disinfectant type
  - *UCMR 3 (2013-2015):* National occurrence of chlorate by disinfectant type and form of chlorine used
  - *UCMR 4 (2018-2020):* National occurrence of HAA5, HAA6Br, and HAA9 by disinfectant type/residual type, treatment process, and source water precursor level (i.e., bromide and TOC)
  - Covering a 12-month period for each of affected systems
  - Including all systems ≥ 10k and randomly selected 800 systems < 10k
  - Analytical results can be grouped with selected categories (see inventory analysis, including disinfectant residual type, etc.)

Relevant National Data Sources – SYR ICR

- Six-Year Review 4 Information Collection Request (SYR4 ICR, 2012-2019): Compliance monitoring data reported under existing MDBP rules as well as Revised Total Coliforms Rule (RTCR), voluntarily provided by states/primary agencies to inform the following:
    - National occurrence/exposure baselines of regulated DBPs, TC and E. coli, disinfectant residuals, representing post-Stage 2 DBPR and RTCR baselines
    - Treatment performance per TOC removal requirements under Stage 1 DBPR
    - Analytical results can be grouped with selected categories (see inventory analysis, including disinfectant residual type, etc.)
- SYR3 ICR (2006-2011): Similar monitoring data as SYR4 ICR, but representing post-Stage 1 DBPR and pre-stage 2 DBPR/RTCR baselines

Relevant National Data Sources – DBP ICR

- DBP Information Collection Rule (DBP ICR, 1998): Mandatory monitoring and reporting among systems serving 100,000 or more people, from source water, through treatment, to distribution system. This data source reflects the national pre-stage 1 DBPR baselines for the given size category
  - *Source Water:* Monthly monitoring of water quality (e.g., TOC, UV254, Br).
  - *Treatment:* Monthly detail operational information (including disinfectant doses and types).
  - *DS:* Monthly/quarterly monitoring of water quality (e.g., regulated and emerging DBPs, residuals).
    - DBPs: TTHM/HAA5/HAA9, HANs, etc.
  - Also, treatment studies on effectiveness of GAC and membranes.

Weblinks for Relevant National Data Sources

SDWIS: https://www.epa.gov/ground-water-and-drinking-water/safe-drinking-water-information-system-sdwis-federal-reporting

UCMR Data: https://www.epa.gov/dwucmr/occurrence-data-unregulated-contaminant-monitoring-rule

SYR4 ICR Data: https://www.epa.gov/dwsixyearreview/microbial-and-disinfection-byproduct-data-files-2012-2019-epas-fourth-six-year

SYR3 ICR Data: https://www.epa.gov/dwsixyearreview/six-year-review-3-compliance-monitoring-data-2006-2011

DBP ICR Data (and Treatment Studies Data):
https://www.epa.gov/dwsixyearreview/supplemental-data-six-year-review-3

Disinfecting vs Non-Disinfecting CWSs*

System Category	#Systems	#Population	%Systems	%Population
SW CWSs	11,599	220,723,474	23.4%	71.1%
Disinfecting GW CWSs	31,523	87,614,569	63.5%	28.2%
Non-Disinfecting GW CWSs	6,488	2,201,216	13.1%	0.7%
All Disinfecting CWSs	43,122	308,338,043	86.9%	99.3%
All CWSs	49,610	310,539,259	100%	100%

*** Based on SDWIS 4th Q in 2019 and SYR4 ICR in 2019**

Disinfecting CWSs with Percentages of Purchased Water*

System Category	Percentages of Purchased Water	#Systems	#Population	%Systems	%Population
SW CWSs	100%	5,675	41,731,044	13.20%	13.50%
	>0% & <100%	1,669	67,480,872	3.90%	21.90%
	0%	4,255	111,511,558	9.90%	36.20%
Disinfecting GW CWSs	100%	2,061	3,083,539	4.80%	1.00%
	>0% & <100%	645	5,467,853	1.50%	1.80%
	0%	28,817	79,063,177	66.80%	25.60%
All Disinfecting CWSs	100%	7,736	44,814,583	17.94%	14.53%
	>0% & <100%	2,314	72,948,725	5.37%	23.66%
	0%	33,072	190,574,735	76.69%	61.81%
All Disinfecting CWSs		43,122	308,338,043	100%	100%

*Based on 4Q of 2019 SDWIS Data

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Disinfecting CWSs with Different Residual Types*

System Category	Disinfectant Residual Type	#Systems	#Population	%Systems	%Population
SW CWSs	Free Chlorine	7,816	123,472,631	18.10%	40.00%
	Chloramines	3,783	97,250,843	8.80%	31.50%
Disinfecting GW CWSs	Free Chlorine	27,816	71,146,728	64.50%	23.10%
	Chloramines	3,707	16,467,841	8.60%	5.30%
All Disinfecting CWSs	Free Chlorine	35,632	194,619,359	82.63%	63.12%
	Chloramines	7,490	113,718,684	17.37%	36.88%
All Disinfecting CWSs		43,122	308,338,043	100%	100%

***Collectively based on UCMR4 and SYR4 ICR in 2019**

Issue Area: Precursor Occurrence and Their Effects on DBP Occurrence

Related Requests:

1. How well can we measure/characterize precursors across system types and throughout the country?
2. Unintended consequences: Assessments of source water contamination and impacts on MDBP rules

Supporting Analysis:

1) Characterizing occurrence of source water Br and TOC by system size and source water type (with UCMR4).
2) Using a source water quality matrix (4x4 for Br vs TOC) to assess the use of free chlorine (FCL) vs chloramine (CLM) as a residual, and occurrence of high HAA9 and HAA6Br levels, respectively (with SYR4 ICR and UCMR4).

DBP Precursor Occurrence and Effects on DBP Occurrence – Major Observations

- Groundwater systems have higher source water Br and lower TOC levels than surface water systems. Large systems have higher Br and TOC levels in source water than small systems.
- High levels of source water TOC or Br levels may drive systems to use chloramines more frequently.
- Majority of FCL systems exceeding 60 µg/L Max LAA HAA9 threshold are those systems with relatively low bromide levels in source water.
- Among CLM systems, none of CWSs with TOC < 4 mg/L have Max LAA HAA9 ≥ 60 µg/L.
- Among FCL systems, relatively high HAA6Br levels rarely occurred at low levels of source water bromide (i.e., < 40 µg/L).
- Among CLM systems, relatively high HAA6Br levels occurred only with extremely high levels of Br in source water (i.e., >=120).
- In order to comply with the Stage 1 and 2 MCLs for THMs, many systems that treated high-bromide waters had to change their treatment (e.g., switch to ozone/chloramines). For those that did switch to ozone/chloramines, HAA9 are present at low levels.

Bromide and TOC Levels in Source Water by Source Water Type and System Size (UCMR4)

Observations:

- Table shows the distribution of Br and TOC levels in GW systems have higher source water Br levels and lower TOC levels than SW systems.
- In general, large systems have higher Br and TOC levels in source water than small systems

Statistics	Br Levels (µg/L)				TOC Levels (mg/L)			
	GW		SW		GW		SW	
	<10 k (N=409)	≥ 10 k (N=1,447)	<10 k (N=119)	≥ 10 k (N=1,460)	<10 k (N=409)	≥ 10 k (N=1,445)	<10 k (N=119)	≥ 10 k (N=1,460)
Median	42	53	17	22	0.5	0.5	2.3	2.6
Mean	134	186	39	141	0.8	1.1	2.8	3.1
90%ile	290	233	82	113	1.5	2.0	5.6	5.6
95%ile	486	426	141	203	2.2	4.0	6.0	6.8

Data Source: UCMR4. https://www.epa.gov/dwucmr/occurrence-data-unregulated-contaminant-monitoring-rule#4

Co-Occurrence of TOC & Br in Source Water by Residual Type

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Observation: Chlorine was rarely used at high levels of both TOC & Br. Some systems with low levels of TOC and Br also used chloramines.

FCL Systems (N = 2,517)

	TOC or Br Range	Sys Mean Avg TOC, mg/L				
		< 2	2-4	4-6	≥ 6	All
Sys Avg Br, µg/L	< 40	39.8%	15.6%	2.7%	0.9%	59.0%
	40-80	15.2%	2.5%	1.0%	0.3%	19.1%
	80-120	6.8%	1.0%	0.3%	0.0%	8.1%
	≥ 120	12.4%	1.2%	0.2%	0.0%	13.9%
	All	74.3%	20.3%	4.2%	1.2%	100%

CLM Systems (N = 548)

	TOC or Br Range	Sys Mean Avg TOC, mg/L				
		< 2	2-4	4-6	≥ 6	All
Sys Avg Br, µg/L	< 40	6.8%	14.6%	9.7%	6.6%	37.6%
	40-80	4.7%	6.9%	6.0%	4.4%	22.1%
	80-120	1.1%	3.3%	3.6%	1.8%	9.9%
	≥ 120	3.8%	7.1%	9.9%	9.7%	30.5%
	All	16.4%	31.9%	29.2%	22.4%	100%

* Only included CWSs with Max LAA HAA5 < 60 µg/L

Systems Impacted by an Illustrative HAA9 Threshold by TOC and Br Co-Occurrence in Surface Water

Observations:

1. At the given illustrative threshold, majority of CWSs with FCL as residual exceeding this threshold are those systems with relatively low bromide levels in source water (i.e., < 80 µg/L).
2. Among CLM systems, none of CWSs with TOC < 4 mg/L have exceeded the illustrative threshold.

Among FCL Systems (N = 2,517)

Number of systems with Max LAA HAA9 ≥ 60 µg/L						
		Sys Avg TOC, mg/L				
	TOC or Br Range	< 2	2-4	4-6	≥ 6	All
Sys Avg Br, µg/L	< 40	7	23	6	3	39
	40-80	4	3	4	1	12
	80-120	1	1	1	0	3
	≥ 120	3	1	3	0	7
	All	15	28	14	4	61

Among CLM Systems (N = 548)

Number of systems with Max LAA HAA9 ≥ 60 µg/L						
		Sys Avg TOC, mg/L				
	TOC or Br Range	< 2	2-4	4-6	≥ 6	All
Sys Avg Br, µg/L	< 40	0	0	1	2	3
	40-80	0	0	1	5	6
	80-120	0	0	1	0	1
	≥ 120	0	0	5	3	8
	All	0	0	8	10	18

*Cutoffs are for illustration only and are not suggestive of potential regulatory limits. HAA5 was regulated at 60 ug/L based on what was determined to be technically and economically feasible.

Systems Impacted by an Illustrative HAA6Br Threshold by TOC and Br Co-Occurrence in Source Water

Observations:

- Relatively high HAA6Br levels rarely occurred at low levels of source water bromide among FCL systems.
- Relatively high HAA6Br levels occurred only with high levels of bromide in source water among CLM systems.

Among FCL Systems (N = 2,517)

Number of systems with Max LAA HAA6Br ≥ 30 µg/L						
		Sys Avg TOC, mg/L				
	TOC or Br Range	< 2	2-4	4-6	≥ 6	All
Sys Avg Br, µg/L	< 40	0	1	0	0	1
	40-80	3	2	1	0	6
	80-120	2	1	1	0	4
	≥ 120	0	0	4	0	4
	All	5	4	6	0	15

Among CLM Systems (N = 548)

Number of systems with Max LAA HAA6Br ≥ 30 µg/L						
		Sys Avg TOC, mg/L				
	TOC or Br Range	< 2	2-4	4-6	≥ 6	All
Sys Avg Br, µg/L	< 40	0	0	0	0	0
	40-80	0	0	0	0	0
	80-120	0	0	0	0	0
	≥ 120	0	8	9	4	21
	All	0	8	9	4	21