

MEMORANDUM

**TO: RIVANNA WATER & SEWER AUTHORITY
BOARD OF DIRECTORS**

FROM: THOMAS L. FREDERICK, EXECUTIVE DIRECTOR

SUBJECT: RESPONSES TO PUBLIC COMMENTS

DATE: MAY 22, 2012



At the April Board meeting, all public comment focused on the capital project to upgrade the water plants serving the Urban Water System to permit a proposed 2014 conversion of the secondary disinfectant to chloramines. In offering this response, we want to make clear that we respect the public policy viewpoints and opinions of citizens, including those who may prefer granular activated carbon or another alternative that our Engineer represents will consistently comply with the Stage 2 federal regulation. We also recognize that many of the public comments have been identified as coming from searches on web sites where it is very difficult to know what statements represent correct information and what statements do not. This is an important issue from the perspectives of both regulatory compliance and public acceptance, and the water treatment business is scientific, technical, and much more complex than most citizens probably recognize, so it is understood that change can be difficult. We respect the importance of our citizens having the appropriate factual information and details, and the comments below are offered in that spirit. Statements in bold and italics represent a particular public comment made at the April Board meeting, followed by our response.

1. ***“ . . .according to the RWSA’s own Water Quality Report, the levels of TTHMs and HAAs, which are the regulated byproducts, were well below EPA compliance for both Stage 1 and 2. . .”***

One part of this statement is correct: the Urban Water System is and has been consistently in compliance with the Stage 1 rules currently in effect. However, a review of all data on TTHM and HAA for the Urban Water system between the first quarter of 2001 and the first quarter of 2012, if applied to the future Stage 2 rules for calculating “locational running annual averages”, would show 11 “violations”, with at least one “violation” in each of five of the past eleven years, the latest being 2011.

2. ***“chloramine has its own family of byproducts and they’re much more toxic and much more inflammatory . . . include NDMA, which is a Nitrosamine and includes Hydrazine – which is rocket fuel – and very toxic HAAs and Iodoacetic acids.”***

We have reviewed this item with Dr. Stanford of Hazen and Sawyer and offer the following:

- A.** Regulated HAAs (currently 5 compounds) occur in both chlorinated and chloraminated systems. It is a proven fact that chloramines will produce significantly lower concentrations of regulated HAAs than free chlorine. There are an additional 4 unregulated HAAs that will likewise occur in both chlorinated and chloraminated water, and these four compounds will be at lower concentration in chloraminated water than in chlorinated water. There are 10 additional iodoacids that can occur under very specific conditions that do not exist at RWSA. This is addressed in detail below. Dr. Stanford has advised us he is not aware of any other mystery “very toxic HAAs” of concern in converting to chloramines. The citizen who spoke did not identify any specific compound in what she generalized as “very toxic HAAs”. It would help us and the public to know if the general phrase is connected to a specific science study that can be referenced and further reviewed, or if it is more an opinion or speculation.
- B.** Based on research by the Water Research Foundation, Dr. Stanford advises us that iodoacetic acids are not expected to form in the water treated by RWSA. The research shows that iodoacetic acids can form in chloraminated water only when iodide ions are present at high concentrations. Sources of most iodide ions in water are from ocean (salt) water intrusion, or specialized geologic formations, neither of which exist in our local watershed area. Further, iodide ions are changed to iodate when free chlorine is used for primary disinfection, and iodate is a stable compound that does not form iodoacetic acids. Thus, with little-to-no iodide in the water and the use of free chlorine as a primary disinfectant, iodoacids are very unlikely to form in RWSA’s water. As stated previously, RWSA proposes to continue to use free chlorine for primary disinfection.

Additionally, RWSA was in attendance at a recent technical conference at the University of Richmond where Dr. Plewa from the University of Illinois-Champagne spoke. Dr. Plewa’s research on iodoacetic acid is frequently used by web-based advocacy groups as their “proof” against chloramines. At the conference Dr. Plewa was asked if he agreed that using free chlorine for primary disinfection in front of forming chloramines for secondary disinfection would protect against iodoacetic acid formation, and he did concur affirmatively.

- C.** Research by the Water Research Foundation shows that in order for hydrazine to form in chloraminated water, the water pH must be well above 9.0. RWSA proposes to maintain a pH well below 9.0 with chloraminated water, and the regional team of RWSA, the City and ACSA propose an active water distribution system monitoring program to maintain this pH range so that hydrazine cannot form.
- D.** Nitrosamines (including NDMA) can be found in very low concentrations in both chlorinated water and chloraminated water. Nation-wide occurrence data from EPA’s database found low levels of NDMA in 290 of 10,824 chlorinated water samples collected, and 967 of 2,812 chloraminated water samples collected. In the case of the City of Burlington, Vermont and the Champlain Valley Water District in Vermont, both of which use the same source water but different secondary disinfectants, NDMA was present in the chlorinated water but not in the chloraminated water.

NDMA is commonly found in beer, smoked and processed meats, and other foods at concentrations hundreds to thousands of times higher than has been found in water; nevertheless, EPA is considering future regulation of NDMA in drinking water. The State of California presently has a notification level of 10 parts per trillion (equivalent

concentration to one penny in \$100 billion) and an action level of 300 parts per trillion (equivalent concentration to 300 pennies in that same \$100 billion). EPA is widely expected to set a limit somewhere within California's broad range, possibly toward the lower end. During the evaluation of alternatives, at RWSA's request, Hazen and Sawyer conducted a laboratory evaluation of nitrosamine formation potential with lab-simulated chloramination of RWSA's treated water, under worst case simulation of a long detention time in the distribution system. Laboratory results using high quality methods varied between "not detected" to a maximum 3.3 parts per trillion.

3. ***"lead issues in DC were the direct result of the chloramine"***

It is extremely unfortunate that D C Water initially converted to chloramines without understanding the need to use a corrosion inhibitor in its water, and further very disconcerting that D C Water did not properly notify the public in 2003 when elevated lead levels were found in the water. However, to conclude from this incident that every community who uses chloramines is automatically doomed to the same fate overlooks important technical advances in understanding how chloramines can be used safely, as is being demonstrated in communities across the country that make up 30% to 40% of US citizens safely drinking chloraminated water (including D C Water customers in 2012). RWSA cares deeply about taking every effort possible to avoid lead contamination of water and has used a corrosion inhibitor for many years with its present chlorinated water. RWSA has committed Hazen and Sawyer to conduct significant simulated testing in advance of the conversion to chloramines to determine the correct procedures and training all operators for adjusting the corrosion inhibitor, and the team of RWSA/ACSA/City will also closely monitor the water system as the conversion occurs.

4. ***"hundreds of people in 20 states are showing acute health effects from chloramine exposure, including persistent skin rashes and burns, respiratory issues, digestive issues such as colitis and acid reflux."***

Dr. Stanford reports that none of these statements have been verified through medical studies based on contact with chloraminated drinking water, nor has a direct cause and effect relationship been established. Disorders like skin rashes, burns, respiratory issues, digestive issues, and acid reflux can occur for many different reasons, and absent medical verification, can be easily blamed on the wrong cause. If chloramines were the result of "acute health effects" defined above, given that approximately 40% of the people in the US (and 76% of people in Virginia) now consume chloraminated water, we should see broad statistically significant variation in health reports from communities based on the drinking water, but statistics do not confirm this.

5. ***"you absorb much more toxins into your body in a ten-minute shower than from drinking water all day"***

Dr. Stanford advises us that EPA has demonstrated through what is called "risk cup" analysis that exposure to disinfection byproducts can be greater through showering (and swimming in a pool) than drinking; further, EPA uses overall exposure to establish maximum contaminant levels of byproducts for safe drinking water. An irony in this citizen comment is that EPA's Stage 2 is actually more stringent to further reduce such exposures, and chloraminated water reduces the formation of byproducts, thereby

reducing exposure to byproducts by both showering and drinking, compared to chlorinated water from the same water treatment process.

6. ***"Chloramine poses a national security issue because it is more stable and does not react in a biological attack . . . as a result, many military bases are now prohibiting its use on their properties."***

The citizen making this comment did not cite any specific military base, which would be most helpful in trying to verify this claim. We were only able, therefore, to address this generally, and we were not able to find any military prohibition on the use of chloramine for drinking water treatment. We did learn from American Water, a private sector water company who operates water systems for many federal facilities, that they were not aware of any military base that prohibited chloraminated water. Hazen and Sawyer provides consulting in the Fayetteville, North Carolina area and was able to confirm that Fort Bragg, a major U S Army base, uses chloraminated water. The Virginia Department of Health confirmed that many Virginia-based military installations use chloraminated water including Fort Lee, the Naval Weapons Station, Cheatham Annex Naval Supply Center, Fort Eustis, Norfolk Naval Base, Fort Story, Fort Belvoir, and the Norfolk Naval Shipyard.

Chloramine is used as a secondary disinfectant as part of a multi-barrier approach to public safety in drinking water treatment, along with water filtration and free chlorine for primary disinfection. The multi-barrier approach provides strong protection in treatment against both natural and human-made threats.

7. ***"Nevada specifically forbids the use of chloramines"***

Section 445A.66825 of the State of Nevada Administrative Code states "Chloramines may be used as a secondary disinfectant to maintain an effective residual of disinfectant in a distribution system".

8. ***"New Mexico, Rhode Island, Tennessee, Utah, West Virginia, Connecticut, and Oklahoma actively discourage its use and to my knowledge no municipality in those states use chloramines"***

Chloramine use is permitted in all of the states mentioned above. Specific links and examples are provided below:

- NM Regulations adopt EPA's stand on chloramines per 20.7.10 NMAC (<http://www.nmenv.state.nm.us/dwb/regulations/documents/NMDrinkingWaterRegs2011Complete.pdf>)
- Rhode Island allows chloramines per R46-13-DWQ (<http://sos.ri.gov/documents/archives/regdocs/released/pdf/DOH/5536.pdf>)
- Tennessee allows chloramines per Bureau of Environment, Division of Water Supply, Chapter 1200-5-1-.04 (<http://tn.gov/sos/rules/1200/1200-05/1200-05-01.pdf>)
- Utah allows chloramines per R309-520-5; "Allowable secondary disinfectants are chlorine (gas, hypochlorite solution, and hypochlorite tablets) and chloramine." (<http://www.drinkingwater.utah.gov/rules.htm#500>)
- Tulsa, OK is switching to chloramines beginning in June 2012

- Connecticut allows chloramines per 19-13-B102 (http://www.ct.gov/dph/lib/dph/agency_regulations/sections/pdfs/title_19._health_and_safety/phc/chapter_ii/19-23._standards_for_quality....pdf)
- Charleston, WV and Charles Town, WV are on chloramines

9. ***“Ohio requires communities to prove they cannot meet EPA regulations any other way before issuing a permit and to my knowledge no municipalities in Ohio use chloramines”***

The state of Ohio does not have an enforceable regulation that requires utilities to “prove” they cannot meet EPA regulations “by any other way” prior to switching to chloramines. The state does offer recommendations on performance evaluation and testing that is not unlike the testing that RWSA has already completed or will complete prior to conversion to chloramine. (http://www.epa.ohio.gov/portals/28/documents/pws/Chloramination_policy_091603.pdf)

The city of Mahoning Valley, OH and the city of Warren, OH use chloramines.

10. ***“A number of municipalities converted from chloramines back to chlorine including Poughkeepsie NY, Seminole County FL, Sault Saint Marie, Ontario, West Columbia SC. Westview Water Authority in PA converted back in 2010 specifically due to high lead levels”***

We have contacted the utilities mentioned above and learned the following:

- A. The City of Poughkeepsie, New York used chloramines for three years without following practices that are now better understood for the proper use of chloramines. Proper use includes free chlorine for primary disinfection, pH control, proper chlorine to ammonia ratio, proper mixing, proper addition of a corrosion inhibitor, and proper monitoring of the water distribution system. Hazen and Sawyer has recommended and the team of RWSA/ACSA/City have agreed to maintain these best practices.
- B. Seminole County, Florida reported that they have not used chloramines in the past, but are now considering it in response to Stage 2.
- C. Sault Saint Marie, Ontario used chloramines from the 1950s until recently for reasons unrelated to disinfection byproducts (Canadian regulations on byproducts are less stringent than EPA and compliance with Canadian regulations has never been an issue for this community). They had phenols in their source water from an upstream industrial discharge. The chloramines were effective in avoiding a disagreeable taste and odor that occurs when free chlorine reacts with phenols in water. Operators report that chloramines were successfully used for over 50 years. As phenol levels in the source water have recently dropped below detection levels, they are converting to free chlorine as a cost saving measure (avoid the cost of adding ammonia).
- D. West Columbia, South Carolina used chloramines successfully from the early 1990s to 2006. Operators report their decision to make changes were unrelated to any problems with chloramination, but instead a response to more stringent risk management rules related to storage of chlorine gas at the water treatment plant. They implemented a proprietary electrolytic process that generates a mixed oxidant without the need for chlorine storage. Some of the chemicals used in this proprietary process are a trade secret, accordingly, the unknowns have created understandable skepticism and limited its broader use to date within the water industry.

- E. Westview Water Authority, Pennsylvania used chloramines without a corrosion inhibitor and did experience lead problems similar to D C Water. As stated above, a corrosion inhibitor appropriate to the chemistry of the water is current recommended practice and the policy of RWSA.

The list above is very small by comparison to the number of communities who have successfully converted to chloramines and maintained its use. Further, those communities who moved away from chloramines fit two categories: (1) a failure to operate the system by what are known today as chloramine best operating practices; or (2) reasons completely unrelated to disinfection byproducts or lead. RWSA is committed to best operating practices, including precise ratio of chlorine to ammonia, optimal pH of water, and appropriately refined use of corrosion inhibitor, and distribution system monitoring and control.

11. *“Hazen and Sawyer did not recommend the use of chloramines for New York City even though their TTHM and HAA data were higher than RWSAs. In 2010 New York made changes to water without chloramines and brought their levels down”*

According to Dr. Stanford, Hazen and Sawyer and another engineering firm, CDM, worked as a joint venture and evaluated several DBP control options for New York City. The NY City water supply is completely different from RWSA in that they currently do not have an existing filtration plant, thus they are chlorinating raw water. Based on this fact, the chemistry of New York City’s water, and the ability to draw water from many reservoirs, they found that system optimization measures (including building a 280 million gallon per day drinking water treatment plant) were sufficient to assure continuous EPA compliance with Stage 2, but it was recognized in their study that further tightening of future EPA regulations could require further consideration of other measures, such as chloramines.

Hazen and Sawyer audited RWSA’s existing optimization program in its study reported in July 2011. Because RWSA is already practicing optimization, there was less opportunity for further gains, except by changing coagulants. The Engineer also found a wider variability over time in natural organic matter in the reservoir water used by RWSA, and concluded that changing coagulants alone was not sufficient to assure continuous compliance with Stage 2 across the range of variability RWSA should plan for.

12. *[Chloramines] “is a well-known pulmonary, neurologic, and GI toxin [and byproducts are] carcinogenic and immunogenic. . . We don't know much about these byproducts except they are highly toxic”*

The subject of ‘toxicity’ is very complex, and cannot responsibly be reduced to “black or white” answers. If a compound is toxic in one form or concentration, it does not mean it is universally toxic in every form or concentration. As an example, there are vitamins and minerals whose presence are essential to human life at low concentrations (absence can result in death), but can have toxic effects on human health at much higher concentrations. Trivalent chromium is an excellent example in that it is a necessary nutrient for body functions including blood sugar control, and is present in many dietary supplements, and yet is also regulated by the US EPA in drinking water.

With respect to “chloramines” there are three different inorganic forms: monochloramine, dichloramine, and trichloramine. Dichloramine and trichloramine in sufficient concentration are irritants and, at extremely high levels (far, far above what is found in drinking water even under the worst conditions), are toxic. Chlorine is also toxic and poisonous at very high levels. At the levels regulated by EPA in drinking water these compounds are not toxic. Both the World Health Organization and the US EPA recognize chloramines as a safe and effective chemical for use in drinking water. Furthermore, in drinking water treatment, monochloramine is by far the dominant species and can be selected and controlled based on pH of the water and the amount of chlorine and ammonia that are added at the water treatment plant. RWSA will be operating its system well within the boundaries to select for monochloramine and will be operating its system below the maximum residual level allowed by the EPA.

13. ***Hazen and Sawyer repeatedly demonstrated in DDBP report that “ferric sulfate dramatically [reduced] organic compounds [in water compared to alum] and that RWSA is still seasonally feeding chlorine at head of plant”. Can adjustments in these two areas alone consistently comply with Stage 2?***

The answer to this question is reflected in complex and detailed evaluations by Hazen and Sawyer. To understand and appreciate the degree to which Hazen and Sawyer has examined this question, Attachment A to this report provides their complete response to the above question, both as a short answer and a long answer. The quick response from Hazen and Sawyer is “no, implementing ferric sulfate and moving the point of chlorination is unfortunately not sufficient to consistently comply with Stage 2”.

Attachment A – Hazen and Sawyer’s response to Question 13.

Short Answer:

The formation of DBPs in the system must always be thought of as a moving target that is highly dependent upon the amount of total organic carbon (TOC, also known as natural organic matter or NOM), the water age in the pipes (time), and water temperature, among other factors. Throughout the year you have seasonally warmer (or cooler) water and daily changes in the amount of TOC in the water. Water age changes with daily and seasonal water demands.

In the distribution system, there will be some times where your formation of DBPs will be higher due to increases in TOC and the warmer water temperatures while at other times it will be lower. The challenge is to ensure that during the periods of high TOC and warm water that you can still comply with the DBP regulations, even when you consider the effect of averaging the data.

When evaluating changes in chemicals (in this case ferric vs. alum) to examine the effect on DBPs you should always keep in mind that the data collected during the tests must also be considered when you have very high TOC and the times when you have very low TOC. In the tests that were performed for RWSA the TOC was slightly above average (technically the TOC was around the 60th percentile). This means that 40% of the TOC measurements would have been *higher* than what was observed during the jar tests.

Thus, the differences in TOC removal and DBP formation between ferric and alum must be enough to bring RWSA within compliance not only when the tests were performed *but also during the other 40% of the time when TOC levels are higher*. Yes, ferric reduced the DBP formation potential, but it was not enough to ensure compliance during high TOC periods.

When the data from the ferric tests were extrapolated to adjust for the periods of time when TOC would be much higher, the expected THM formation was on the order of 160 ppb (vs. the MCL of 80 ppb) and HAA formation was on the order of 80 to 110 (vs. the MCL of 60 ppb). [Editor’s Note: ppb represents parts per billion]

However, when chloramine is used with ferric, the projected maximum THM formation was 30 to 60 ppb range, and the maximum HAA formation was in the same range. All below the MCL values.

Therefore, while ferric alone offered a substantial reduction in DBP formation, it was not enough to ensure compliance and was therefore not selected as an alternative treatment method.

Long Answer with Data Analysis:

First, a few definitions:

- Point of Chlorination (POC) = the location in the treatment plant where chlorine is added.
- Initial Distribution System Evaluation (IDSE) = these were the sample locations selected to capture an initial look at Stage 2 Disinfectants/Disinfection Byproduct Rule (Stage 2 D/DBPR)
- Water Treatment Plant (WTP)
- Total Organic Carbon (TOC), also referred to as natural organic matter (NOM)
- Simulated Distribution System (SDS) Test = a test where treated water is stored at constant temperature, in the dark, over a specific period of time in order to simulate water age and DBP formation that would occur in the distribution system.

The RWSA goal for controlling DBPs is to:

- 1) be in compliance at all times and at all points in the distribution system, and
- 2) eliminate the need for operational evaluations due to high levels of DBPs at a single sample site.

Based on a thorough analysis of the operational and experimental data, our opinion is that RWSA cannot be assured of compliance with the Stage 2 D/DBP Rule, and eliminate operational evaluations, with a simple change in coagulant and change in chlorination feed point.

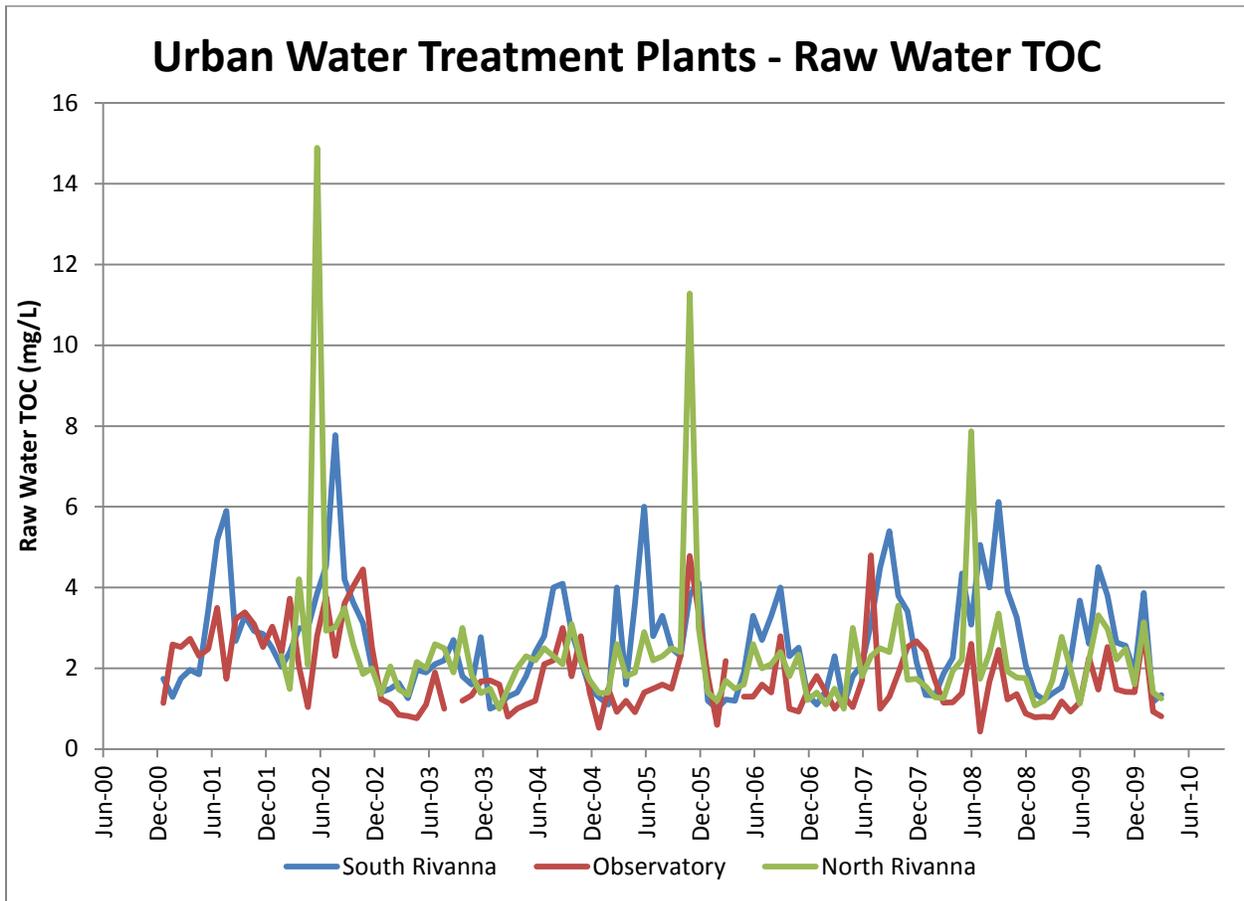
Several factors played into the possible use of ferric and point of chlorination (POC) change as a means of compliance with the Stage 2 D/DBP Rule.

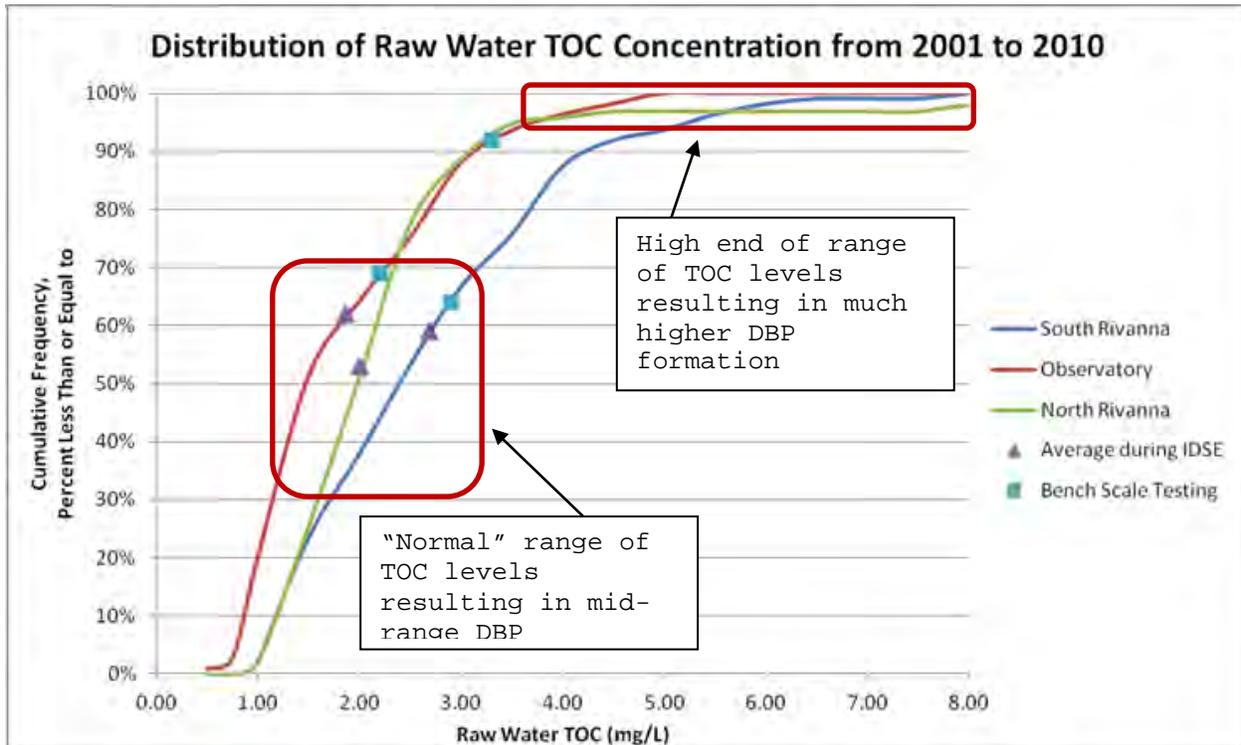
The factors that were part of the decision included:

- The removal of TOC and the resultant DBP formation as observed in the comparative Bench Tests
- The variability of source water TOC (DBP precursors) in all of the water sources based on historical data (See the following figure)
- Both Bench and IDSE data (pages 4-3 and 4-4 in the report) which showed high DBP levels.
- Actual DBP data collected during the study after moving point of chlorination in all the plants during a full scale test
- New compliance points at the worst case DBP levels in the system that include very long water age sites, and this will increase values over historical data.
- Compliance *at each point individually*, not just system averages

The following figures show the variability in TOC in the sources water serving the Urban water plants. TOC is a significant part of ultimate DBP formation as higher levels cause higher DBPs when chlorine is added. The graph showing TOC and frequency depicts how often we might see elevated TOC levels based on over 9 years of historical data.

The graph also shows the TOC conditions when bench tests were conducted in Fall 2010 to capture warmer water. The IDSE (2007) study average TOC is also shown.





Coagulants and Chlorination in Treatment.

The use of a ferric (versus aluminum) as a coagulant to remove more organics is a way to lower DBPs; and moving the point of chlorination (POC) from the head of the plant to pre-filter can allow for lower DBP formation. In many cases, Ferric tends to remove TOC better than alum through the coagulation process.

Moving the POC allows for DBP formation to be delayed until coagulation has removed some of the organic DBP precursors. Some precursors will always remain after coagulation and filtration, and will still form DBPs. *All surface waters, even after treatment have some level of DBPs.*

The plants (South Rivanna and North Rivanna WTPs) currently move the POC on a seasonal basis (when water is about 15 °C or lower) in order to meet disinfection requirements during cold water conditions. During warm water conditions (which generate higher DBPs) the chlorination point is now moved to pre-filter to provide less free chlorine contact time, while still meeting primary disinfection requirements.

Observatory has traditionally fed chlorine at the head of the plant since source water organic levels are lower than the other plants and Stage 1 DBP Rule Compliance was attainable.

The work conducted to assess these options included both bench testing and full scale testing. The tests during the study are summarized below:

Moving POC to lower System DBPs.

The Urban system is fed by three water plants and mixing of water from the three plants takes place in the system depending on water demands and plant output to meet water demands. Certain areas of the system could have water from more than one plant (i.e. Observatory and South Rivanna) in the distribution system and it is difficult to determine at any point in time.

The POC question was one that was evaluated with a full scale test in the Fall of 2010 by taking DBP samples at the plants and in the system. The full scale test was conducted by physically changing the POC in Observatory to look at the benefit from the perspective of DBPs leaving the plant(s) and select points in the distribution system in areas considered to have long detention times, or possible high DBP levels.

The tests compared two sets of samples; one with Observatory using chlorine at the head of the plant (October); and the second with Observatory using pre-filter chlorination three weeks later (November). Both of the other plants did not switch to raw water chlorination and stayed on prefilter chlorine during the test period to demonstrate a system wide POC strategy.

The results of the testing showed mixed results as shown in the figures on pages 5-48 and 5-49 in the report. As expected, water leaving Observatory was reduced since chlorine has less time to form DBPs before it leaves the plant, and organics were removed to a higher degree before chlorine was added. Water leaving the other plants was approximately the same for both samples as expected since POC was the same.

The distribution system samples, which are were compliance will be required, showed mixed results when POC was evaluated.

TTHMs (MCL 80 ppb): Two of the six distribution sample sites actually increased (A18 from 57.7 to 73.3 ppb, and A54 from 66.9 to 80 ppb) and one site stayed about the same (C04 from 52.5 to 47.2 ppb). We expect these were mostly fed by South or North Rivanna WTPs. Sites near Observatory in the distribution system (A19 and C37) did decrease from 55.0 and 61.4 to about 40 ppb .

The results did not show with confidence, as we had hoped, that a POC change would significantly lower TTHM, and allow for us to consistently comply with the Stage 2 Rule (that requires compliance at all locations in the system). It also confirmed elevated levels at LRAA points (73.3 to 80 ppb) , even with a change in POC at all plants.

HAAs (MCL 60 ppb): The six sites for HAA testing showed that one site decreased (A08 from 58.2 to 46.8 ppb) and one site increased (A54 from 47.4 to 56.6 ppb). All of the other distribution system sites showed levels that stayed basically the same (A19: 42.1 to 41.5 ppb / C37: 40.8 to 39.3 ppb / C04 23.1 to 24.0 ppb). Site A18 had very low levels which may be an outlier since the TTHMs were high. HAAs can however decrease with long water age due to biodegradation. (Note: Biodegradation is not a compliance strategy.)

Similar to the TTM results, the POC change did not indicate a significant reduction in HAAs.

Ferric Coagulation as a Solution.

The evaluation of ferric sulfate as a coagulant was evaluated in bench tests *assuming that the POC would be placed prior to filtration at all the plants*. The testing was based on taking water and treating it with ferric rather than alum, and simulating the plant conditions with free chlorine for primary disinfection, and then free chlorine or chloramines as a residual disinfectant.

Bench tests are snap shot, or a single point in time, of expected results and must be weighed with other factors such as historical raw water organics (TOC) trends, historical levels of DBPs in the system, and the realization that all points in the system, including new sample points with very long water age (time), will need to comply.

The testing of RWSA water was used to simulate relative differences in DBPs after a water age of two weeks in the distribution system (14 day SDS). We know some sites in the system have longer water age and could see higher DBPs, so the SDS test is only a relative indicator.

Tests of adding ammonia (forming chloramines) with water from the plant after disinfection was also done as a check on the ability of chloramines after free chlorine disinfection to stop DBP formation without elevated levels still leaving the plant. With chloramines, DBP formation essentially stops after water leaves the plant. All water customers see about the same level of DBPs regardless of water age. With free chlorine, growth still occurs and the concern is how high and fast DBPs form after free chlorine disinfection.

Ferric Bench Tests and Historical TOC.

The following summarizes the results of the bench tests conducted in late September and early October 2010 and key results.

North Rivanna. The DBP results of testing for North Rivanna (with a raw water TOC of 3.3 mg/L) showed that Ferric could reduce DBPs at the longer detention time locations (14 days). The use of chloramines after either alum or ferric coagulation and disinfection showed much more dramatic reductions. The results are shown below.

Strategy	TTHM ppb (MCL 80 ppb)	HAA ppb (60 ppb)
Alum	112	84
Ferric	71	48
Alum and Chloramine	29	33
Ferric and Chloramine	17	14

The results showed good reductions in TTHM from 112 to 71 ppb. The value of 71 ppb represents a 37 percent reduction in TTHM formation which is promising. However, the concentration of 71 ppb was still quite high considering and MCL of 80 ppb and a desire to be below the MCL as a strategy. HAAs showed a 43% reduction in concentration with a level of 48 ppb.

The chloramine strategy showed very low values of both TTHM and HAA around 30 ppb (or a 70% reduction vs. alum) and this would be expected throughout the distribution system. Unlike chlorine, growth of DBPs (TTHM and HAA) is stopped with little to no growth in the system after chloramines are formed.

TOC Consideration. The other factor we need to consider is the variability of the source water TOC, since both *TOC and chlorine* contribute to TTHM, HAA and other DBP byproduct formation. .

The TOC was 3.3 mg/L during the bench tests. The North Rivanna WTP raw water has also shown excursions of source water TOC as high as 7.8 to 14 ppb which is 236 to 420% of the TOC tested bench scale.

A look at the variability and possible influence on DBPs during excursions is below. These are estimates but they put the variability of TOC issue in context considering the benefit of a 37% reduction shown above (say, 111ppb to 70 ppb with Ferric). The use of chloramines is shown.

Ferric as a solution:

TTHM: 71 ppb with Ferric x TOC ratio (2.36) = 168 ppb
 HAA: 48 ppb with Ferric x TOC ratio (2.36) = 113 ppb

→ *Well above the 80/60 MCLs as a goal for individual samples and likely MCL violation*

Chloramines as a solution:

TTHM w Chloramine and Ferric: 17 ppb x TOC ratio = 40 ppb
 HAA w Chloramine and Ferric: 14 ppb x TOC ratio = 33 ppb

→ *Well below the 80/60 MCLs and very high tolerance even for high TOC excursion even at the high record level of 14 mg/L above.*

Observatory. The bench results of testing for Observatory (with a raw water TOC of 2.2 mg/L) showed that Ferric *did not* reduce TTHM or HAA at the long detention time locations (based on 14 days). *The testing simulated chlorine added prefilter, and not at the head of the plant.*

The plant was using PACl (polyaluminum chloride) at the time so it was tested along with alum. The results are shown below:

Strategy	TTHM ppb (MCL 80 ppb)	HAA ppb (60 ppb)
Alum / PACl	77 / 75	38 / 45
Ferric	76	36
Alum / PACl and Chloramine	21 / 21	17 / 15

Ferric and Chloramine	19	17
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The ferric results showed no reductions in TTHM with all values in the mid-70s. *Values were near the MCL of 80 ppb.* The HAAs for alum and ferric were about the same at 38 and 36 respectively. The chloramine strategy showed very low values of both TTHM and HAA under 20.6 ppb) and this would be expected throughout the distribution system.

TOC Consideration. Based on historical data, the TOC of 2.2 mg/L during the bench tests was about the 67th percentile. The Observatory WTP raw water has also shown periodic excursions of source water TOC as high as 4.8 mg/L, or 220% higher than the bench tests. Again, these periods would create higher DBPs regardless of coagulant used.

Similar to the discussion earlier, for the impact of higher TOC (except using 220% peak value in this case); chloramines leaves low DBP values in the distribution system at 46 ppb TTHM and 37 ppb HAA; well below 80/60 MCL values.

South Rivanna. The bench results of testing for South Rivanna WTP (with a raw water TOC of 2.9 mg/L), like the tests above, evaluated ferric as well as the difference in raw (head of the plant) versus prefilter chlorination on DBPs at long detention times.

The ferric data for free chlorine were considered inaccurate as the DBPs were 11 ppb or less which is impossible with free chlorine since the chloramines values were higher. (Sample preparation or lab error is suspect.)

As with the other plants, the use of chloramines after either alum or ferric coagulation and chlorine disinfection showed good reductions. The results are shown below.

Strategy	TTHM ppb (MCL 80 ppb)	HAA ppb (60 ppb)
Alum w PreFilter Cl ₂ / Raw Cl ₂	102 / 98	65 / 100
Ferric	N/A* (64 est)	N/A* (37 est)
Alum and Chloramines	26	26
Ferric and Chloramines	21	15

*Lab or preparation error. Estimate based on results seen at NR.

Moving the POC (currently done seasonally) resulted no TTHM change with values about 100 ppb, and about a 35% reduction in HAA on this test day from 100 to 65 ppb.

The chloramine strategy showed very low values of both TTHM and HAA under 30 ppb (or a 70% reduction vs. alum).

TOC Consideration. Based on historical data, the TOC of 2.9 mg/L during the bench tests was about the 64th percentile value.

The South Rivanna WTP raw water has also shown excursions of source water TOC as high as 6.0 to 7.8 mg/L, which is 210 to 270% of the TOC tested bench scale. These periods would create higher DBPs. Similar to the other options, chloramines or ferric

and chloramines can tolerate very high TOC levels much better than the ferric alone option.

Answer to the Question based on Summary of Discussion:

POC data did not show significant reductions based on full scale testing at the future monitoring sites tested. The results were mixed and some data very near the MCL. All of the plants feed the distribution system and mixing of waters takes place. The IDSE data collected in 2007 also showed high DBP values in water from these plants while the plants (NR and SR) were using pre-filter chlorination.

Ferric testing with a POC change in bench tests showed good reductions at North Rivanna and South Rivanna but not Observatory. The reductions would help but the level of DBPs with ferric were still near the TTHM MCL of 80 ppb. (North Rivanna = 71ppb/ Observatory = 76 ppb) Stage 2 D/DBP sites with higher water age and considering TOC variability, could have higher levels than the bench testing snap shot, so we need to be conservative in the compliance strategy.

The variability in TOC makes the use of POC and ferric coagulation a move in the right direction; but we **cannot be assured of compliance** which is the goal. Ferric would compliment chloramines well in the future (if it is needed) and it could be implemented fairly quickly. It is a logical tool for “further optimization” should an operational evaluation be triggered in the future.

In Summary:

Positives: The change in point of chlorination at all the plants all the time can help lower TTHM and HAAs. Ferric coagulation can also help lower these DBPs.

The reasons we consider it a risk as a stand-alone answer for compliance:

- Highly variable source water TOC, water age, and temperature will impact TTHM and HAA levels
- Full scale tests evaluating POC showed mixed results with some high levels of DBPs
- Bench tests results with high levels of DBPs, and still did not reflect the higher (and highest) TOC levels often seen based on historical data.
- New compliance monitoring points will be needed to reflect worse case concentrations including long water age
- We should be conservative with strategies to meet drinking water standards if possible.

*Note: Other factors, which were not considered specifically in this study, but a general consideration for some utilities, is the impact of **climate change** and the concern for warmer water causing more algae blooms, droughts, and more variability (or higher TOC excursions) in source water quality in the future.*

*Also, the issue of **water conservation** is also being discussed industry wide as conservation creates lower water demand, longer water age and more DBPs as time and free chlorine increases concentrations of TTHM.*