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To:	Jeff Cameron, Amy Blain – City of Longview	**Date:**	July 29, 2015
From:	Stephen Booth, Michael Hallett, and Melinda Friedman – Confluence	**Project:**	Softening Alternatives & Baltimore Street Water Quality Evaluation
Cc:		**Subject:**	Home Water Quality Profiling - Final

Introduction and Objectives

Water quality conditions within the City's distribution system have improved significantly since the summer of 2014, however, some customers are experiencing tastes and odors at the tap. It is possible that water quality may be degrading within premise plumbing and this degradation could be contributing to these taste and odor issues. The objective of this task was to profile water quality at two premises to better understand if the chemistry of the water in the system may be changing between the distribution system main and the customer's tap.

Testing Approach

Water quality profiling was performed at the following two homes:

- **Home A**: 500 block of 19th Ave, sampled May 13, 2015. PEX plumbing was installed during a 2007 remodel. The home likely has a 1-inch line between the meter and the home and ½-inch PEX pipe within the home.
- **Home B**: 2600 block of Garfield St, sampled on May 27, 2015. House is of 1968 construction and Type L copper (¾-inch) tubing connects the meter to the point of entry to the home and plumbing within the home is PEX (½-inch).

Confluence prepared mobile analytical equipment and coordinated with City staff and three laboratories for analysis of the samples collected at each of these homes. Sampling at Home A began at 7am after a 6 to 8 hour standing time. Sampling at Home B began in the afternoon, after the home had been unoccupied for several days.

Sampling and Analysis Plan

For each home, samples were collected from the kitchen cold tap, a bathroom cold water tap, and the hot water tap in a bathroom. The kitchen tap was sampled first followed by the bathroom cold tap. A series of sequential 500-mL aliquots, with no delay between filling each bottle, were collected from each cold water tap. A 1-gallon sample was then collected from the bathroom hot water tap and a 1-gallon sample was also collected from the hydrant nearest the home after several minutes of flushing, to be representative of distribution system water.

Free and total chlorine residuals, cellular ATP (cATP), and turbidity, along with iron and manganese (for Home B only) were determined on each of the individual aliquots to provide a water quality profile of both cold taps. Once that analysis was complete a composite sample was prepared to provide sufficient

volume for the required lab tests. In addition to the aforementioned analyses, iron and sulfur bacteria, HPC, sulfide, and Flavor Rating Assessment (FRA) tests were performed on the composite samples. This range of analyses was selected to provide an adequate characterization of in-home water quality with the overall goal of determining if any significant degradation in water quality occurred between the distribution system and the customer's tap.

pH, temperature, DO, and ORP were measured using a Hach HQ 40 with appropriate probes and turbidity was measured using a Hach 2100Q portable turbidimeter. Temperature was measured within each home during sample collection. The samples were then taken to the MFRWTP where selected analyses were performed. The aliquots were then composited and samples were sent to laboratories for analyses. Locations of analyses and methods used in this study are presented in Table 1.

Table 1. Analytical Methods and Analysis Locations

Parameter	Analysis Location	Method
Free Cl_2 (mg/L)	MFRWTP	Hach 10245
Total Cl_2 (mg/L)	MFRWTP	Hach 8167
Fe (mg/L)	MFRWTP/ALS Analytical	Hach 8008/EPA 200.7
Mn (mg/L)	MFRWTP/ALS Analytical	Hach 8149/EPA 200.7
cATP (pg/mL)	MFRWTP	Luminultra QGA
Iron Bac. (#/L)	Water Management Laboratories	Microscopic examination
Sulfur Bac. (#/L)	Water Management Laboratories	Microscopic examination
HPC R2A[1] (CFU/mL)	Water Management Laboratories	SM 9215C
Sulfide (mg/L)	ALS Analytical	SM 4500-S2-D
Flavor Rating Assessment	SPU Laboratory	SM 2160

Notes:
1. Incubated for 7 days at 26 °C.

Results

Temperature Data

Temperature data for the sequential aliquots collected at the kitchen and bathroom cold taps in Home A are presented in Figure 1. The water temperature was initially somewhat higher in the bathroom and kitchen cold water taps compared to the distribution system. The water remained somewhat warmer compared to the distribution system for the first four aliquots. The temperature of the fifth aliquot was close to the distribution system water temperature.

Temperature data for the sequential aliquots drawn from Home B are presented in Figure 2. Water temperatures were higher in Home B compared to Home A and the kitchen cold tap temperature was initially higher than that of the bathroom cold tap. Water temperatures for both taps stabilized at close to 16°C and remained above the temperature measured in the distribution system of 13.1°C. The lateral connecting this home to the system may have been longer than for Home A resulting in either a significantly longer time for the in-home cold water temperature to equalize with that of the system or a higher steady state temperature within the home than that of the system. The cold water temperature in the home remained above the distribution system temperature during this testing.

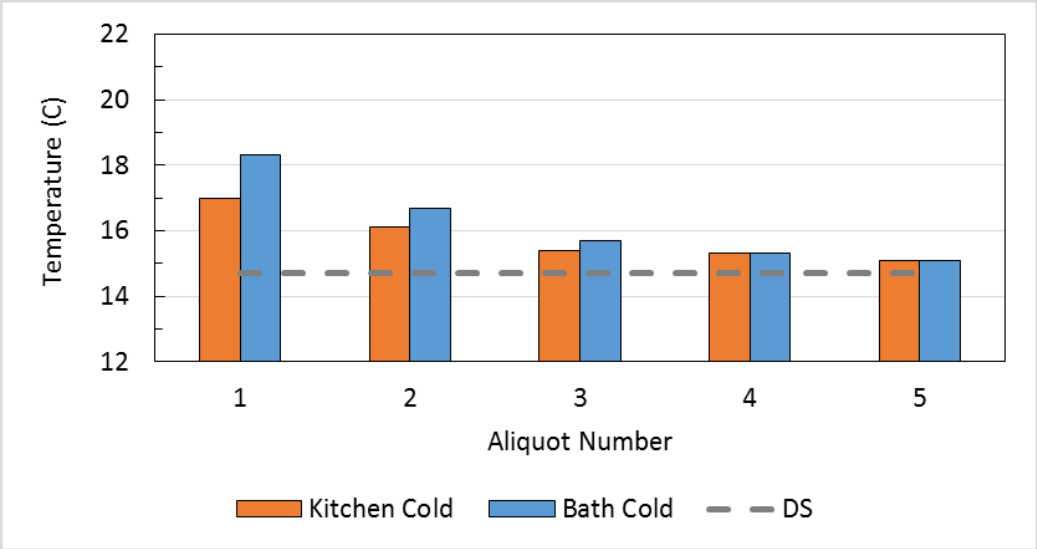

Figure 1. Temperature data for Home A.

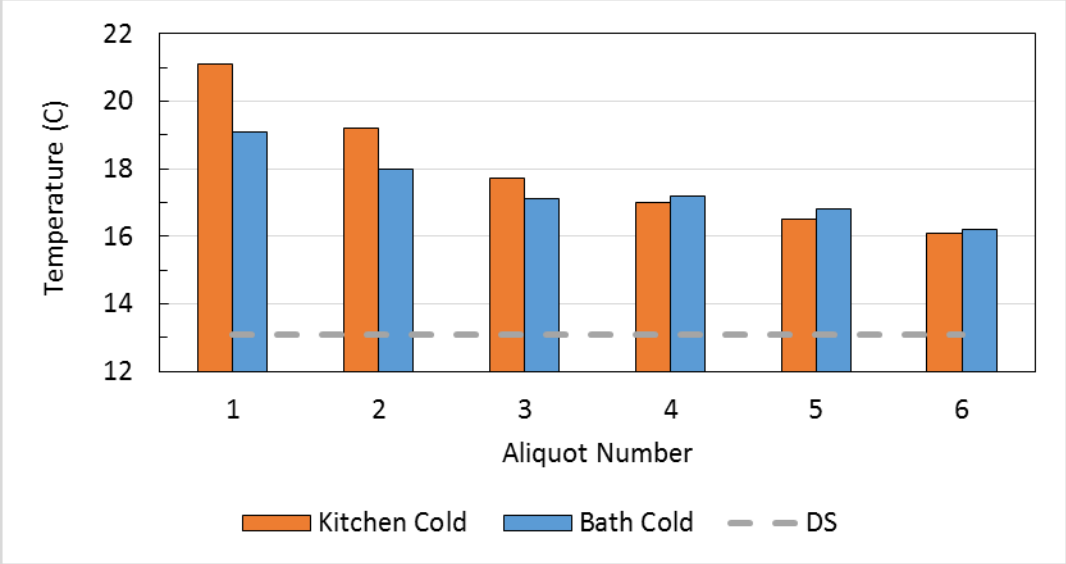

Figure 2. Temperature data for Home B.

Water Quality Data for Home A

Water quality data measured at the kitchen and bathroom taps for Home A are presented in Tables 2 and 3, respectively. The distribution system water quality monitoring program conducted by the City indicated that a free chlorine residual of ≥ 0.6 mg/L generally helped to keep iron and manganese levels to acceptable levels in the system. The free chlorine residual measured in the distribution system near Home A was below that level and iron was above the secondary MCL of 0.3 mg/L, although manganese was low. cATP was only slightly above the test kit vendor's suggested target of 0.5 pg/mL for good microbial control. The water also had a low level of HPCs and no detectable sulfur bacteria, however, iron bacteria were detected.

Table 2. Water Quality Data for Distribution System and Home A Kitchen Cold Tap

Parameter[1]	D.S.[2]	Kitchen Cold Tap Aliquots					
		1	2	3	4	5	C[3]
Free Cl_2 (mg/L)	0.35	0.22	0.13	0.11	0.12	0.17	-
Total Cl_2 (mg/L)	0.41	0.28	0.20	0.16	0.20	0.13	-
Turbidity (NTU)	-	-	0.24	0.21	0.23	0.23	-
Fe (mg/L)	0.502	-	-	-	-	-	0.118
Mn (mg/L)	0.0058	-	-	-	-	-	0.0026
cATP (pg/mL)	0.55	2.54	0.44	3.55	0.72	0.17	-
Iron Bac. (#/mL)	15	-	-	-	-	-	1.5
Sulfur Bac. (#/mL)	ND	-	-	-	-	-	ND
HPC (CFU/mL)	15	-	-	-	-	-	76
Sulfide (mg/L)	<0.005	-	-	-	-	-	<0.005

Notes:

1. Samples collected at Home A were taken to the MFRWTP where chlorine residuals, turbidity, and cATP were measured. All other parameters were sent to laboratories for analysis.
2. Additional distribution system water quality data are as follows: pH = 7.8, temperature = 14.7 °C, DO = 0.55 mg/L, ORP = 618 mV.
3. Composite of the individual aliquots.

Table 3. Water Quality Data for Distribution System and Home A Bathroom Taps

Parameter[1]	D.S.[2]	Bath Cold Tap Aliquots						Bath Hot
		1	2	3	4	5	C[3]	
Free Cl_2 (mg/L)	0.35	0.12	0.35	0.37	0.41	0.51	-	<0.05
Total Cl_2 (mg/L)	0.41	0.19	0.38	0.44	0.49	0.44	-	<0.02
Turbidity (NTU)	-	-	0.21	0.17	0.16	0.13	-	0.15
Fe (mg/L)	0.502	-	-	-	-	-	0.085	0.048
Mn (mg/L)	0.0058	-	-	-	-	-	0.0022	0.0024
cATP (pg/mL)	0.55	1.21	0.18	0.15	0.16	0.10	-	2.17
Iron Bac. (#/mL)	15	-	-	-	-	-	0.42	1.3
Sulfur Bac. (#/mL)	ND	-	-	-	-	-	0.02	ND
HPC (CFU/mL)	15	-	-	-	-	-	28	970
Sulfide (mg/L)	<0.005	-	-	-	-	-	<0.005	0.0062

Notes:

1. Samples collected at Home A were taken to the MFRWTP where chlorine residuals, turbidity, and cATP were measured. All other parameters were sent to laboratories for analysis.
2. Additional distribution system water quality data are as follows: pH = 7.8, temperature = 14.7 °C, DO = 0.55 mg/L, ORP = 618 mV.
3. Composite of the individual aliquots.

Free chlorine residuals were detectable but somewhat lower in the kitchen cold tap compared to that of the distribution system for all aliquots. After collecting samples from the kitchen cold water tap, samples were than collected from the bathroom cold tap. The chlorine residuals in the first aliquot from the bathroom cold tap remained below that of the distribution system, however, subsequent aliquots had comparable chlorine residuals comparable to the distribution system. Turbidities remained low in both the bathroom and kitchen cold taps indicating a low level of suspended solids. Iron and manganese levels were lower within the home compared to the distribution system at all sampling locations.

cATP results were variable for the kitchen cold tap and there appeared to be a general trend of decreasing levels of cATP with increasing volume of water collected from the bath cold tap. The low chlorine residuals in the home plumbing resulted in some microbiological growth in the bulk water and/or some degree of biofilm development and sloughing as the taps were run to collect the samples. Microbiological water quality stabilized with corresponding lower levels of cATP as the volume of water collected from the house increased.

FRA data for Home A are presented in Figure 3. The distribution system water had the lowest average FRA score and no discernible odors or tastes were noted by the panelist performing the analysis, despite iron being greater than the secondary MCL and some evidence of microbial activity. Both the kitchen and bathroom cold taps had somewhat elevated FRA scores with a slight pencil shaving odor and taste. A pencil shaving taste and odor has been attributed to plastic pipe used for home plumbing, such as PEX used in both the homes included in this study. The hot water in the bathroom had a sulfur odor exceeding the threshold SPU considers unacceptable (*i.e*. average FRA ≥ 5). The sulfur odor would likely be objectionable to Longview residents.

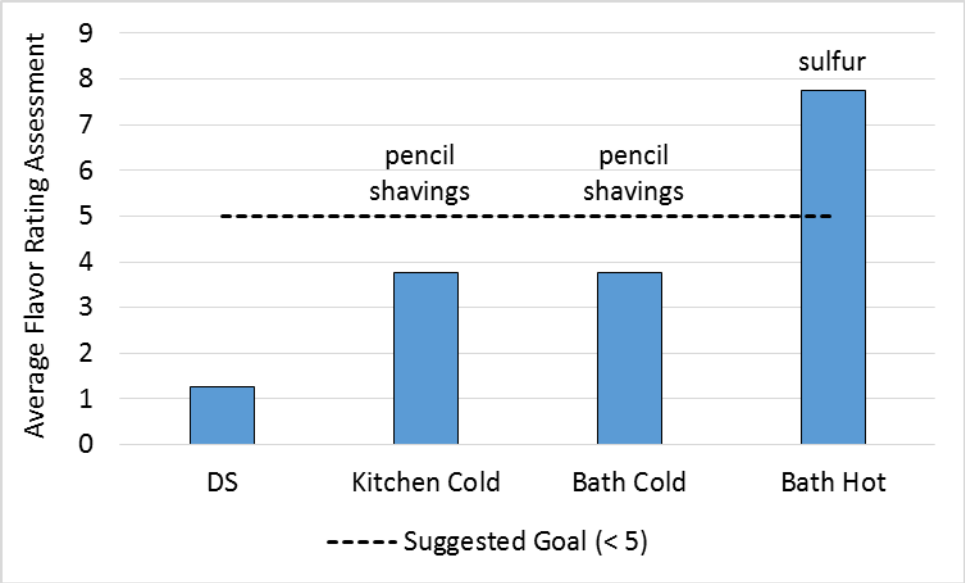

Figure 3. FRA data for Home A.

Sniff tests were performed on individual aliquots as an informal indication of the presence of odors which may be objectionable to consumers. Sniff tests indicated a slight sulfur odor in the first aliquot collected from the bathroom cold tap of Home A. A slight chlorinous odor was also noted in a majority of the aliquots collected from both the kitchen and bathroom despite the low chlorine residuals.

Water Quality Data for Home B

Water quality data measured at the kitchen and bathroom taps for Home B are presented in Tables 4 and 5, respectively. The distribution system water near Home B had a free chlorine residual of approximately 1 mg/L and low levels of turbidity, iron, and manganese. cATP was also low and neither sulfur bacteria nor HPCs were detected, however, iron bacteria were detected in the distribution system water.

Table 4. Water Quality Data for Distribution System and Home B Kitchen Cold Tap

Parameter[1]	D.S.[2]	Kitchen Cold Tap Aliquots						
		1	2	3	4	5	6	C[3]
Free Cl_2 (mg/L)	0.99	<0.05	0.10	0.07	<0.05	0.05	<0.05	<0.05
Total Cl_2 (mg/L)	1.15	0.04	0.16	0.16	0.04	0.04	<0.02	0.03
Turbidity (NTU)	0.21	0.05	0.04	0.06	0.07	0.10	0.13	-
Fe (mg/L)	0.054	<0.02	-	<0.02	-	<0.02	-	<0.02
Mn (mg/L)	0.0059	0.015	-	<0.005	-	0.019	-	<0.001
cATP (pg/mL)	0.09	2.02	0.85	0.04	0.40	0.11	0.22	0.31
Iron Bac. (#/mL)	0.8	-	-	-	-	-	-	0.38
Sulfur Bac. (#/mL)	ND	-	-	-	-	-	-	ND
HPC (CFU/mL)	ND	-	-	-	-	-	-	200
Sulfide (mg/L)	<0.005	-	-	-	-	-	-	<0.005

Notes:

1. Samples collected at Home B were taken to the MFRWTP where chlorine residuals, turbidity, and cATP were measured. All other parameters were sent to laboratories for analysis, except iron and manganese on the individual aliquots which were measured at the MFRWTP.
2. Additional distribution system water quality data are as follows: pH = 7.8, temperature = 13.1 °C, DO = 0.12 mg/L, ORP = 696 mV.
3. Composite of the individual aliquots.

Table 5. Water Quality Data for Distribution System and Home B Bathroom Taps

Parameter[1]	D.S.[2]	Bath Cold Tap Aliquots							Bath Hot
		1	2	3	4	5	6	C[3]	
Free Cl_2 (mg/L)	0.99	0.43	0.76	0.43	0.28	0.52	0.67	0.40	<0.05
Total Cl_2 (mg/L)	1.15	0.46	0.95	0.51	0.55	0.59	0.71	0.42	<0.02
Turbidity (NTU)	0.21	0.07	0.05	0.05	0.07	0.09	0.09	-	0.08
Fe (mg/L)	0.054	0.03	-	0.02	-	0.04	-	<0.02	<0.02
Mn (mg/L)	0.0059	0.016	-	0.011	-	0.005	-	<0.001	0.0017
cATP (pg/mL)	0.09	0.38	0.30	0.56	0.26	0.24	0.15	0.15	1.52
Iron Bac. (#/mL)	0.8	-	-	-	-	-	-	0.92	0.1
Sulfur Bac. (#/mL)	ND	-	-	-	-	-	-	ND	ND
HPC (CFU/mL)	ND	-	-	-	-	-	-	7	50
Sulfide (mg/L)	<0.005	-	-	-	-	-	-	<0.005	<0.005

Notes:

1. Samples collected at Home B were taken to the MFRWTP where chlorine residuals, turbidity, and cATP were measured. All other parameters were sent to laboratories for analysis, except iron and manganese on the individual aliquots which were measured at the MFRWTP.
2. Additional distribution system water quality data are as follows: pH = 7.8, temperature = 13.1 °C, DO = 0.12 mg/L, ORP = 696 mV.
3. Composite of the individual aliquots.

Although the distribution system water near Home B had an acceptable level of free chlorine (above 0.6 mg/L), chlorine residuals for the kitchen cold tap were much lower with some samples below the detection limit (Table 4). Turbidity, iron, and manganese were all low and within acceptable ranges for all the kitchen cold tap aliquots. Iron and sulfur bacteria in the kitchen cold tap composite sample were similar to that of the distribution system. cATP levels in the first two kitchen cold tap aliquots were elevated

compared to that of the distribution system. Sulfides were not detected in either the kitchen or bathroom cold taps.

Chlorine residuals were higher in the bathroom cold tap compared to the kitchen cold tap and approached the residuals measured in the distribution system. The higher chlorine residuals measured in the bathroom compared to the kitchen tap are likely due to the fact that the bathroom was sampled after the kitchen. It is likely that a sufficient volume of water had been collected in the kitchen such that the water collected at the bathroom reflected fresh distribution system water beginning to enter the home and blending with existing water within the premise plumbing.

Turbidity, iron, and manganese in the bathroom cold tap were all similar to that of the distribution system. All aliquots collected in the bathroom had higher levels of cATP than the distribution system. Levels of iron and sulfur bacteria at the tap were similar to the distribution system. HPC levels were somewhat elevated at the bathroom hot water tap, compared to other sampling locations.

Average FRA scores for Home B are presented in Figure 4. The distribution system water had only a slight chlorine odor. Both the kitchen and bathroom cold taps had elevated objectionable odors including pencil shaving and sulfurous taste and odor. The hot water tap in the bathroom was the most objectionable with a sour milk taste and odor, possibly indicating elevated anaerobic microbiological activity occurring within the hot water tank. The FRA test is more sensitive with regard to the detection of sulfurous odors compared to the chemical analytical method, for which, sulfides were not detected in Home B (Tables 4 and 5).

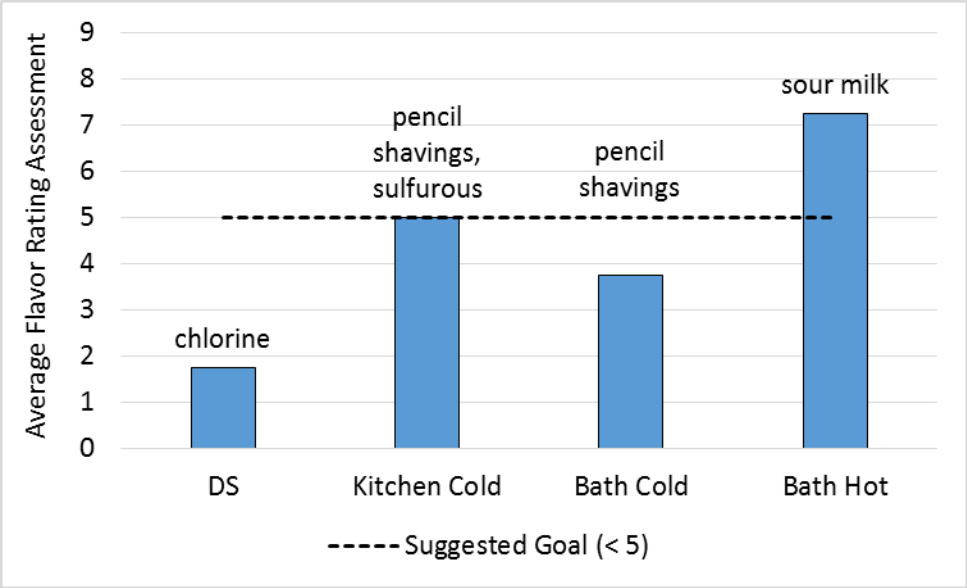

Figure 4. FRA data for Home B.

Discussion

cATP data collected in Homes A and B are presented graphically in Figures 5 and 6, respectively. A level of 0.5 pg/mL or less is suggested by the cATP test kit vendor as representing good microbial control. The kitchen tap water and bathroom hot water had higher levels of cATP compared to the bathroom cold water tap for Home A. The lower levels of cATP in the bathroom cold tap may be a result of having drawn sufficient volume at the kitchen tap such that the water collected at the bathroom cold water tap was

likely at least a mix of fresh distribution system water, having a higher chlorine residual, with the water that had been standing in the premise plumbing. The lower chlorine residuals measured in both the distribution system and premise plumbing of Home A corresponded with higher cATP levels. Consistently running water at the tap appeared to improve water quality with respect to these two microbiological parameters for both homes.

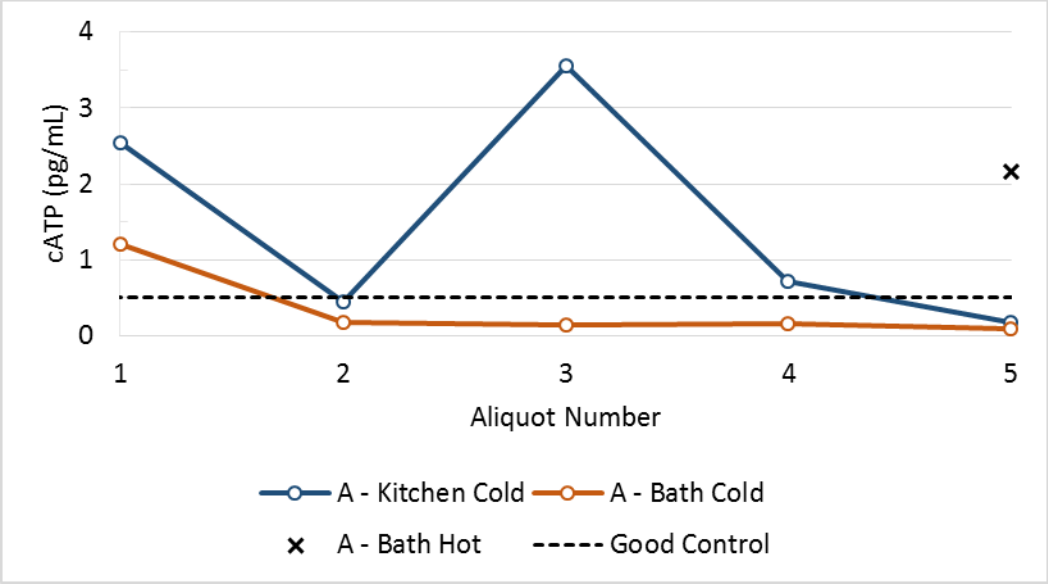

Figure 5. cATP data for Home A.

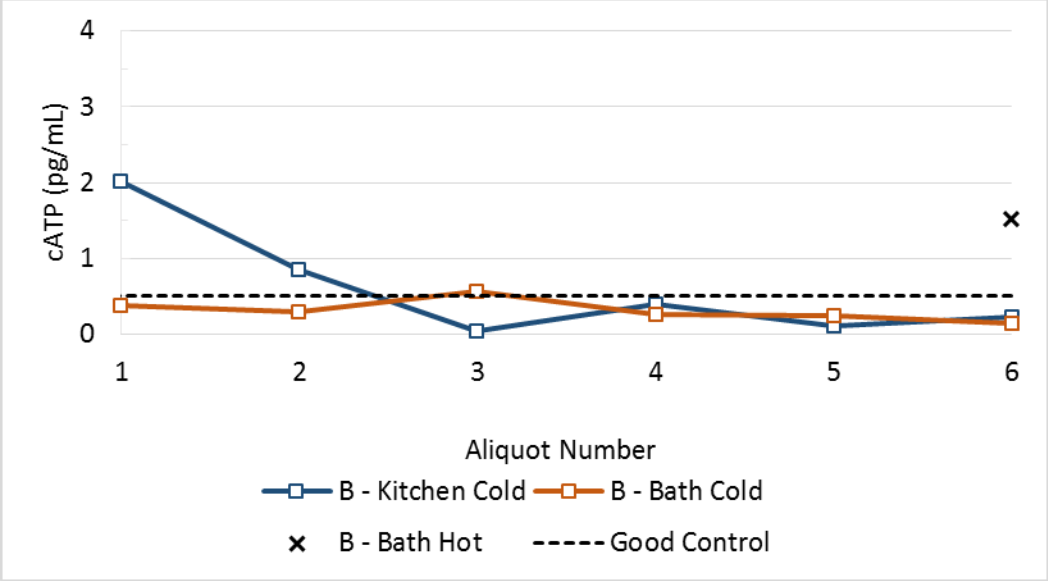

Figure 6. cATP data for Home B.

With regard to Home B, the kitchen tap had higher levels of cATP compared to the bathroom cold tap for the first two aliquots. Subsequent aliquots for the kitchen and bath cold taps had similar levels of cATP. The bathroom hot tap had a higher level of cATP than the bathroom cold tap. In general, cATP levels were

lower at Home B compared to Home A, likely due to the higher level of free chlorine residual in the distribution system at the time of sampling. Both homes had low chlorine residuals in the first several aliquots drawn from the kitchen tap. The elevated cATP and low chlorine residuals for the kitchen cold tap indicate growth of microbes in the bulk water and/or biofilm development within premise plumbing. If a biofilm forms within premise plumbing it would tend to cause an increase in the rate of chlorine residual decay.

Figure 7 presents a compilation of all the cATP and free chlorine residual data collected in this study. When the free chlorine residual is above 0.3 mg/L corresponding cATP levels are generally ≤ 0.5 pg/mL, indicating good microbial control. When the free chlorine residual falls below 0.3 mg/L, cATP becomes more variable with the majority of the data points in excess of 0.5 pg/mL. Maintaining a free chlorine residual in the distribution system of at least 0.6 mg/L will likely help to increase the free chlorine residual within homes, which in turn, will likely help to control microbial growth within premise plumbing.

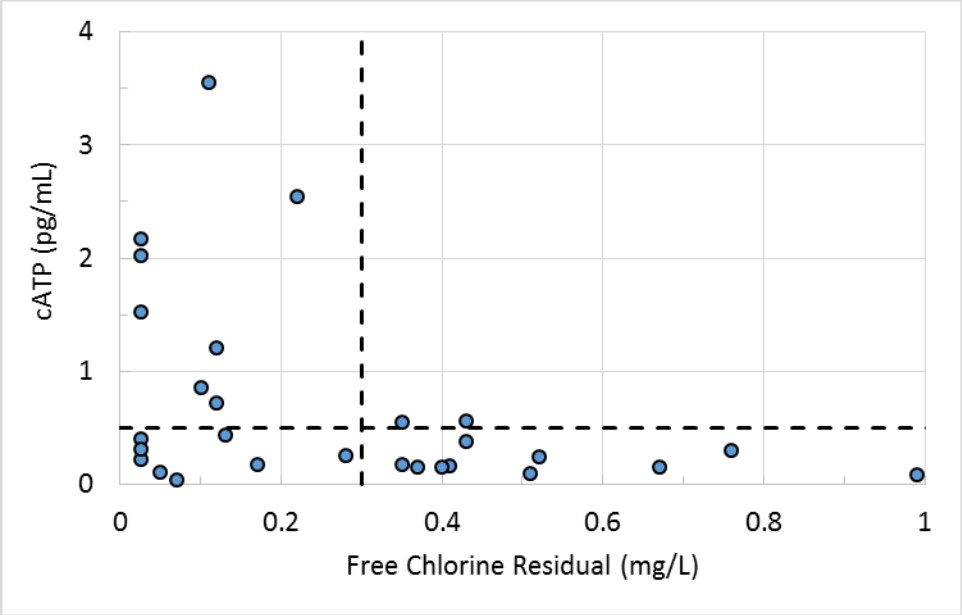

Figure 7. Correlation of cATP and free chlorine residual data.

HPC data for Homes A and B are presented in Figure 8. Distribution system levels of HPCs were reasonably low at both sampling locations. The kitchen cold tap composite samples had HPC levels one to two orders of magnitude higher than in the distribution system. The bathroom cold tap composite samples were of the same order of magnitude as the corresponding distribution system samples. The HPCs in the bathroom hot water tap were two and one order of magnitude greater than the corresponding distribution system samples for Homes A and B, respectively.

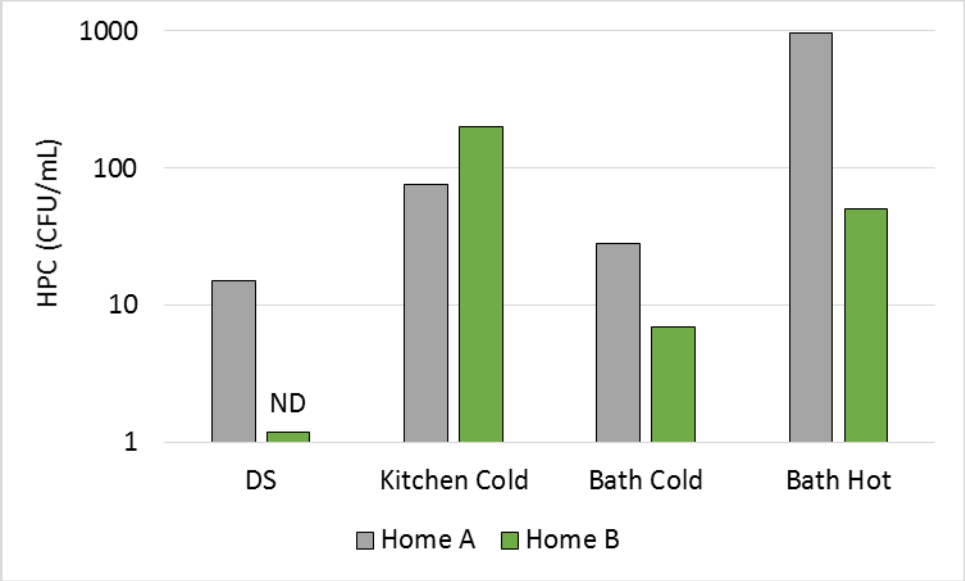

Figure 8. HPC data summary.

Conclusions

Objectionable tastes and odors that are not present in the distribution system water appear to be formed in premise plumbing. Other specific conclusions from this investigation are as follows:

Microbial Activity

- Microbial activity is generally higher in the homes compared to distribution system water. This may be expected given the higher pipe wall surface area per volume of water within home plumbing systems and daily stagnation patterns resulting in higher temperatures and lower disinfectant residuals.
- The free chlorine residual within the homes were lower than that of the distribution system prior to sample collection. During subsequent sampling the microbial activity in the bulk water decreased as a function of increasing sample volume collected, indicating that flushing at the tap may help to improve water quality.
- In general, the hot water samples collected from the bathrooms had the highest microbial activity.
- In general, the kitchen cold water tap had higher levels of microbial growth compared to the bathroom cold water tap in both homes. Microbial growth in the kitchen cold water taps was likely a combination of bulk water growth and sloughing of biofilm from premise plumbing during sampling. The lower levels of microbes in the bathroom cold water taps may have been an artefact of having sampled the bathrooms after the kitchens. Fresh water had likely begun to enter the home plumbing of both homes after the kitchens were sampled.
- Sulfur bacteria were not detected in this study and low levels of iron bacteria were measured. Thus, the growth and proliferation of these bacteria may not be problematic within these homes.
- The higher free chlorine residual in the distribution system water near Home B resulted in a generally lower level of microbial activity within that home compared to Home A, which had a much lower free chlorine residual in the distribution system water.

Tastes and Odors

- In general, the aesthetic character of the water was most objectionable for the hot water from both homes. FRA tests confirmed the presence of an objectionable sulfur odor, as reported by some consumers. Sulfur odors occurred in the hot water of Home A and the kitchen cold water tap of Home B. An objectionable sour milk odor was noted in the hot water of Home B, possibly indicating anaerobic microbial growth in the hot water tank of that home. This type of microbial activity could lead to the formation of sulfides, as observed in Home A.
- The flavor descriptor of pencil shavings was noted in the cold water from both homes. This descriptor has been attributed to plastic plumbing. Both homes have plastic (PEX) plumbing which may account for the occurrence of this type of odor. Pencil shavings have also been used to describe woody or hay odors in the literature, although those odors were traced to an algal bloom in a surface water supply and, as such, would not be the cause of these odors in this case.
- A slight sulfur odor was observed in sniff tests performed during sampling of the first aliquot collected from the bathroom cold water tap of Home A, indicating a somewhat more objectionable odor in first-draw samples.
- A slight chlorinous odor was noted during sniff tests performed on individual aliquots for a majority of samples collected at Home A, even for samples with low chlorine residuals. This may be an indication of the presence of low levels of di- and tri-chloramine species potentially contributing to objectionable odors.

Iron, Manganese and Turbidity

- Iron, manganese, and turbidity within premise plumbing were found to be low for both homes and were significantly less than their secondary MCLs at all locations.
- Elevated iron levels were measured in the distribution system near Home A. It is possible that iron, stirred up during operation of the hydrant to collect the sample, was still present in the hydrant barrel during sampling, or is representative of water quality conditions in the area serving Home A.

Recommendations

In this section, recommendations are provided that homeowners and the City and can consider.

Homeowners

- Homeowners may benefit from flushing plumbing and running water at the kitchen tap until it is cold to obtain water quality more representative of the distribution system.
- To attempt to remove accumulated biofilm, homeowners can consider implementing a rigorous whole-house flush, in which aerators and screens are removed from all fixtures, and starting at the bottom floors, all taps are opened at full velocity, flowing to the drain. The homeowner then makes their way up stairs, continuing to open taps. After fresh, cold water is flowing from all taps for about 30 minutes, taps can be slowly closed, beginning at the lowest level of the house, making their way back upstairs.
- Homeowners should check the temperature settings on their hot water heaters. According to the “Water Quality Complaint Investigator’s Guide” (AWWA, 2005), the most likely cause of a sour/acidic smell is low temperature in the hot water tank.

- Homeowners may want to have the anode on their hot water heaters checked and replaced. These can become fouled over time and cause significant “rotten egg” odor. Replacing the anode may significantly improve the odor of the hot water in the house.
- Additionally, procedures for sanitizing hot water heaters are available to reduce the “rotten egg” odor.

City of Longview

- The water entering both homes was found to be of acceptable quality with regard to microbial activity, and taste and odor, however, iron levels near Home A exceeded the secondary MCL. The City should continue to reduce the iron inventory and iron release through flushing and maintenance of oxidizing conditions throughout the distribution system. Increased flushing may be appropriate in the vicinity of Home A.
- It is possible that injection of dissolved oxygen at the MFRWTP will help to combat the development of sulfurous and chlorinous odors within the distribution system and premise plumbing systems. A pilot study could be conducted at a home or within a portion of the distribution system to assess benefits.
- Prepare and distribute step-by-step instructions for homeowners to flush their piping systems.
- Prepare a Fact Sheet describing causes of sulfurous odors from hot water heaters and mitigation strategies that can be implemented by homeowners.