American Water Works Association | ACE18 ANNUAL CONFERENCE & EXPOSITION

Monitoring Drinking Water Chemical Quality Changes at a Residential Net-Zero Energy Building

Tolu Odimayomi, Maryam S. Esfandarani, Christian Ley, Jade Mitchell, Janice Beecher, Joan Rose, Juneseok Lee, Pouyan Nejadhashemi, Erin Dreelin, Tiong Gim Aw, Amisha Shah, Matt Syal, Gulshan Singh, Ryan Julien Kara Dean, Ian Kropp, and Andrew J. Whelton

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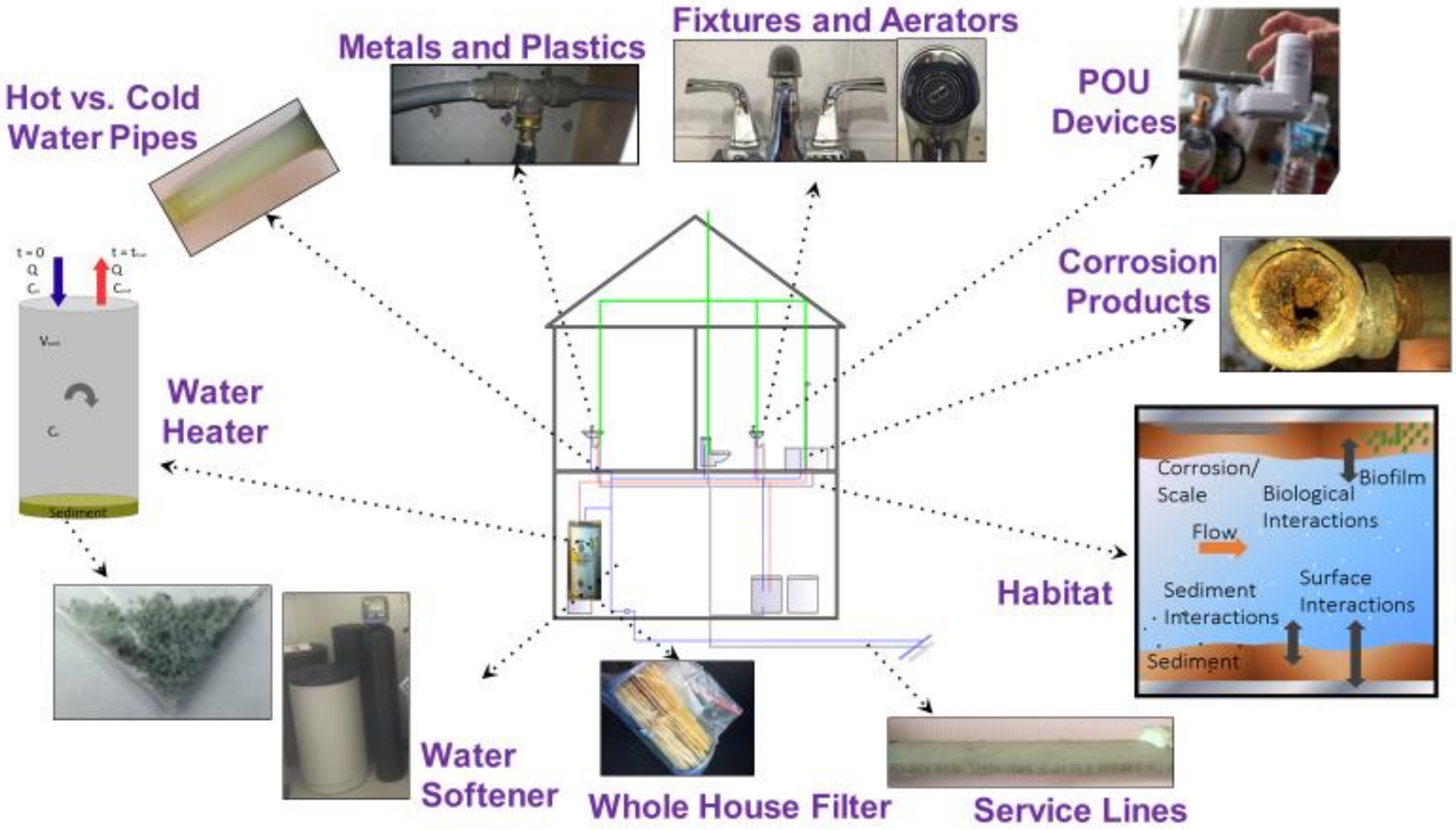

Fixtures and Aerators
Metals and Plastics
Hot vs. Cold Water Pipes
POU Devices
Corrosion Products
Water Heater
Sediment
Habitat
Corrosion/ Scale
Biofilm
Biological Interactions
Flow
Sediment Interactions
Surface Interactions
Sediment
Water Softener
Whole House Filter
Service Lines

How old is your water before reaching the faucet?

$$\frac{\text{Volume of water stored in pipes}}{\text{Flowrate of water exiting the faucet}}$$

…our water systems are not designed to handle lower use

Retrofitted Net-Zero Energy, Water and Waste

- Low flow fixtures
- Flow rate monitoring at each fixture
- Continuous water usage monitoring
- Four water heater tanks in series, three 108 gal and one 40 gal

City water: Groundwater, treated with free chlorine residual and a corrosion inhibitor, PVC and Iron water mains

PEX-A

Project Objectives

- Understand chemical and microbial variability in drinking water for this building
  - System switched to city water on October 5, 2017
  - Samples were collected every other day for one-two weeks
  - 3 sampling periods
  - No aerators removed, fixture used as is

1920s
Construction of single-family building, area: 266 m^2, 4 bedroom, 2 bath

2014
Renovated with new PEX-A plumbing, city water use only

2015
1 yr old PEX plumbing removed, new PEX-A plumbing installed, city and rainwater use

May 13-June 4 2017
Sampling Period 4

Oct 10-16 2017
Sampling Period 1

Jan 22-Feb 5 2018
Sampling Period 2

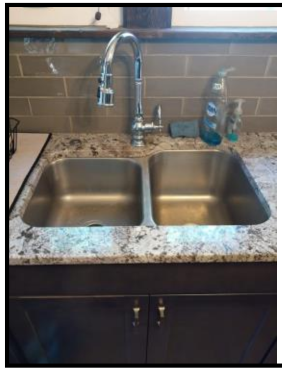
Feb 19-March 7 2018
Sampling Period 3

TODAY
AWWA ACE 18

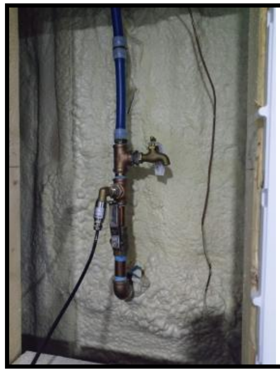
June 25-Sep 26 2018
Sampling Periods 5 & 6

Oct 2018
Switch to rain water at ReNEWW House

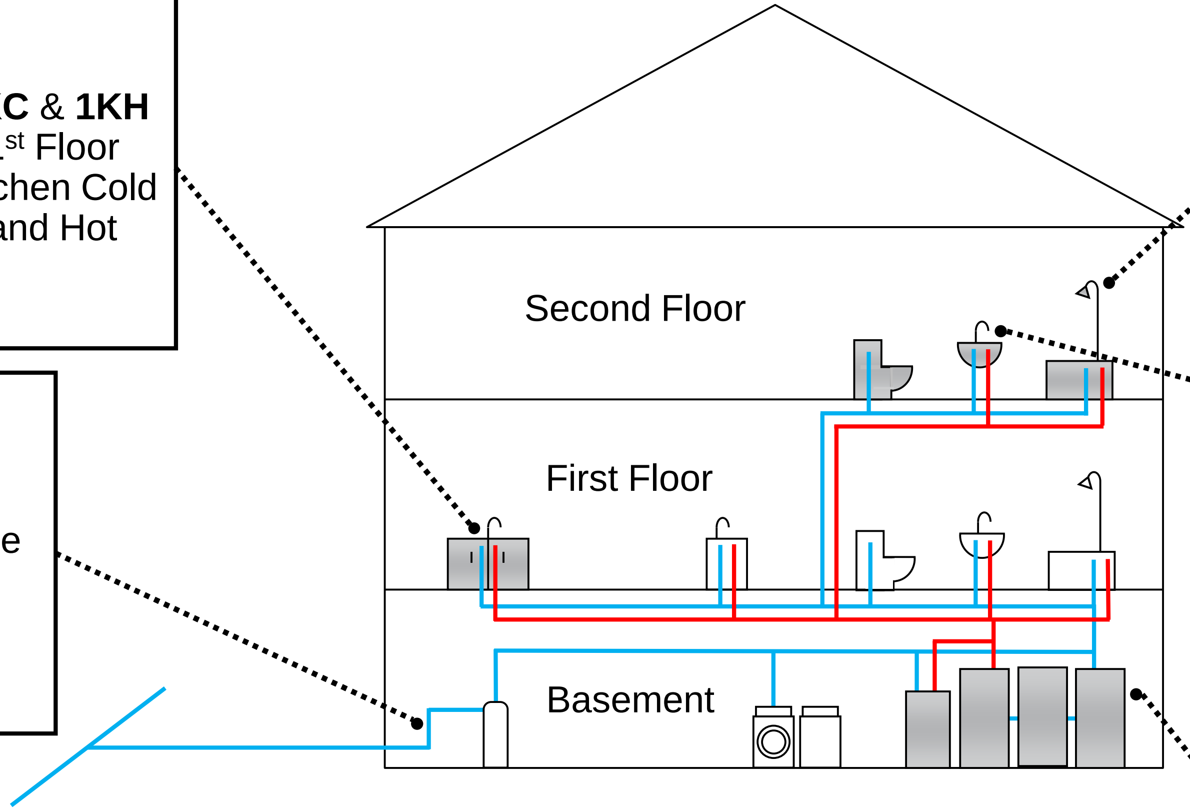
Sampling Plan



1KC & **1KH** 1st Floor Kitchen Cold and Hot



SL Service Line

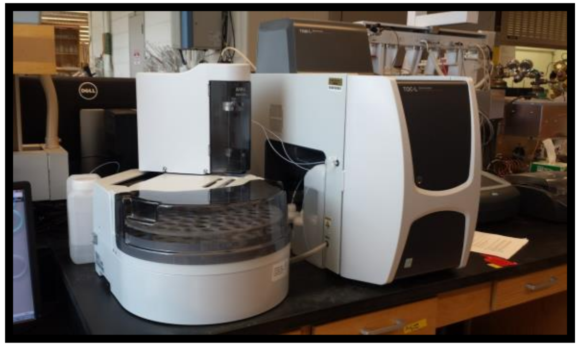


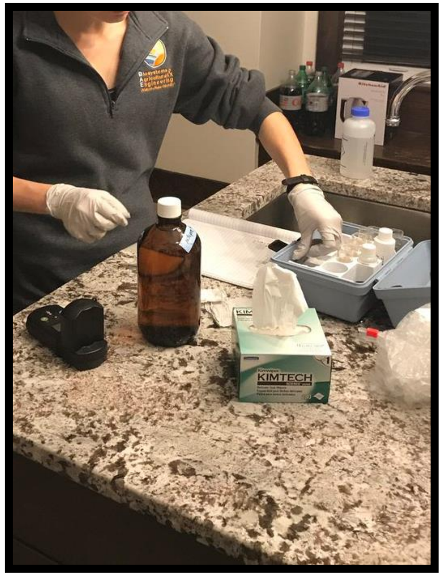
2S 2nd Floor Shower

2BC & **2BH** 2nd Floor Bathroom Sink Cold and Hot

HT Water Heater Tank

Sampling Plan





Chemical Quality

Chlorine Residual, pH, Temperature, Dissolved Oxygen (DO)
Total and Dissolved Organic Carbon (TOC, DOC)
Total and Dissolved Metals
Ion Chromatography (IC)
Total Trihalomethanes (TTHM)

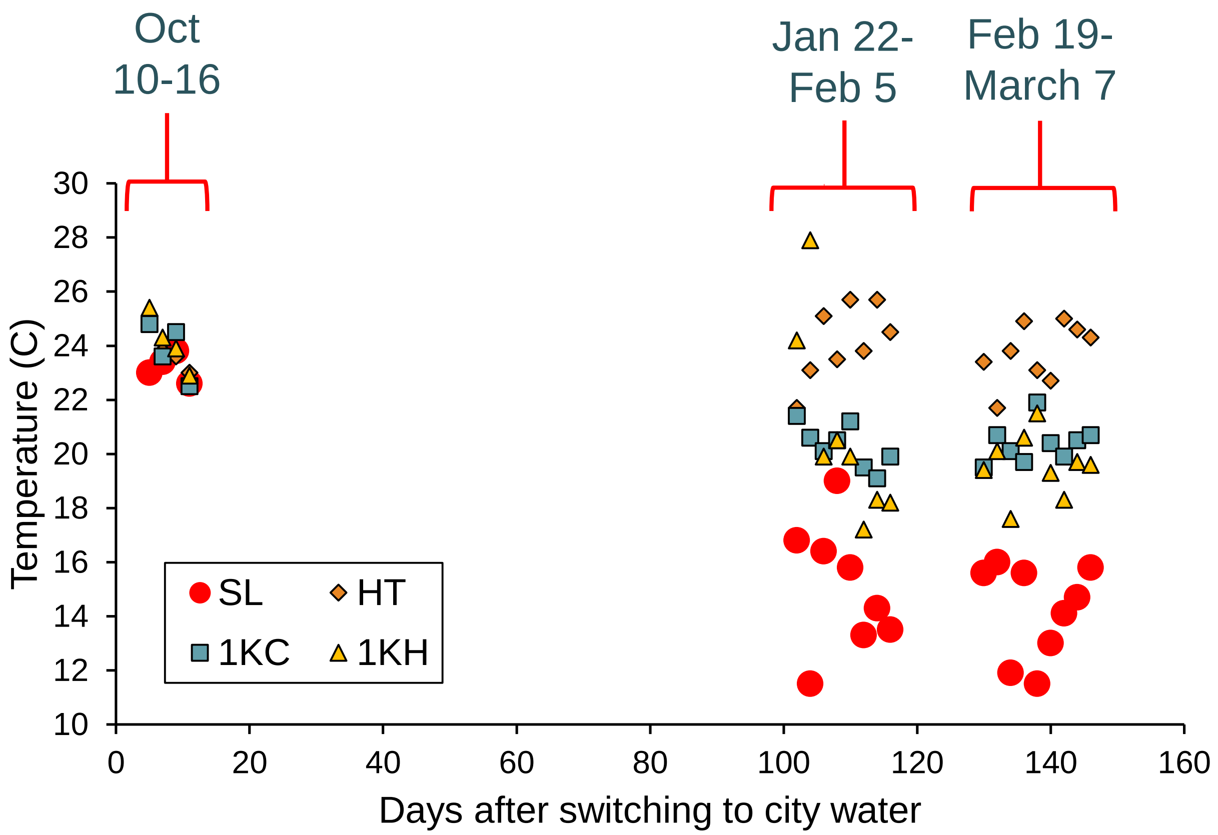
Microbial Quality

Culture-based Heterotrophic Plate Count (HPC)
Assimilable Organic Carbon (AOC)
Quantitative Polymerase Chain Reaction (qPCR)

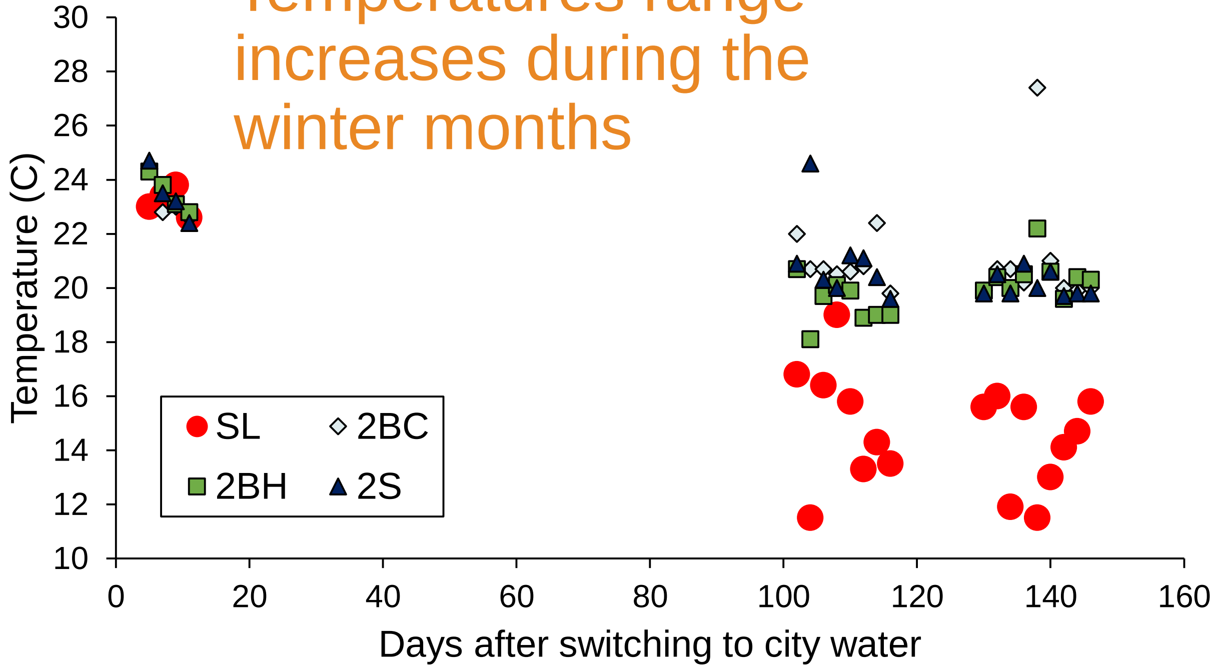
	Service Line	Cold Water Lines	Hot Water Lines	MCL[1] SDWR[2]
pH	7.65 –(7.73)– 7.81	7.60 –(8.11)– 8.66	7.66 –(8.09)– 9.00	6.5-8.5[2]
Total Chlorine (mg/L)	0.0 –(0.8)– 1.6	0.0 –(0.2)– 0.8	0.0 –(0.3)– 1.7	State Dependent
Temperature (C)	11.5 –(16.3)– 23.8	19.1 –(21.2)– 27.4	17.2 –(21.8)– 27.9	N/A
DO (mg/L)	4.5 –(9.1)– 11.1	3.8 –(7.8)– 10.3	4.0 –(8.0)– 10.8	N/A
TTHM (µg/L)	0.00 –(1.16)– 6.08	1.91 –(13.06)– 30.61	3.42 –(19.78)– 39.20	80[1]
TOC (mg/L)	0.40 –(0.47)– 0.56	0.40 –(0.68)– 1.93	0.49 –(0.80)– 2.52	N/A
Calcium (mg/L)	79.13 –(92.32)– 109.48	0.35 –(2.21)– 77.29	0.50 –(1.64)– 14.19	N/A
Iron (µg/L)	5.4 –(16.7)– 40.3	4.2 –(12.9)– 33.6	6.2 –(9.0)– 13.0	300[2]

[1]Maximum Contaminant Level
[2]Secondary Drinking Water Regulation

Water Temperature



Temperatures range increases during the winter months

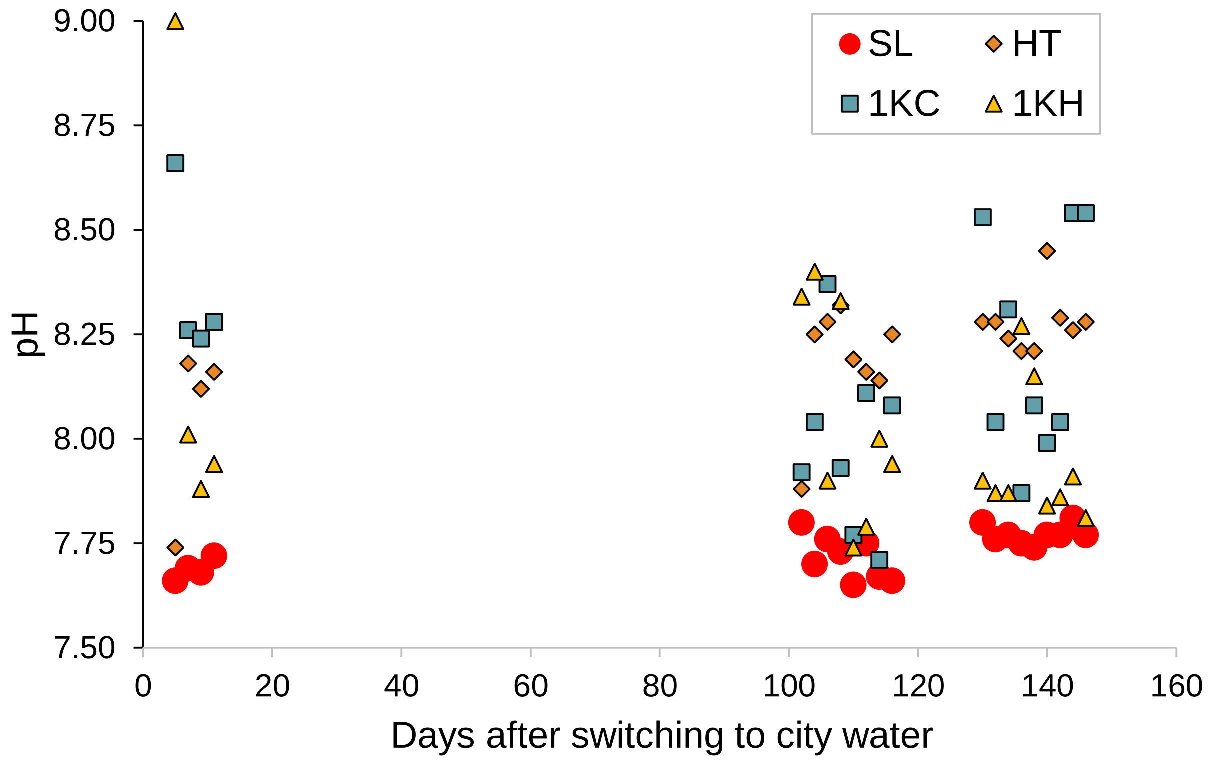


Water pH

pH levels within the house where higher compared to city water

Little change was seen in average pH across the sampling periods

Water pH ranged from 7.6 to 9.0

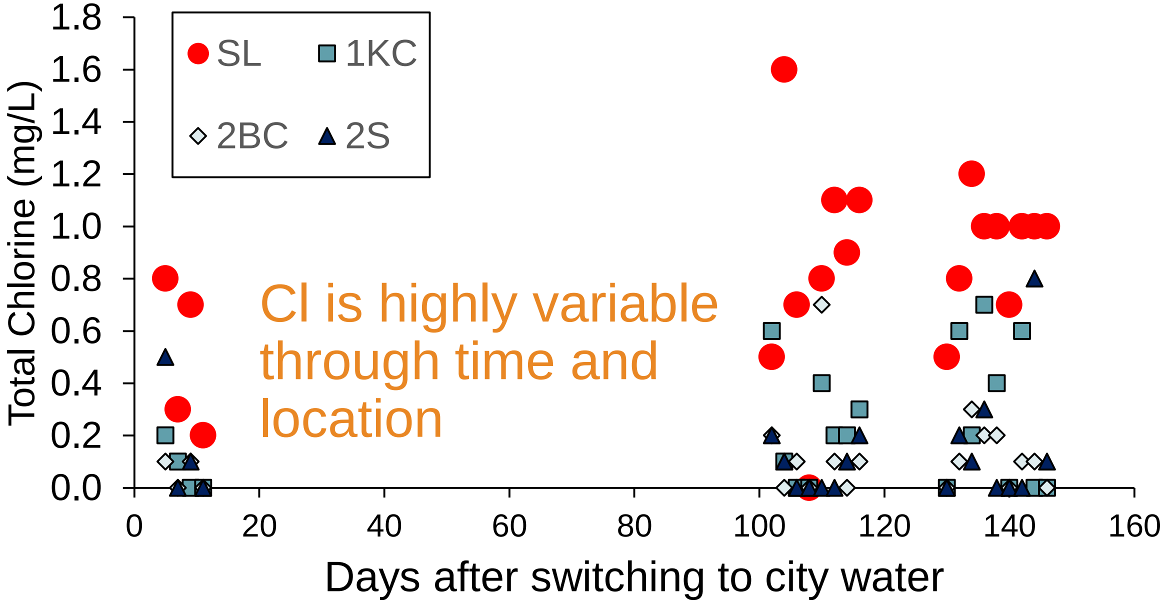


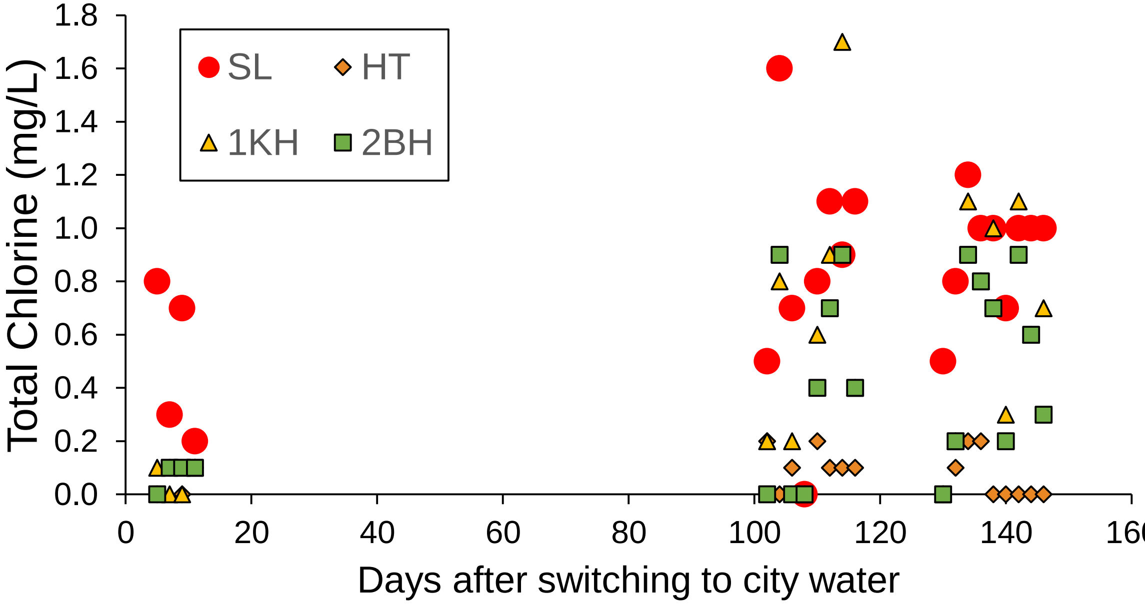
Total Chlorine

Chlorine residual is greatest at in the city water

Chlorine level ranged from 0.0 to 1.7 mg/L

Total chlorine is undetectable for over 60% of samples taken at the water heater and shower





Where and how is chlorine lost?

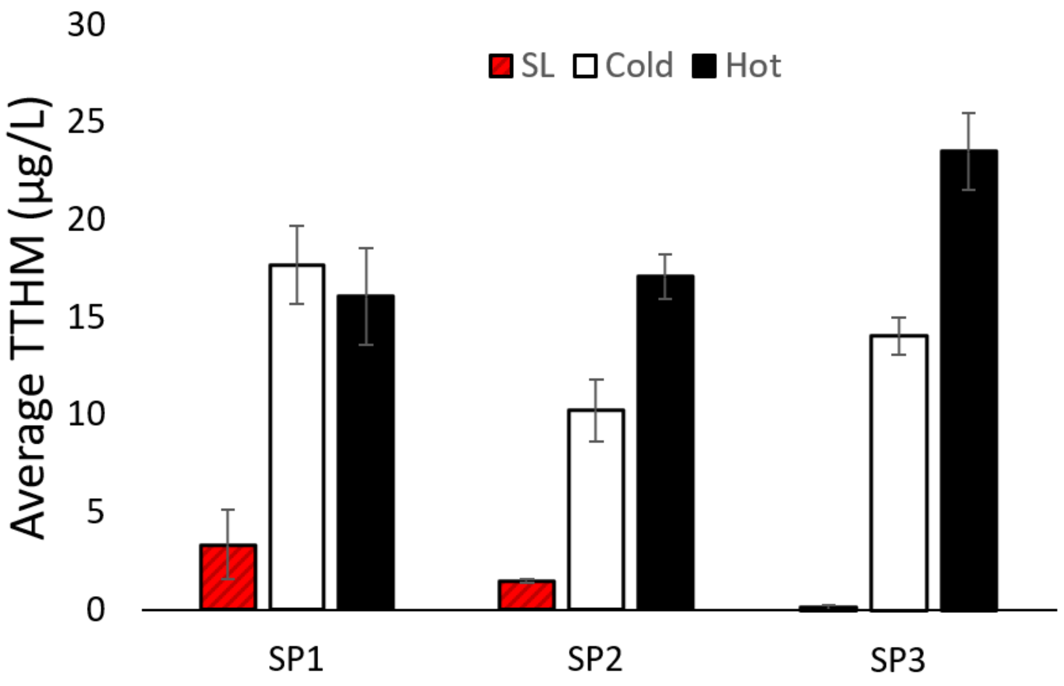
TTHM

CHCl3 CHCl2Br CHClBr2 CHBr3

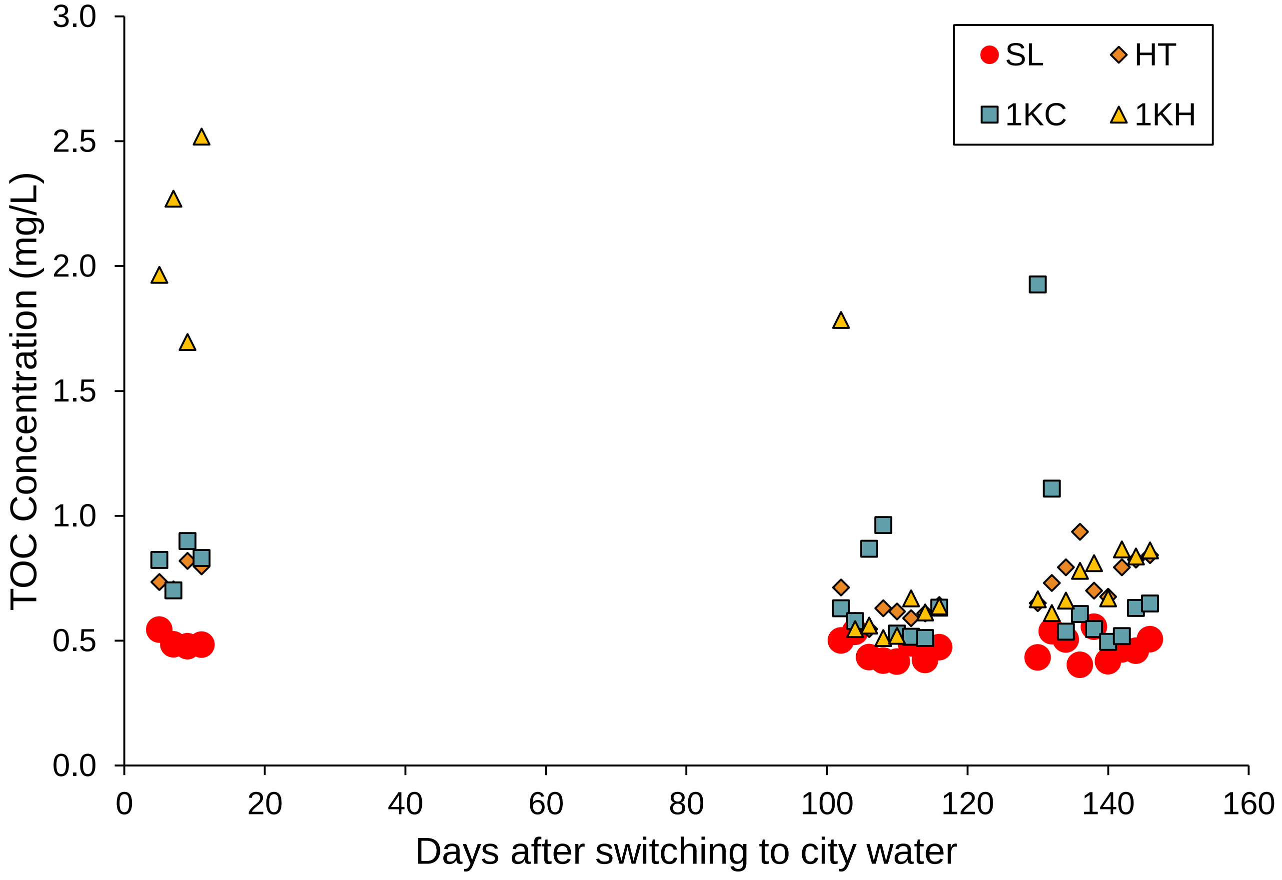
TTHM levels are consistently higher within the house when compared to city water entering the house

A larger concentration of TTHMs are present in hot compared to cold pipes for sampling periods 2 and 3

98.8% of TTHMs are generated within the house



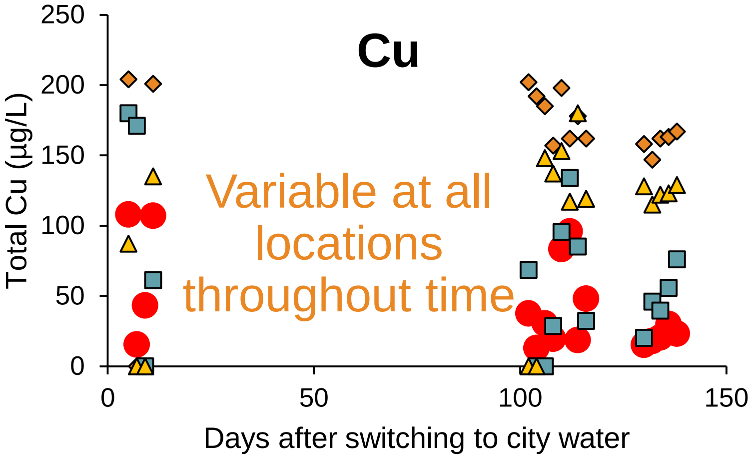
TOC & DOC

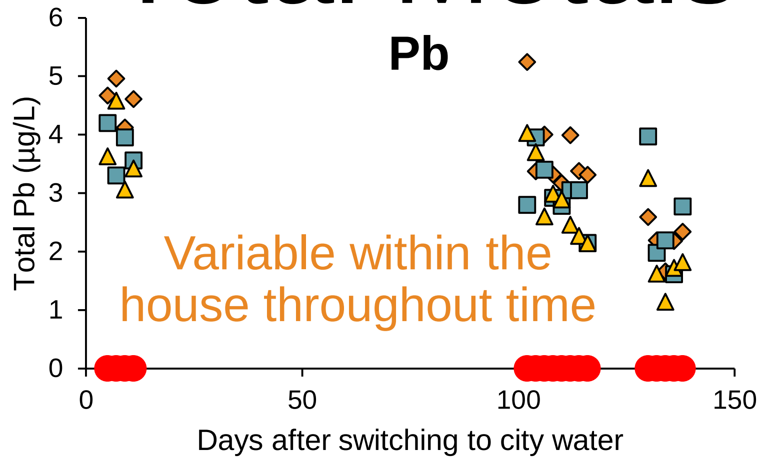


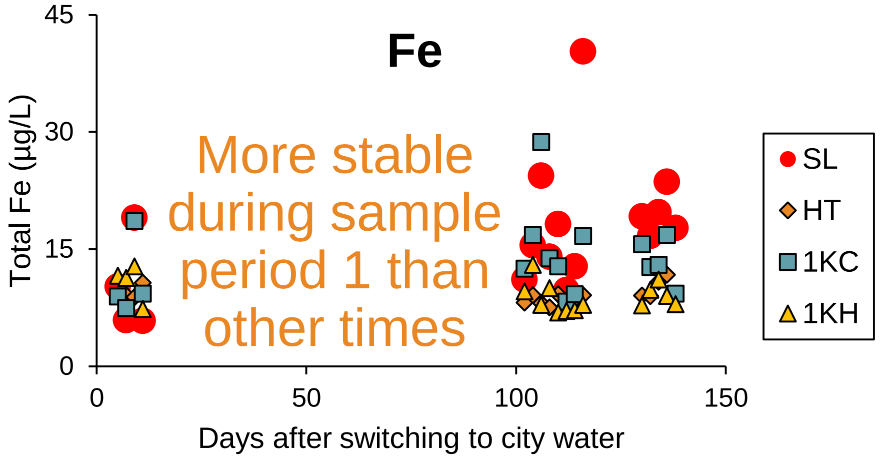
TOC is stable through time at each location for sampling periods 2 and 3

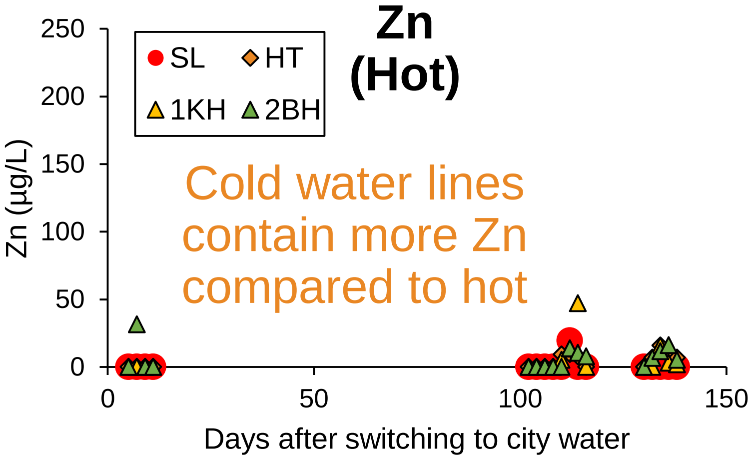
Above 80% of the organic total organic carbon was dissolved for sampling periods 1 and 2. During sampling period 3 this values dropped to 70% and above.

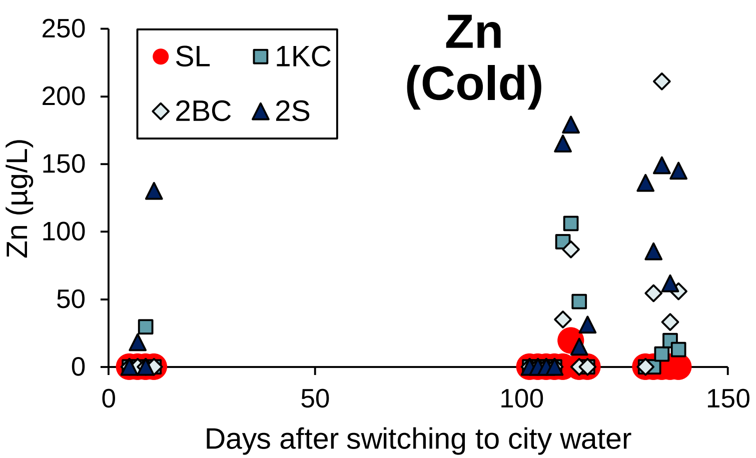
Total Metals











Dissolved Metals

Cu	83.8%
Pb	67.7%
Fe	19.7%
Zn	9.9%

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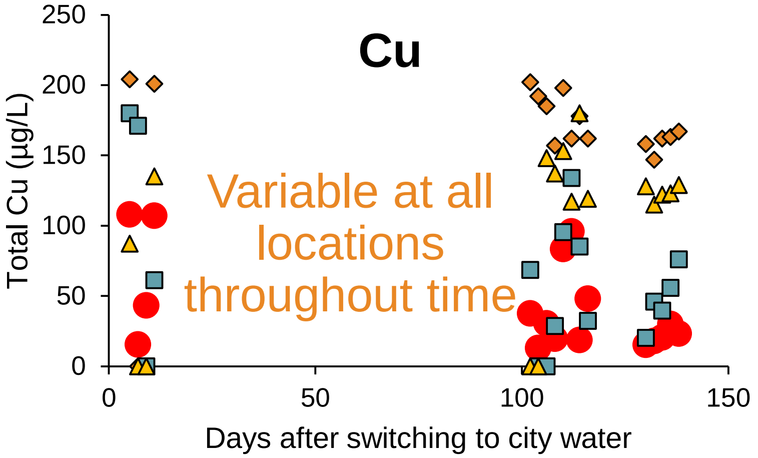
Total Metals



Journal American Water Works Association

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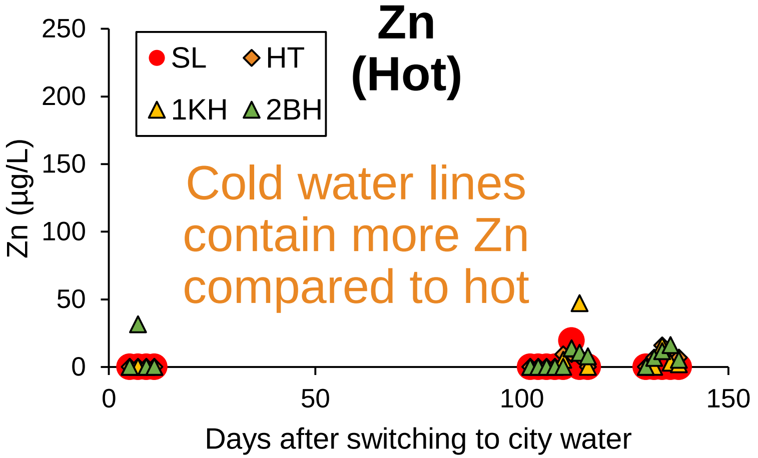
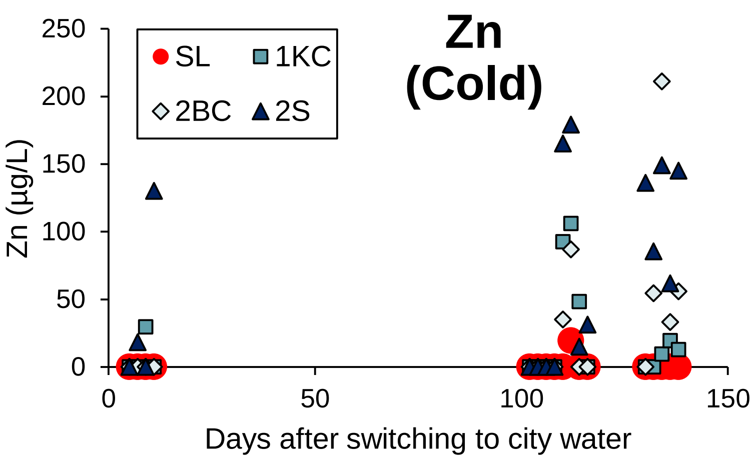
Metal Accumulation in Representative Plastic Drinking Water Plumbing Systems

Maryam Salehi, Xianzhen Li, Andrew J. Whelton

First published: 01 November 2017 | https://doi.org/10.5942/jawwa.2017.109.0117





Dissolved Metals

Cu	83.8%
Pb	67.7%
Fe	19.7%
Zn	9.9%

Conclusions

- Water quality at the service line differed significantly from water inside the house (pH, TOC, DOC)
- Some locations were more prone to have low to no chlorine residual
- Water from the distribution system contained greater levels of some metals (Cu, Fe, Mn) while others appear to be originate from the building plumbing (Cu, Pb, Zn)
- After switching from rain to city water, water quality was variable before becoming more consistent
- Few TTHMs entered the house, but levels reached nearly 40 µg/L within the house

Some Future Activities

- Continue sampling city water at the ReNEWW House to build and calibrate a hydraulic water quality model
- Monitor drinking water chemical and microbial quality after switching to rain water at ReNEWW House
- Analyze water quality in an office building (The Nature Conservancy), middle school (Avon Middle School North), and pilot system

Acknowledgment

Thanks to Environmental Protection Agency (grant R836890) for funding.

Special thanks to Whirlpool Corporation including Eric Bowler, Jason Schneemann, Stephen Caskey, and Ronald Vogelwede for providing technical assistance and hosting the test-site at the ReNEWW House Project.

The authors also thank Dr. Chloe De Perre for assisting in ICP-MS analysis, Dr. Amisha Shah, Kyungyeon Ra, Xiangning Huang, and Kun Huang, for helping run and analyze water samples.

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Building Plumbing Safety: Right Sizing Tomorrow's Water Systems for Efficiency, Sustainability, & Public Health

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Tolu Odimayomi, todimayo@purdue.edu
Andrew Whelton, awhelton@purdue.edu

Andrew Whelton, Jade Mitchell, Janice Beecher, Joan Rose, Juneseok Lee, Pouyan Nejadhashemi, Erin Dreelin, Tiong Gim Aw, Amisha Shah, Matt Syal, Maryam Salehi, Gulshan Singh, Ryan Julien Kara Dean, Ian Kropp

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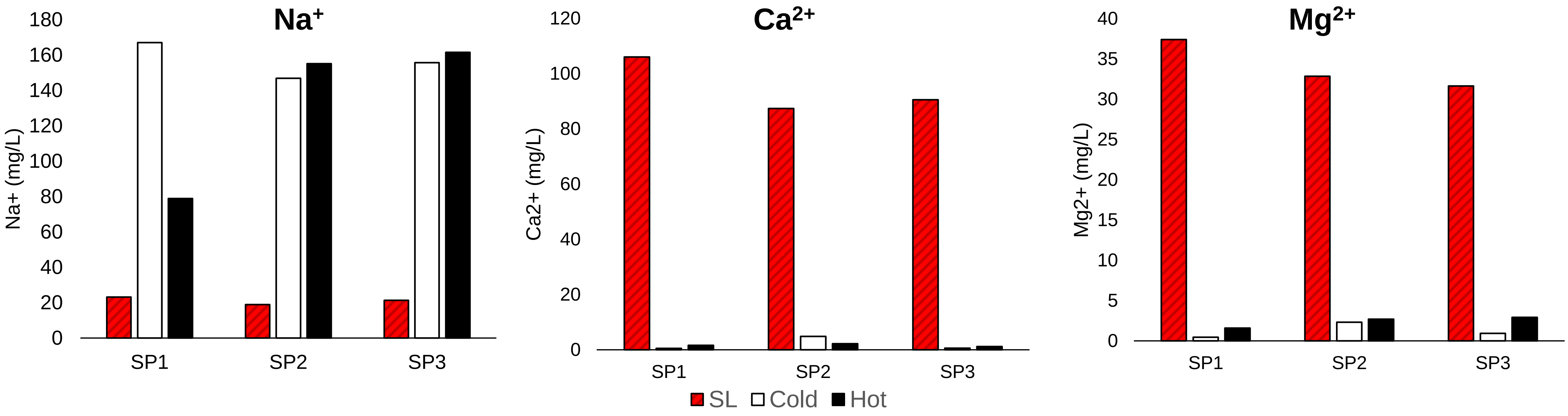
Metals Limits

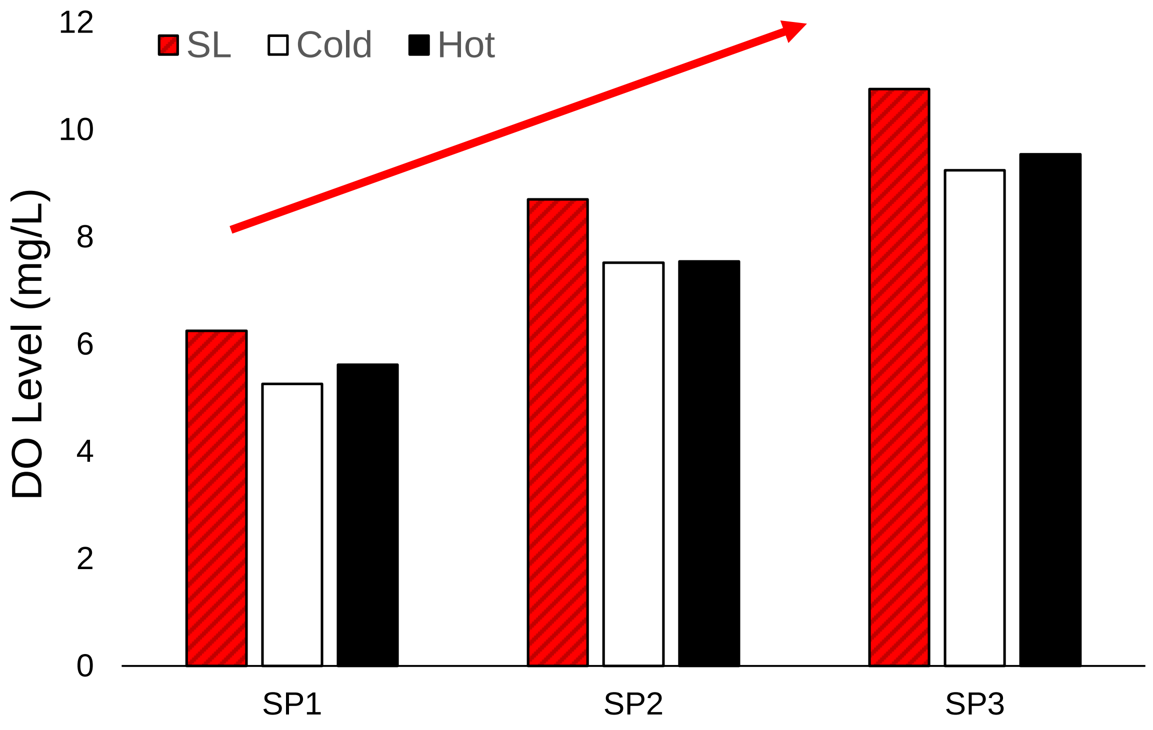
	Cu		Pb		Fe	Zn	
Sampling Period	1	2&3	1	2&3	1,2&3	1&2	3
LOD (µg/L)	5	1	1	1	1	1	1
LOQ (µg/L)	5	1	2	1	1	5	2
Max (µg/L)	250		250		250	250	

Ion Chromatography



An increase in Na+ and decline in Ca2+ and Mg2+ was seen after the water softener

Dissolved Oxygen



DO levels within the house where lower compared to city water for the second and third sampling periods

DO level increases during each sampling period

TABLE 2 Finished water quality reported by the local water treatment plant

Water Quality Parameter	2016 Value
pH	7.0 to 7.5
Alkalinity—*mg/L as* $CaCO_3$	NR
Ca—*mg/L*	104.0
Mg—*mg/L*	34.0
Mn—*mg/L*	0.02
P—*mg/L*	NR
Zn—*mg/L*	ND
Al—*mg/L*	ND
Fe—*mg/L*	0.05
Na—*mg/L*	26.0
Pb—*mg/L*	ND[a]
Cu—*mg/L*	0.564[a]
As—*mg/L*	0.004
Cr—*μg/L*	ND to 0.14
Ni—*mg/L*	0.005

Al—aluminum, As—arsenic, Ca—calcium, $CaCO_3$—calcium carbonate, Cr—chromium, Cu—copper, Fe—iron, Mg—magnesium, Mn—manganese, Na—sodium, ND—not detected, Ni—nickel, NR—not reported, P—phosphorus, Pb—lead, Zn—zinc

[a]90th percentile results

According to the utility drinking water 2016 Consumer Confidence Report, hardness is typically 248 to 416 mg/L as $CaCO_3$.

Salehi, M. , Li, X. and Whelton, A. J. (2017), Metal Accumulation in Representative Plastic Drinking Water Plumbing Systems. Journal - American Water Works Association, 109: E479-E493. doi:10.5942/jawwa.2017.109.0117